Chapter Eleven

Managing the New Product Development Process

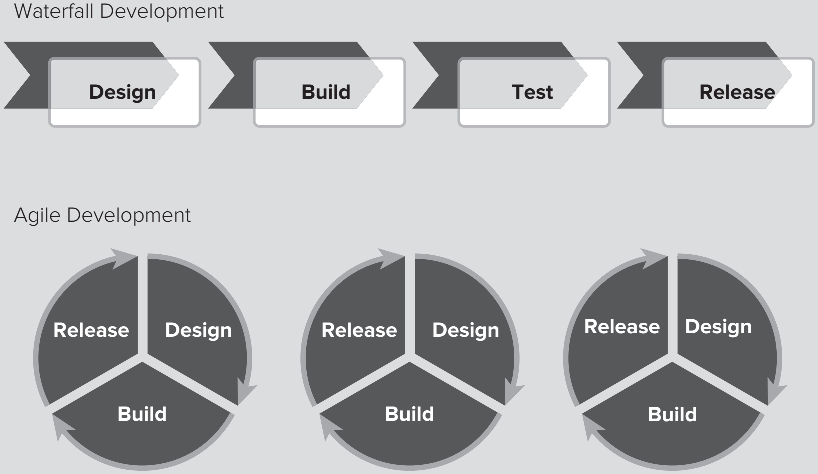
Scrums, Sprints, and Burnouts: Agile Development at Cisco Systems

Cisco Systems, founded in 1984 in San Francisco, had grown to become a global leader in networking technology such as routers, servers, switches, networking software, security software, and more. For most of the company's existence, it had used the "waterfall" method to develop software.[a] The typical waterfall method began with analysis that would result in documents specifying the business case, product requirements, marketing requirements, and so on. Different teams would then be formed to sequentially design, build, test, and deploy the product. A team could begin working only when the previous team had completed its stage of the process, and the entire process could take 18 months or more.[b]

This approach was similar to "stage-gate" methods and consistent with how the company developed hardware products. But managers in the software divisions were unsatisfied; they worried that their development cycles were too long compared to other software companies, making it hard to compete. In 2014, they decided to try a new approach called *agile development* to make software development faster and more flexible at the firm.

Agile development began as a set of principles laid out by a group of 17 software engineers at a three-day retreat at a ski resort in Snowbird Utah in 2001.[c] Their objective was to come to an agreement about how to make software development faster and leaner. They ended up developing a set of core values and practices that emphasize collaboration, self-organization, and cross-functional teams.[d] The key distinction between traditional waterfall methods and agile methods was that rather than designing a complete product upfront and moving through a sequential process that culminates in testing and release, the product is broken up into many smaller parts or features that are built and

FIGURE 1
Waterfall versus Agile Development



released quickly, enabling the developers to get feedback and fix bugs early (see Figure 1). The process also gave developers considerably more autonomy.

The method rapidly grew in popularity, attracting companies such as Google, Spotify, Netflix, and Twitter. Furthermore, though it was designed for software development, it had also been adopted for managing other kinds of projects, and had even been adopted by companies such as Lockheed Martin, Walmart, and ExxonMobil.[e]

The Agile Development Process

In agile development, a manager deemed the *product owner* (a person at the organization who represents the customer's interests) assembles a complete list of functions to be developed for the product based on *user stories*—short descriptions of functions described by customers in their own words. This list is called the *product backlog*. Work on the product backlog is organized into a series of *sprints,* periods of roughly two weeks in which a small set of features from the product backlog are developed and tested. Work is conducted by *scrum teams,* small, self-organizing teams with no titles or team manager. There is no formal task assignment; each member just contributes in whatever way they can to complete the work and the team makes decisions as a whole. Sometimes agile development projects also have a *scrum master* who acts as a coach for multiple scrum teams. The scrum master does not provide day-to-day direction or impose any particular technical solution; rather, the scrum master's job is to help guide the scrum process itself.

The teams figure out what items they can commit to and create a *sprint backlog*—a list of tasks they will complete during the sprint. Each day of the sprint, all the team members and the product owner attend a quick scrum meeting of 15 minutes max where they share what they worked on the previous day, what they will work on that day, and any obstacles to their progress. During the sprint, the scrum team takes a small set of features from idea through coding and testing.

At the end of each sprint, there should be work that can be demonstrated to a client—a *minimum viable product* feedback early and often, helping the scrum teams weed out or refine their ideas. A *burndown chart* shows the amount of work remaining in a sprint or a product release, and is used to determine whether a sprint or release is on schedule.

"Release Early, Release Often"

In agile development, rather than having grand comprehensive product redesigns, the product is constantly, incrementally adapted. Introducing small changes one or a few at a time helps to reduce risk, and also improves transparency about what works and what does not work. By contrast, when many changes are introduced simultaneously, it is harder to tell why the overall product succeeds or fails.

For this approach to work, a product has to be fairly modular. That is, it must be possible for a large product to be broken down into many smaller, relatively independent problems that can be worked on separately (something that is not possible with all products).[f] Furthermore, a potential downside of the agile approach is that it may be more difficult (or less likely) to make large-scale systemic changes to a product.

In the right setting, however, agile development can accelerate product development, improve customer satisfaction, and even improve employee satisfaction because the process gives them much more autonomy and a sense of ownership in their jobs. As one team member at Cisco put it, "My boss used to come and tell me to get my team to do this or do that. Now, I tell him that I cannot tell my team to do this or that; I can suggest it to them, but they will discuss and decide if it's the right thing to do."[g]

Discussion Questions

1. What are some of the advantages and disadvantages of the agile development process?
2. How is agile development similar to or different from (a) the stage-gate process and (b) the parallel development process described in the chapter?
3. What are some of the likely changes agile development requires in managing development personnel?
4. What kinds of projects do you think agile development is appropriate for? What kinds of projects do you think it might be inappropriate for?

[a] https://www.scaledagileframework.com/cisco-case-study/

[b] R. Chen, R. Ravichandar, and D. Proctor, "Managing the Transition to the New Agile Business and Product Development Model: Lessons from Cisco Systems," Indiana University Kelley School of Business Teaching Case (2016).

[c] http://agilemanifesto.org/history.html

[d] "Agile Manifesto", 2001, *Agile Alliance.* https://www.agilealliance.org/agile101/the-agile-manifesto/

[e] C. M. Nyce, "The Winter Getaway that Turned the Software World Upside Down," *The Atlantic,* December 8, 2017 https://www.theatlantic.com/technology/archive/2017/12/agile-manifesto-a-history/547715/.

[f] M. A. Schilling, "Modularity in Multiple Disciplines," in R. Garud, R. Langlois, and A. Kumaraswamy eds., *Managing in the Modular Age: Architectures, Networks and Organizations* (Oxford, England: Blackwell Publishers, 2002) pp. 203–214.

[g] R. Chen, R. Ravichandar, and D. Proctor, "Managing the Transition to the New Agile Business and Product Development Model: Lessons from Cisco Systems," Indiana University Kelley School of Business Teaching Case (2016).

OVERVIEW

In many industries, the ability to develop new products quickly, effectively, and efficiently is now the single most important factor driving firm success. In industries such as computer hardware and software, telecommunications, automobiles, and consumer electronics, firms often depend on products introduced within the past five years for more than 50 percent of their sales. Yet despite the avid attention paid to new product development, the failure rates for new product development projects are still agonizingly high. By many estimates, more than 95 percent of all new product development projects fail to result in an economic return.[1] Many projects are never completed, and of those that are, many flounder in the marketplace. Thus, a considerable amount of research has been focused on how to make the new product development process more effective and more efficient. This chapter discusses some strategic imperatives for new product development processes that have emerged from the study of best—and worst—practices in new product development.

We will begin by looking at the three key objectives of the new product development process: maximizing fit with customer requirements, minimizing cycle time, and controlling development costs. We then will turn to methods of achieving these objectives, including adopting parallel development processes, using project champions, and involving customers and suppliers in the development process. Next we will look at a number of tools firms can utilize to improve the effectiveness and efficiency of the development process, including creating go/kill decision points with stage-gate processes, defining design targets with quality function deployment, reducing costs and development time with design for manufacturing and CAD/CAM systems, and using metrics to assess the performance of the new product development process.

OBJECTIVES OF THE NEW PRODUCT DEVELOPMENT PROCESS

For new product development to be successful, it must simultaneously achieve three sometimes-conflicting goals: (1) maximizing the product's fit with customer requirements, (2) minimizing the development cycle time, and (3) controlling development costs.

Maximizing Fit with Customer Requirements

For a new product to be successful in the marketplace, it must offer more compelling features, greater quality, or more attractive pricing than competing products. Despite the obvious importance of this imperative, many new product development projects fail to achieve it. This may occur for a number of reasons. First, the firm may not have a clear sense of which features customers value the most, resulting in the firm's overinvesting in some features at the expense of features the customer values more. Firms may also overestimate the customer's willingness to pay for particular features, leading them to produce feature-packed products that are too expensive to gain significant market penetration. Firms may also have difficulty resolving heterogeneity in customer demands; if some customer groups desire different features from other groups, the firm may end up producing a product that makes compromises between these conflicting demands, and the resulting product may fail to be attractive to any of the customer groups.

Numerous new products have offered technologically advanced features compared to existing products but have failed to match customer requirements and were subsequently rejected by the market. For example, consider Apple's Newton MessagePad, a relatively early entrant into the personal digital assistant market. The Newton was exceptional on many dimensions. It had a highly advanced ARM610 RISC chip for superior processing performance. Its operating system was object oriented (a feature that software programmers had been clamoring for), and Apple openly licensed the architecture to encourage rapid and widespread adoption by other vendors. Also, its weight, size, and battery life were better than many of the other early competitors. However, the Newton MessagePad was still much too large to be kept in a pocket, limiting its usefulness as a handheld device. Many corporate users thought the screen was too small to make the product useful for their applications. Finally, early problems with the handwriting recognition software caused many people to believe the product was fatally flawed.

Another example is Philips' attempt to enter the video game industry. In 1989, Philips introduced its Compact Disc Interactive (CD-i). The CD-i was a 32-bit system (introduced well before Sega's 32-bit Saturn or Sony's 32-bit PlayStation), and in addition to being a game player, it offered a number of educational programs and played audio CDs. However, Philips had overestimated how much customers would value (and be willing to pay for) these features. The CD-i was priced at $799, more than double the cost of Nintendo or Sega video game systems. Furthermore, the product was very complex, requiring a half-hour demonstration by a skilled sales representative. Ultimately, the product failed to attract many customers and Philips abandoned the product.

Minimizing Development Cycle Time

Even products that achieve a very close fit with customer requirements can fail if they take too long to bring to market. As discussed in Chapter Five, bringing a product to market early can help a firm build brand loyalty, preemptively capture scarce assets, and build customer switching costs. A firm that brings a new product to market late may find that customers are already committed to other products. Also, a company that is able to bring its product to market early has more time to develop (or encourage others to develop) complementary goods that enhance the value and attractiveness of the product.[2] Other things being equal, products that are introduced to the market earlier are likely to have an installed base and availability of complementary goods advantage over later offerings.

development cycle time
The time elapsed from project initiation to product launch, usually measured in months or years.

Another important consideration regarding **development cycle time** relates to the cost of development and the decreasing length of product life cycles. First, many development costs are directly related to time. Both the expense of paying employees involved in development and the firm's cost of capital increase as the development cycle lengthens. Second, a company that is slow to market with a particular generation of technology is unlikely to be able to fully amortize the fixed costs of development before that generation becomes obsolete. This phenomenon is particularly vivid in dynamic industries such as electronics where life cycles can be as short as 12 months (e.g., personal computers, semiconductors). Companies that are slow to market may find that by the time they have introduced their products, market demand has already shifted to the products of a subsequent technological generation.

Finally, a company with a short development cycle can quickly revise or upgrade its offering as design flaws are revealed or technology advances. A firm with a short development cycle can take advantage of both first-mover *and* second-mover advantages.

Some researchers have pointed out the costs of shortening the development cycle and rushing new products to market. For example, Dhebar points out that rapid product introductions may cause adverse consumer reactions; consumers may regret past purchases and be wary of new purchases for fear they should rapidly become obsolete.[3] Other researchers have suggested that speed of new product development may come at the expense of quality or result in sloppy market introductions.[4] Compressing development cycle time can result in overburdening the development team, leading to problems being overlooked in the product design or manufacturing process. Adequate product testing may also be sacrificed to meet development schedules.[5] However, despite these risks, most studies have found a strong positive relationship between speed and the commercial success of new products.[6]

Controlling Development Costs

Sometimes a firm engages in an intense effort to develop a product that exceeds customer expectations and brings it to market early, only to find that its development costs have ballooned so much that it is impossible to recoup the development expenses even if the product is enthusiastically received by the market. This highlights the fact that development efforts must be not only *effective,* but also *efficient.* Later in the chapter, ways to monitor and control development costs are discussed.

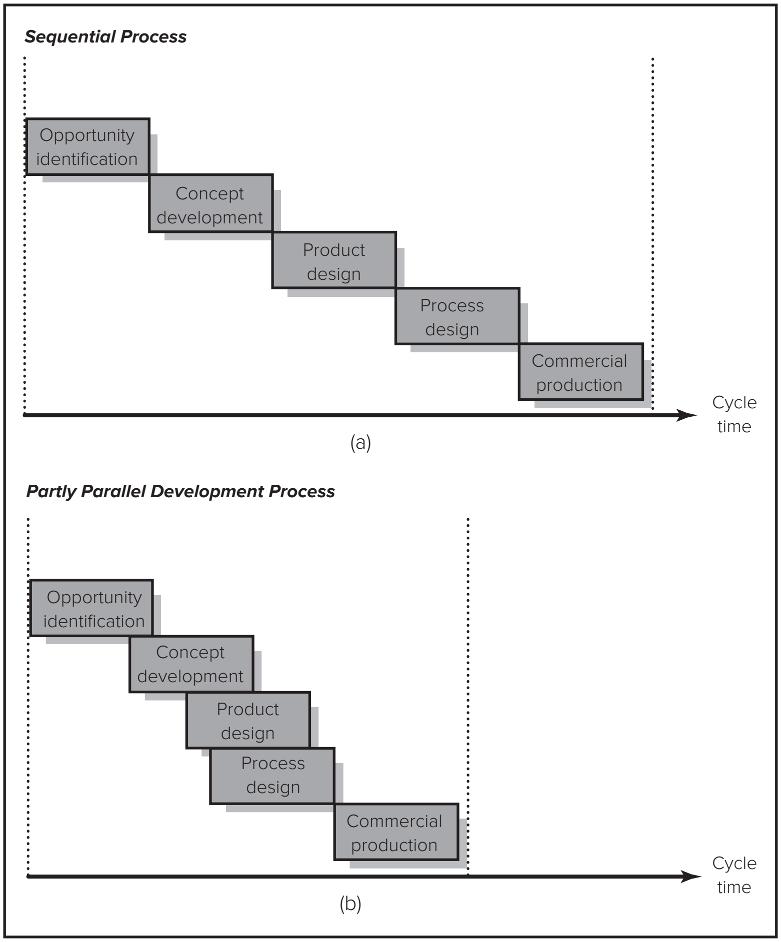
SEQUENTIAL VERSUS PARTLY PARALLEL DEVELOPMENT PROCESSES

partly parallel development process
A development process in which some (or all) of the development activities at least partially overlap. That is, if activity A would precede activity B in a partly parallel development process, activity B might commence before activity A is completed.

Before the mid-1990s, most U.S. companies proceeded from one development stage to another in a sequential fashion (see Figure 11.1a). The process included a number of gates at which managers would decide whether to proceed to the next stage, send the project back to a previous stage for revision, or kill the project. Typically, R&D and marketing provided the bulk of the input in the opportunity identification and concept development stages, R&D took the lead in product design, and manufacturing took the lead in process design. According to critics, one problem with such a system emerges at the product design stage when R&D engineers fail to communicate directly with manufacturing engineers. As a result, product design proceeds without manufacturing requirements in mind. A sequential process has no early warning system to indicate that planned features are not manufacturable. Consequently, cycle time can lengthen as the project iterates back and forth between the product design and process design stages.[7]

To shorten the development process and avoid time-consuming and costly iterations between stages of the development cycle, many firms have adopted a **partly parallel development process**, as shown in Figure 11.1b.[8] Product design is initiated before

FIGURE 11.1
Sequential versus Partly Parallel Development Processes



concurrent engineering
A design method in which stages of product development (e.g., concept development, product design, and process design) and planning for later stages of the product lifecycle (e.g., maintenance, disposal, and recycling) occur simultaneously.

concept development is complete, and process design is begun long before product design is finalized, enabling much closer coordination between the different stages and minimizing the chance that R&D will design products that are difficult or costly to manufacture. This should eliminate the need for time-consuming iterations between design stages and shorten overall cycle time. One type of parallel development process, **concurrent engineering**, involves not only conducting the typical product development stages simultaneously but also takes into account downstream stages of a product's lifecycle such as maintenance and disposal.

Parallel development processes are not universally endorsed, however. In some situations, using a parallel development process can substantially increase the risks or costs of the development process. If, for example, variations in product design require significant changes to the process design, beginning process design before product design is finalized can result in costly rework of the production process. Such risks are especially high in markets characterized by rapid change and uncertainty.[9]

Theory in Action The Development of Zantac

In the 1970s, Glaxo Holdings PLC of Great Britain was one of the larger health care conglomerates in the world, known principally for its baby food, but it needed a new hit product to stimulate sales. While contemplating research possibilities, the head of Glaxo's research laboratory, David Jack, attended a lecture by James Black, a Nobel Prize–winning scientist and researcher for U.S.-based SmithKline Beecham. During the lecture, Black described a new possibility for treating ulcers that involved compounds called H_2 blockers that would inhibit gastrointestinal cells from secreting acid. Jack was intrigued. Ulcers were a common problem, and thus represented a large market opportunity for an effective solution. Jack began experimenting with different compounds in pursuit of a formula that would be safe and effective. Unfortunately, researchers at SmithKline Beecham beat Glaxo to the finish line, introducing Tagamet in 1977. Tagamet revolutionized ulcer treatment, and sales grew phenomenally.[a]

Discouraged but not thwarted, Jack's team kept working. Other companies (including Merck and Eli Lilly) were also developing their own ulcer treatments, and Jack believed that beating them to market might still give the company a shot at a significant share. In that same year, the team came up with a compound based on ranitidine (Tagamet was based on a compound called cimetedine) that achieved the desired objectives. However, Jack realized that if Glaxo was going to beat Merck and Eli Lilly to market, it would need to radically shorten the typical 10-year testing period required to secure regulatory approval and bring the product to market. To achieve this, Jack proposed the first parallel development process used in the pharmaceutical industry. Instead of following the typical sequence of testing (e.g., from rats to monkeys, and from short-term toxicity to long-term toxicity), Jack proposed doing all of the tests concurrently.[b] This intensified development process could potentially cut the cycle time in half—to five years—however, it would also be expensive and risky. If the development efforts increased the research costs substantially, it would be much harder to recoup those expenses through sales of the drug.

Fortunately for Jack's team, Paul Girolami, Glaxo's director of finance, chose to champion the project. Girolami argued that the company should be willing to risk its range of decently profitable products for one potentially sensational drug, stating, "Having all your eggs in one basket concentrates the mind because you had better make sure it is a good basket."[c] Not only was he able to convince the company that it was worth investing in the shortened development process, but also insisted that the product be modified so that it could be taken once a day (Tagamet required twice-a-day use) and so that the product would have fewer side effects than Tagamet. These features would help differentiate Zantac as a superior product, and it was hoped they would enable Glaxo to take share away from SmithKline Beecham. The development process was successful, and the product was ready for launch in 1982. To recoup its development costs, Girolami chose a premium pricing strategy for the product (one-third higher than Tagamet), arguing that its advantages would warrant its additional cost. He also insisted that the product be launched globally in all major markets, and he set up a distribution alliance with Hoffman-LaRoche to speed up the product's penetration of the U.S. market.

Girolami's strategies were successful, and by the end of the year, Zantac was stealing about 100,000 patients a month from Tagamet. By 1987, Zantac sales had exceeded Tagamet's, and by 1991, Zantac became the world's No. 1 selling prescription drug and the first drug ever to achieve $1 billion in U.S. sales.[d] Both David Jack and Paul Girolami were knighted, and Sir Paul Girolami was appointed chairman of Glaxo.[e]

[a] A. Corsig, T. Soloway, and R. Stanaro, "Glaxo Holdings PLC: Zantac," in *New Product Success Stories,* ed. R. Thomas (New York: John Wiley & Sons, Inc., 1995), pp. 242–52.
[b] Ibid.
[c] C. Kennedy, "Medicine Man to the World," *Director* 46, no. 4 (1992), pp. 106–10.
[d] "Anti-Ulcer Drugs: Too Much Acid," *The Economist* 318, no. 7700 (1991), pp. 82–84.
[e] Corsig, Soloway, and Stanaro, "Glaxo Holdings PLC: Zantac."

Furthermore, once process design has commenced, managers may be reluctant to alter the product design even if market testing reveals that the product design is suboptimal. It is precisely these risks that the stage-gate* process (discussed later in the chapter) attempts to minimize.

PROJECT CHAMPIONS

A number of studies on new product development have suggested that firms should assign (or encourage) a senior member of the company to champion a new product development project.[10] Senior executives have the power and authority to support and fight for a project. They can facilitate the allocation of human and capital resources to the development effort, ensuring that cycle time is not extended by resource constraints, and help ensure that the project can sustain the necessary momentum to surmount the hurdles that inevitably will arise.[11] A senior project champion also can stimulate communication and cooperation between the different functional groups involved in the development process. Given that interfunctional communication and cooperation are necessary both to compress cycle time and to achieve a good fit between product attributes and customer requirements, the use of executive sponsors can improve the effectiveness of the development process. As of 2001, 68 percent of North American firms, 58 percent of European firms, and 48 percent of Japanese firms reported using senior managers to champion new product development projects.[12] An example of a successful use of project championing is described in the accompanying Theory in Action: The Development of Zantac.

Risks of Championing

Vigorous project championing, however, also has its risks. A manager's role as champion may cloud judgment about the true value of the project. Optimism is the norm in product development—surveys indicate a systematic upward bias in estimates of future cash flows from a project.[13] In the role of champion, this optimism is often taken to extreme levels. Managers may fall victim to escalating commitment and be unable (or unwilling) to admit that a project should be killed even when it is clear to many others in the organization that the project has gone sour, or the factors driving the project's original value are no longer relevant. While it is common to read stories about projects that succeed against all odds because of the almost fanatical zeal and persistence of their champions, bankruptcy courts are full of companies that should have been less zealous in pursuing some projects. Managers who have invested their reputations and years of their lives in development projects may find it very difficult to cut their losses, in much the same way that individuals tend to hold losing stocks much longer than they should due to the temptation to try to recoup what they have lost. Though the champion's seniority is an asset in gaining access to resources and facilitating coordination, this same seniority may also make others in the firm unwilling to challenge the project champion even if it has become apparent that the project's expected value has turned negative.[14]

Firms may benefit from also developing "antichampions" who can play the role of devil's advocate. Firms should also encourage a corporate culture open to the

*Note: Stage-Gate® is a registered trademark of Stage-Gate International Inc.

Research Brief Five Myths about Product Champions

Stephen Markham and Lynda Aiman-Smith argue that a number of myths have become widely accepted about new product champions. While Markham and Aiman-Smith believe that product champions are critical to new product development, they also argue that for product champions to be effective, their role in the development process must be completely understood. Markham and Aiman-Smith conducted a systematic review of the theoretical and empirical literature on product champions and identified five popular myths:

Myth 1: *Projects with champions are more likely to be successful in the market.* Markham and Aiman-Smith's review of the empirical data on use of project champions found that projects with champions were just as likely to be market failures as market successes. Markham and Aiman-Smith point out that while champions may improve the likelihood of a project being completed, the factors determining its market success are often beyond the champion's control.[a]

Myth 2: *Champions get involved because they are excited about the project, rather than from self-interest.* Markham and Aiman-Smith report that empirical evidence suggests champions are more likely to support projects that will benefit the champion's own department.[b]

Myth 3: *Champions are more likely to be involved with radical innovation projects.* Empirical evidence from multiple large sample studies indicates that champions were equally likely to be involved with radical versus incremental innovation projects.

Myth 4: *Champions are more likely to be from high (or low) levels in the organization.* Markham and Aiman-Smith argue that there are myths about both high-level and low-level managers being more likely to be product champions. Though stories abound featuring prominent senior managers supporting projects, as do stories featuring low-level champions fighting vigorously for a project's success, empirical evidence suggests that champions may arise from any level in the organization. (Note that this research does not indicate champions from all levels of the firm are equally effective.)

Myth 5: *Champions are more likely to be from marketing.* Markham and Aiman-Smith argue that while anecdotal evidence may more often emphasize champions who have marketing backgrounds, an empirical study of 190 champions found that champions arose from many functions of the firm. Specifically, the study found that 15 percent of champions were from R&D, 14 percent were from marketing, 7 percent were from production and operations, and 6 percent were general managers. Interestingly, 8 percent of champions were potential users of the innovations.[c]

[a] S. Markham, S. Green, and R. Basu, "Champions and Antagonists: Relationships with R&D Project Characteristics and Management," *Journal of Engineering and Technology Management* 8 (1991), pp. 217–42; S. Markham and A. Griffin, "The Breakfast of Champions: Associations between Champions and Product Development Environments, Practices, and Performance," *The Journal of Product Innovation Management* 15 (1998), pp. 436–54; and S. Markham, "Corporate Championing and Antagonism as Forms of Political Behavior: An R&D Perspective," *Organization Science* 11 (2000), pp. 429–47.

[b] Markham, "Corporate Championing and Antagonism as Forms of Political Behavior."

[c] D. Day, "Raising Radicals: Different Processes for Championing Innovative Corporate Ventures," *Organization Science* 5 (1994), pp. 148–72.

expression of dissenting opinion, and champions should be encouraged to justify their projects on the basis of objective criteria, without resorting to force of personality.[15] The accompanying Research Brief describes five myths that have become widely accepted about project champions.

INVOLVING CUSTOMERS AND SUPPLIERS IN THE DEVELOPMENT PROCESS

As mentioned previously, many products fail to produce an economic return because they do not fulfill customer requirements for performance and price, or because they take too long to bring to market. Both of these problems can be reduced by involving customers and suppliers in the development process.

Involving Customers

Firms often make decisions about projects on the basis of financial considerations and level of production and technical synergy achieved by the new product proposal rather than on marketing criteria. This can lead to an overemphasis on incremental product updates that closely fit existing business activities.[16] The screening decision should focus instead on the new product's advantage and superiority to the consumer, and the growth of its target market.[17] The end customer is often the one most able to identify the maximum performance capabilities and minimum service requirements of a new product. Including the end customer in the actual development team or designing initial product versions and encouraging user extensions can help the firm focus its development efforts on projects that better fit customer needs.[18] Distributors can also be valuable partners in the new product development process. These organizations will often be the first to know who is buying the product, how they are using it, and be the first to hear of problems with the product or suggestions for how it might be improved.[19]

agile development A process commonly used in software whereby the overall product is broken down into smaller independent pieces that are worked on by autonomous, self-organizing teams. Features are developed and presented to customers quickly so that the overall product can be rapidly and continuously adapted.

lead users Customers who face the same general needs of the marketplace but are likely to experience them months or years earlier than the rest of the market and stand to benefit disproportionately from solutions to those needs.

Customers may be involved in the new product development process as an information source, or as actual co-developers of a new product.[20] Many firms use *beta testing* to get customer input early in the development process. A *beta version* of a product is an early working prototype of a product released to users for testing and feedback. Beta versions also enable a firm to signal the market about its product features before the product reaches the commercial production stage. **Agile development** processes (that are now often used in software development) take this approach even further. In agile development, the product is divided into many smaller features or functionalities, and these are rapidly developed into *minimum viable products* and presented to the customer for feedback, enabling rapid incremental adaptation. Other firms involve customers in the new product development process in even more extensive ways, such as enabling customers to *co-create* the end product (this is discussed more in the section below on crowdsourcing).

Some studies suggest that firms should focus on the input of lead users in their development efforts rather than a large sample of customers. **Lead users** are those who face the same needs of the general marketplace but face them months or years earlier than the bulk of the market, and expect to benefit significantly from a solution to those needs.[21] According to a survey by the Product Development & Management Association, on average, firms report using the lead user method to obtain input into 38 percent of the projects they undertake. Not surprisingly, when customers help co-create an innovation, the resulting innovations tend to better fit their needs or expectations.[22] More detail on how firms use lead users is provided in the accompanying Theory in Action section: The Lead User Method of Product Concept Development.

Theory in Action The Lead User Method of Product Concept Development

Hilti AG, a European manufacturer of construction components and equipment, turned to the lead user method in its development of a pipe hanger (a steel support that fastens pipes to walls or ceilings of buildings). The firm first used telephone interviews to identify customers who had lead user characteristics (were ahead of market trends and stood to benefit disproportionately from the new solution). The lead users were invited to participate in a three-day product concept generation workshop to develop a pipe hanging system that would meet their needs. At the end of the workshop, a single pipe hanger design was selected as the one that best met all the lead users' objectives. The company then presented this design to 12 routine users (customers who were not lead users but who had a long, close relationship with Hilti). Ten of the 12 routine users preferred the new design to previously available solutions, and all but one of the 10 indicated they would be willing to pay a 20 percent higher price for the product. Not only was the project successful, but the lead user method was also faster and cheaper than the conventional market research methods the firm had used in the past to develop its product concepts. Hilti's typical process took 16 months and cost $100,000, but the lead user method took 9 months and cost $51,000.

Source: C. Herstatt and E. von Hippel, "Developing New Product Concepts via the Lead User Method: A Case Study in a Low-Tech Field," *Journal of Product Innovation Management* 9 (1992), pp. 213–21.

Involving Suppliers

Much of the same logic behind involving customers in the new product development process also applies to involving suppliers. By tapping into the knowledge base of its suppliers, a firm expands its information resources. Suppliers may be actual members of the product team or consulted as an alliance partner. In either case, they can contribute ideas for product improvement or increased development efficiency. For instance, a supplier may be able to suggest an alternative input (or configuration of inputs) that would achieve the same functionality but at a lower cost. Additionally, by coordinating with suppliers, managers can help to ensure that inputs arrive on time and that necessary changes can be made quickly to minimize development time.[23] Consistent with this argument, research has shown that many firms produce new products in less time, at a lower cost, and with higher quality by incorporating suppliers in integrated product development efforts.[24]

crowdsourcing
A distributed problem-solving model whereby a design problem or production task is presented to a group of people who voluntarily contribute their ideas and effort in exchange for compensation, intrinsic rewards, or a combination thereof.

Boeing's development of the 777 involved both customers and suppliers on the new product development team; United employees (including engineers, pilots, and flight attendants) worked closely with Boeing's engineers to ensure that the airplane was designed for maximum functionality and comfort. Boeing also included General Electric and other parts suppliers on the project team, so that the engines and the body of the airplane could be simultaneously designed for maximum compatibility.

Crowdsourcing

Firms can also open up an innovation task by directing an *innovation challenge* to third parties such as the general public, or specific, targeted groups of innovators from different networks. Sometimes firms work with third parties directly, and other times they use a professional crowdsourcing service provider with their own network of innovators. For example, one professional crowdsourcing service provider, NineSigma, manages innovation challenges using a network of more than two million scientists and engineers globally. Similarly, Topcoder helps firms access a community of more than one million software coders. Some of these service providers (such as InnoCentive) operate their service as a closed network where the firm seeking the innovation does not know the details of the solution provider. Others (such as NineSigma) operate open networks where the firm seeking the innovation solution can see all the solution proposals submitted, as well as all contact details of all solution providers that submitted a response to the challenge.

Crowdsourcing challenges typically go through a four step process:

1. **Need translation.** A clear, concise, and compelling need statement is articulated that reduces industry jargon to a minimum, and that brings the challenge down to its most basic science. For example, NineSigma helped a client seeking ways to reduce wrinkles in shirts coming out of a dryer by producing a statement that read: "Our client is seeking ways to reduce surface tension of an organic material." The advantage of such a statement is that the specific application is removed, which invites interest from solution providers from seemingly unrelated industries. In this example, a professor doing integrated circuit research had developed a special polymer that was the solution most favored by the client. The need statement is usually a short one- to two-page document, often called a *Request for Proposal.* Andy Zynga of NineSigma notes, "It is very important to have a very clean and concise need statement to trigger interest. There may be a temptation to put two needs into one statement, but that is highly discouraging to solution providers and will reduce the chances of success."[25]
2. **Connecting.** The innovation challenge must be broadcast to the network of potential solution providers that have been selected as most suitable to respond.
3. **Evaluation/Selection.** Submitted proposals get an in-depth review, and the most interesting solution proposals get selected and collated in the form of a report.
4. **Acquisition.** The firm engages with the solution provider and negotiates an agreement to transfer knowledge, a license, patent, and so on. This usually involves a monetary or other compensation scheme. It may also be necessary to adapt the incoming solution to the specific needs of the firm.

Thousands of companies and many public bodies have used crowdsourcing to solve challenges that seemed almost impossible to solve. For example, reducing plastics in our oceans, or addressing the opioid crisis are "Grand Challenges" that are being tackled with crowdsourcing approaches right now.

People participate in crowdsourcing for a variety of reasons that often do not include monetary rewards. For example, Ben & Jerry's asked its customers to invent new varieties of ice cream flavors—the submitters of the best flavors were given a trip to the Dominican Republic to see a sustainable fair trade cocoa farm. However, individuals also often participate for the sheer excitement and challenge of solving the problem,[26] or for social or reputational benefits.[27] For example, Fiat Brazil used crowdsourcing to develop a new concept car called the *Fiat Mio* ("My Fiat"). Fiat created a Web site inviting people to create the car of the future. More than 17,000 people from around the world submitted over 11,000 ideas—and not just in the design. Participants were invited to contribute solutions at every stage of the development process, including solving problems related to fuel efficiency and production. Participants received no rewards from their participation other than the pleasure they derived from interacting with Fiat and with each other, and the satisfaction they felt at having their ideas incorporated into the car. Hundreds of Fiat Mio's co-creators turned up at the unveiling of the car at a Sao Paulo motor show.

TOOLS FOR IMPROVING THE NEW PRODUCT DEVELOPMENT PROCESS

Some of the most prominent tools used to improve the development process include stage-gate processes, quality function deployment ("house of quality"), design for manufacturing, failure modes and effects analysis, and computer-aided design/computer-aided manufacturing. Using the available tools can greatly expedite the new product development process and maximize the product's fit with customer requirements.

Stage-Gate Processes

As discussed in a previous section, escalating commitment can lead managers to support projects long after their expected value has turned negative, and the cost of pushing bad projects forward can be very high. To help avoid this, many managers and researchers suggest implementing tough **go/kill decision points** in the product development process. The most widely known development model incorporating such go/kill points is the stage-gate process developed by Robert G. Cooper.[28] The stage-gate process provides a blueprint for moving projects through different stages of development. Figure 11.2 shows a typical stage-gate process.

go/kill decision points
Gates established in the development process where managers must evaluate whether or not to kill the project or allow it to proceed.

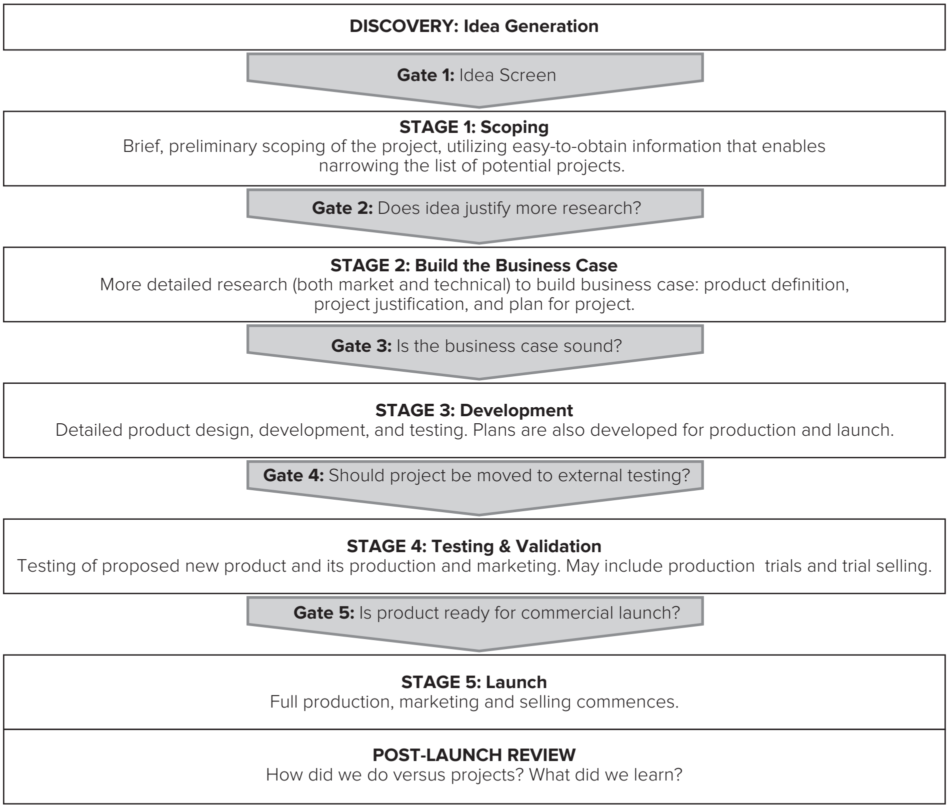
At each stage, a cross-functional team of people (led by a project team leader) undertakes parallel activities designed to drive down the risk of a development project. At each stage of the process, the team is required to gather vital technical, market, and financial information to use in the decision to move the project forward (go), abandon the project (kill), hold, or recycle the project.

In Stage 1, the team does a quick investigation and conceptualization of the project. In Stage 2, the team builds a business case that includes a defined product, its business justification, and a detailed plan of action for the next stages. In Stage 3, the team begins the actual design and development of the product, including mapping out the manufacturing process, the market launch, and operating plans. In this stage, the team also defines the test plans utilized in the next stage. In Stage 4, the team conducts the verification and validation process for the proposed new product, and its marketing and production. At Stage 5, the product is ready for launch, and full commercial production and selling commence.[29]

Preceding each stage is a go/kill gate. These gates are designed to control the quality of the project and to ensure that the project is being executed in an effective and efficient manner. Gates act as the funnels that cull mediocre projects. Each gate has three components: *deliverables* (these are the results of the previous stage and are the inputs for the gate review), *criteria* (these are the questions or metrics used to make

FIGURE 11.2
Typical Stage-Gate Process, from Idea to Launch

Source: R. G. Cooper, "Stage-Gate Idea to Launch System," *Wiley International Encyclopedia of Marketing: Product Innovation & Management* 5, B. L. Bayus (ed.), (West Sussex UK: Wiley, 2011).



the go/kill decision), and *outputs* (these are the results of the gate review process and may include a decision such as go, kill, hold, or recycle; outputs should also include an action plan for the dates and deliverables of the next gate).

Because each stage of a development project typically costs more than the stage preceding it, breaking down the process into stages deconstructs the development investment into a series of incremental commitments. Expenditures increase only as uncertainty decreases. Figure 11.3 shows the escalation costs and cycle time for each stage of a typical development process in a manufacturing industry.

Many companies have adapted the stage-gate process to more specifically meet the needs of their firm or industry. For example, while managers at Exxon were strong advocates of using a stage-gate process to track and manage development projects, they also felt that the standard five-stage system did not adequately address the needs of a company in which basic research was a primary component in generating innovations. Exxon managers created their own extended stage-gate system to include directed basic research. The resulting stage-gate system included two basic research stages (Stages A and B in Figure 11.4) and five applied research and development stages. In Stage A, the company identifies the potential business incentives and competitive advantages of an envisioned technology. The company then develops a basic research plan that establishes specific scientific deliverables, the methods of achieving

FIGURE 11.3
Escalation of Development Time and Costs by Stage

Source: Adapted from F. Buggie, "Set the 'Fuzzy Front End' in Concrete," *Research Technology Management* 45, no. 4 (2002), pp. 11–14.

Stage	Time	Cost
0. "Here's an idea!"		
1. Formulate–describe and sketch	1 week	$100
2. Conduct preliminary investigations	2 weeks	$1,000
3. Design and define specifications	1 month	$10,000
4A. Develop prototype and test		
4B. Market research		
4C. Strategic fit evaluation and NPV risk analysis	2 months	$100,000
5A. Scale up, build pilot plant		
5B. Market test	8 months	$1 million
6A. Build plant		
6B. Promote, launch, market	16 months	$10 million

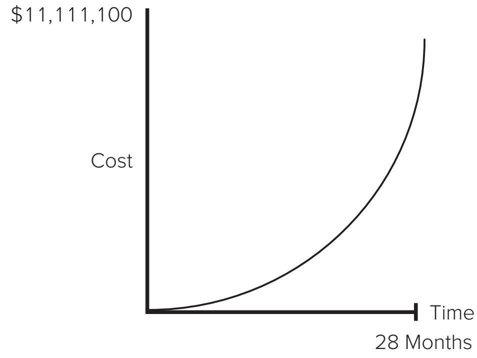
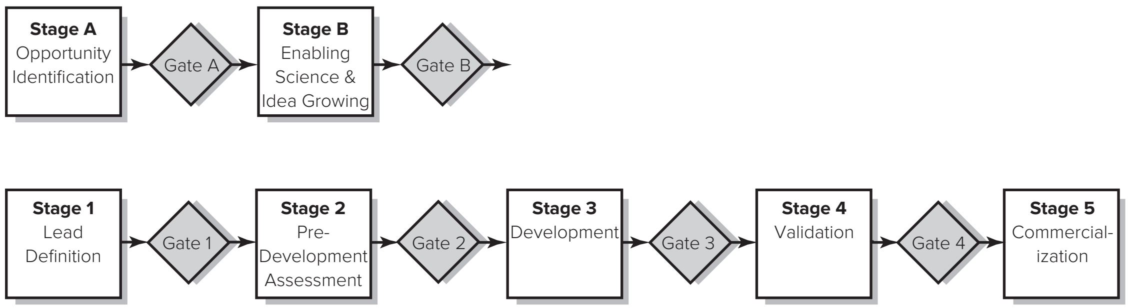


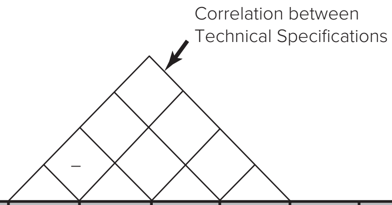
FIGURE 11.4
Exxon Research and Engineering's Stage-Gate System



these deliverables, and the required resources. In Stage B, Exxon's research division begins to execute the plan developed in Stage A, using scientific methods to generate leads for addressing the business opportunity. Stage 1 then identifies the best leads, using "proof-of-principle" assessments to establish whether the leads are feasible.[30] Stages 2 through 5 proceed according to a typical stage-gate process.

According to studies by the Product Development and Management Association, nearly 60 percent of firms (including IBM, Procter & Gamble, 3M, General Motors, and Corning) use some type of stage-gate process to manage their new product development process. Corning has made the process mandatory for all information system development projects, and Corning managers believe that the process enables them to better estimate the potential payback of any project under consideration. They also report that the stage-gate process has reduced development time, allows them to identify projects that should be killed, and increases the ratio of internally developed products that result in commercial projects.[31]

FIGURE 11.5
Quality Function Deployment House of Quality for a Car Door



	Engineering Attributes	Importance	Weight of Door	Stiffness of Hinge	Tightness of Door and Seal	Tightness of Window Seal	Competitor A	Competitor B	Evaluation of New Design
Customer Requirements	Easy to Open	15	9	3			7	4	
	Stays Open on Hill	10	3	9			6	7	
	Does Not Leak	35			9	9	7	6	
	Isolates Occupant from Road Noise	20	1		9	9	4	7	
	Crash Protection	20	9				4	7	
Relative Importance of Each Engineering Attribute			365	135	495	495			
Design Targets									

Quality Function Deployment (QFD)—The House of Quality

QFD was developed in Japan as a comprehensive process for improving the communication and coordination among engineering, marketing, and manufacturing personnel.[32] It achieves this by taking managers through a problem-solving process in a very structured fashion. The organizing framework for QFD is the "house of quality" (see Figure 11.5). The house of quality is a matrix that maps customer requirements against product attributes. This matrix is completed in a series of steps.

1. The team must first identify customer requirements. In Figure 11.5, market research has identified five attributes that customers value most in a car door: it is easy to open and close, it stays open on a hill, it does not leak in the rain, it isolates the occupant from road noise, and it protects the passengers in the event of crashes.
2. The team weights the customer requirements in terms of their relative importance from a customer's perspective. This information might be obtained from focus group sessions or direct interaction with the customers. The weights are typically entered as percentages, so that the complete list totals 100 percent.
3. The team identifies the engineering attributes that drive the performance of the product—in this case, the car door. In Figure 11.5, four attributes are highlighted: the weight of the door, the stiffness of the door hinge (a stiff hinge helps the door stay open on a hill), the tightness of the door seal, and the tightness of the window seal.
4. The team enters the correlations between the different engineering attributes to assess the degree to which one characteristic may positively or negatively affect another. The correlations are entered into the matrix that creates the peaked roof

of the house. In this case, the negative sign between door weight and hinge stiffness indicates that a heavy door reduces the stiffness of the hinge.

5. The team fills in the body of the central matrix. Each cell in the matrix indicates the relationship between an engineering attribute and a customer requirement. A number (in this example, one, three, or nine) is placed in the cell located at the intersection of each row (customer requirements) with each column (engineering attributes), which represents the strength of relationship between them. A value of one indicates a weak relationship, a three indicates a moderate relationship and a nine indicates a strong relationship. The cell is left blank if there is no relationship. The ease of opening the door, for example, is strongly related to the weight of the door and moderately related to the stiffness of the door hinge, but is not related to the tightness of the door seal or window seal.
6. The team multiplies the customer importance rating of a feature by its relationship to an engineering attribute (one, three, or nine). These numbers are then summed for each column, yielding a total for the relative importance of each engineering attribute. For example, the stiffness of the hinge influences how easy the door is to open, and whether the door stays open on a hill. Thus to calculate the relative importance of the stiffness of the hinge, the team multiplies the customer importance rating of how easy the door is to open by its relationship to the stiffness of the hinge ($15 \times 3 = 45$), then multiplies the customer importance rating of the door staying open on a hill by its relationship to the stiffness of the hinge ($10 \times 9 = 90$), and then adds these together for the total relative importance of the hinge stiffness ($45 + 90 = 135$). These scores indicate that the tightness of the door and window seals is the most important engineering attribute, followed by the weight of the door.
7. The team evaluates the competition. A scale of one to seven is used (one indicating a requirement is not addressed, and seven indicating a requirement is completely satisfied) to evaluate the competing products (in this case A and B) on each of the customer requirements. These scores go in the right-hand "room" of the house of quality.
8. Using the relative importance ratings established for each engineering attribute and the scores for competing products (from step 7), the team determines target values for each of the design requirements (e.g., the door's optimal weight in pounds).
9. A product design is then created based on the design targets from step 8. The team then evaluates the new design that was created. The team assesses the degree to which each of the customer requirements has been met, entering a one to seven in the far right column of the house of quality, permitting it to compare the new design with the scores of the competing products.

The great strength of the house of quality is that it provides a common language and framework within which the members of a project team may interact. The house of quality makes the relationship between product attributes and customer requirements very clear, it focuses on design trade-offs, it highlights the competitive shortcomings of the company's existing products, and it helps identify what steps need to be taken to improve them. The house of quality is used in settings as diverse as manufacturing, construction,

FIGURE 11.6
Design Rules for Fabricated Assembly Products

Source: Adapted from M. A. Schilling and C. W. L. Hill, "Managing the New Product Development Process," *Academy of Management Executive*, vol. 12, no. 3, pp. 67–81.

Design Rule	Impact on Performance
Minimize the number of parts	Simplifies assembly; reduces direct labor; reduces material handling and inventory costs; boosts product quality
Minimize the number of part numbers (use common parts across product family)	Reduces material handling and inventory costs; improves economies of scale (increases volume through commonalty)
Eliminate adjustments	Reduces assembly errors (increases quality); allows for automation; increases capacity and throughput
Eliminate fasteners	Simplifies assembly (increases quality); reduces direct labor costs; reduces squeaks and rattles; improves durability; allows for automation
Eliminate jigs and fixtures	Reduces line changeover costs; lowers required investment

police service, and educational curriculum design.[33] Advocates of QFD maintain that one of its most valuable characteristics is its positive effect upon cross-functional communication and, through that, upon cycle time and the product/customer fit.[34]

Design for Manufacturing

Another method of facilitating integration between engineering and manufacturing, and of bringing issues of manufacturability into the design process as early as possible, is the use of design for manufacturing methods (DFM). Like QFD, DFM is simply a way of structuring the new product development process. Often this involves articulating a series of design rules. Figure 11.6 summarizes a set of commonly used design rules, along with their expected impact on performance.

As shown in Figure 11.6, the purpose of such design rules is typically to reduce costs and boost product quality by ensuring that product designs are easy to manufacture. The easier products are to manufacture, the fewer the assembly steps required, the higher labor productivity will be, resulting in lower unit costs. DEKA Research makes a point of bringing manufacturing into the design process early, because as founder Dean Kamen points out, "It doesn't make sense to invent things that ultimately are made of unobtanium or expensium."[35] In addition, designing products to be easy to manufacture decreases the likelihood of making mistakes in the assembly process, resulting in higher product quality.

The benefits of adopting DFM rules can be dramatic. Considering manufacturing at an early stage of the design process can shorten development cycle time. In addition, by lowering costs and increasing product quality, DFM can increase the product's fit with customer requirements. For example, when NCR used DFM techniques to redesign one of its electronic cash registers, it reduced assembly time by 75 percent, reduced the parts required by 85 percent, utilized 65 percent fewer suppliers, and reduced direct labor time by 75 percent.[36]

Failure Modes and Effects Analysis

Failure modes and effects analysis (FMEA) is a method by which firms identify potential failures in a system, classify them according to their severity, and put a plan into place to prevent the failures from happening.[37] First, potential failure modes are identified. For example, a firm developing a commercial aircraft might consider failure modes such as "landing gear does not descend," or "communication system experiences interference"; a firm developing a new line of luxury hotels might consider failure modes such as "a reservation cannot be found" or "guest experiences poor service by room service staff." Potential failure modes are then evaluated on three criteria of the risk they pose: severity, likelihood of occurrence, and inability of controls to detect it. Each criterion is given a score (e.g., one for lowest risk, five for highest risk), and then a composite risk priority number is created for each failure mode by multiplying its scores together (i.e., risk priority number = severity × likelihood of occurrence × inability of controls to detect). The firm can then prioritize its development efforts to target potential failure modes that pose the most composite risk. This means that rather than focus first on the failure modes that have the highest scores for severity of risk, the firm might find that it should focus first on failure modes that have less severe impacts, but occur more often and are less detectable.

FMEA was originally introduced in the 1940s by the U.S. Armed Forces and was initially adopted primarily for development projects in which the risks posed by failure were potentially very severe. For example, FMEA was widely used in the Apollo Space Program in its mission to put a man on the moon, and was adopted by Ford after its extremely costly experience with its Pinto model (the location of the gas tank in the Pinto made it exceptionally vulnerable to collisions, leading to fire-related deaths; Ford was forced to recall the Pintos to modify the fuel tanks, and was forced to pay out record-breaking sums in lawsuits that resulted from accidents).[38] Soon, however, FMEA was adopted by firms in a wide range of industries, including many types of manufacturing industries, service industries, and health care. A recent PDMA study found that firms report using FMEA in 40 percent of the projects they undertake.[39]

Computer-Aided Design/Computer-Aided Engineering/ Computer-Aided Manufacturing

Computer-aided design (CAD) and computer-aided engineering (CAE) are the use of computers to build and test product designs. Rapid advances in computer technology have enabled the development of low-priced and high-powered graphics-based workstations. With these workstations, it is now possible to achieve what could previously be done only on a supercomputer: construct a three-dimensional "working" image of a product or subassembly. CAD enables the creation of a three-dimensional model; CAE makes it possible to virtually test the characteristics (e.g., strength, fatigue, and reliability) of this model. The combination enables product prototypes to be developed and tested in virtual reality. Engineers can quickly adjust prototype attributes by manipulating the three-dimensional model, allowing them to compare the characteristics of different product designs. Eliminating the need to build physical prototypes can reduce cycle time and lower costs as illustrated in the accompanying Theory in Action: Computer-Aided Design of an America's Cup Yacht. Visualization tools and 3-D software are even being used to allow nonengineering customers to see and make minor alterations to the design and materials.

Computer-aided manufacturing (CAM) is the implementation of machine-controlled processes in manufacturing. CAM is faster and more flexible than traditional

Theory in Action Computer-Aided Design of an America's Cup Yacht

Team New Zealand discovered the advantages of using sophisticated computer-aided-design techniques in designing the team's 1995 America's Cup yacht. The team had traditionally relied on developing smaller-scale prototypes of the yacht and testing the models in a water tank. However, such prototypes took months to fabricate and test and cost about $50,000 per prototype. This greatly limited the number of design options the team could consider. However, by using computer-aided-design technologies, the team could consider many more design specifications more quickly and inexpensively. Once the basic design is programmed, variations on that design can be run in a matter of hours, at little cost, enabling more insight into design trade-offs. Computer-aided design also avoided some of the problems inherent in scaling up prototypes (some features of the scaled-down prototype boats would affect the flow of water differently from full-scale boats, resulting in inaccurate results in prototype testing). The team would still build prototypes, but only after considering a much wider range of design alternatives using computer-aided-design methods. As noted by design team member Dave Egan,

> Instead of relying on a few big leaps, we had the ability to continually design, test, and refine our ideas. The team would often hold informal discussions on design issues, sketch some schematics on the back of a beer mat, and ask me to run the numbers. Using traditional design methods would have meant waiting months for results, and by that time, our thinking would have evolved so much that the reason for the experiment would long since have been forgotten.

Source: M. Iansiti and A. MacCormack, "Team New Zealand," Harvard Business School case no. 9-697-040, 1997.

manufacturing.[40] Computers can automate the change between different product variations and allow for more variety and customization in the manufacturing process.

three-dimensional printing
A method whereby a design developed in a computer aided design program is printed in three dimensions by laying down thin strips of material until the model is complete.

A recent incarnation of computer-aided manufacturing is **three-dimensional printing** (also known as additive manufacturing), whereby a design developed in a computer-aided design program is literally printed by laying down thin horizontal cross sections of material until the model is complete. Unlike traditional methods of constructing a model, which typically involve machining a mold that can take several days to complete, three-dimensional printing can generate a model in a few hours. By 2018, three-dimensional printing was being used to create products as diverse as food, clothing, jewelry, solid-state batteries, and even titanium landing gear brackets for supersonic jets.[41] Biotechnology firms were even using three-dimensional printing for use in creating organs by depositing layers of living cells onto a gel medium.[42] This method has recently begun rapidly replacing injection molding for products that are produced in relatively small quantities.

TOOLS FOR MEASURING NEW PRODUCT DEVELOPMENT PERFORMANCE

Many companies use a variety of metrics to measure the performance of their new product development process. In addition to providing feedback about a particular new product, such performance assessments help the company improve its innovation

Theory in Action Postmortems at Microsoft

At Microsoft, almost all projects receive either a postmortem discussion or a written postmortem report to ensure that the company learns from each of its development experiences. These postmortems tend to be extremely candid and can be quite critical. As noted by one Microsoft manager, “The purpose of the document is to beat yourself up.” Another Microsoft manager notes that part of the Microsoft culture is to be very self-critical and never be satisfied at getting things “halfway right.” A team will spend three to six months putting together a postmortem document that may number anywhere from less than 10 pages to more than 100. These postmortem reports describe the development activities and team, provide data on the product size (e.g., lines of code) and quality (e.g., number of bugs), and evaluate what worked well, what did not work well, and what the group should do to improve on the next project. These reports are then distributed to the team members and to senior executives throughout the organization.

Source: M. A. Cusumano and R. W. Selby, *Microsoft Secrets* (New York: Free Press, 1995).

strategy and development processes. For example, evaluating the performance of its new product development process may provide insight into which core competencies the firm should focus on, how projects should be selected, whether or not it should seek collaboration partners, how it should manage its development teams, and so on.

Both the metrics used by firms and the timing of their use vary substantially across firms. In a survey by Goldense and Gilmore, 45 percent of companies reported using periodic reviews at calendar periods (e.g., monthly or weekly) and at predetermined milestones (e.g., after product definition, after process design, post launch, etc.).[43] Microsoft, for example, uses postmortems to measure new product development performance, as described in the accompanying Theory in Action: Postmortems at Microsoft. Measures of the success of the new product development process can help management to:

- Identify which projects met their goals and why.
- Benchmark the organization’s performance compared to that of competitors or to the organization’s own prior performance.
- Improve resource allocation and employee compensation.
- Refine future innovation strategies.[44]

Multiple measures are important because any measure used singly may not give a fair representation of the effectiveness of the firm’s development process or its overall innovation performance. Also, the firm’s development strategy, industry, and other environmental circumstances must be considered when formulating measures and interpreting results. For example, a firm whose capabilities or objectives favor development of breakthrough projects may experience long intervals between product introductions and receive a low score on measures such as cycle time or percent of sales earned on projects launched within the past five years, despite its success at its strategy. Conversely, a firm that rapidly produces new generations of products may receive a high score on such measures even if it finds its resources are overtaxed and its projects are overbudget. Additionally, the success rate of new product development can vary significantly by industry and project type. Some authors argue that even firms with excellent new product development processes should not expect to have a greater than 65 percent success rate for all new products launched.[45]

New Product Development Process Metrics

Many firms use a number of methods to gauge the effectiveness and efficiency of the development process. These measures capture different dimensions of the firm's ability to successfully shepherd projects through the development process. To use such methods, it is important to first define a finite period in which the measure is to be applied in order to get an accurate view of the company's current performance; this also makes it easier for the manager to calculate a response. The following questions can then be asked:

1. What was the average cycle time (time to market) for development projects? How did this cycle time vary for projects characterized as breakthrough, platform, or derivative?
2. What percentage of development projects undertaken within the past five years met all or most of the deadlines set for the project?
3. What percentage of development projects undertaken within the past five years stayed within budget?
4. What percentage of development projects undertaken within the past five years resulted in a completed product?

Overall Innovation Performance

Firms also use a variety of methods to assess their overall performance at innovation. These measures give an overall view of the bang for the buck the organization is achieving with its new product development processes. Such measures include:

1. What is the firm's return on innovation? (This measure assesses the ratio of the firm's total profits from new products to its total expenditures, including research and development costs, the costs of retooling and staffing production facilities, and initial commercialization and marketing costs.)
2. What percentage of projects achieve their sales goals?
3. What percentage of revenues are generated by products developed within the past five years?
4. What is the firm's ratio of successful projects to its total project portfolio?

Summary of Chapter

1. Successful new product development requires achieving three simultaneous objectives: maximizing fit with customer requirements, minimizing time to market, and controlling development costs.
2. Many firms have adopted parallel development processes to shorten the development cycle time and to increase coordination among functions such as R&D, marketing, and manufacturing.
3. Many firms have also begun using project champions to help ensure a project's momentum and improve its access to key resources. Use of champions also has its risks, however, including escalating commitment and unwillingness of others in the organization to challenge the project.
4. Involving customers in the development process can help a firm ensure that its new products match customer expectations. In particular, research indicates that involving lead users can help the firm understand what needs are most important

to customers, helping the firm to identify its development priorities. Involving lead users in the development process can also be faster and cheaper than involving a random sample of customers in the development process.

5. Many firms use beta testing to get customer feedback, exploit external development of the product, and signal the market about the firm's upcoming products.
6. Firms can also involve suppliers in the development process, helping to minimize the input cost of a new product design and improving the likelihood that inputs are of appropriate quality and arrive on time.
7. Stage-gate processes offer a blueprint for guiding firms through the new product development process, providing a series of go/kill gates where the firm must decide if the project should be continued and how its activities should be prioritized.
8. Quality function deployment can be used to improve the development team's understanding of the relationship between customer requirements and engineering attributes. It can also be a tool for improving communication between the various functions involved in the development process.
9. Failure Modes and Effects Analysis can be used to help firms prioritize their development efforts in order to reduce the likelihood of failures that will have the greatest impact on the quality, reliability, and safety of a product or process.
10. Design for manufacturing and CAD/CAM are additional tools development teams can use to reduce cycle time, improve product quality, and control development costs.
11. Firms should use a variety of measures of their new product development effectiveness and overall innovation performance to identify opportunities for improving the new product development process and improving the allocation of resources.

Discussion Questions

1. What are some of the advantages and disadvantages of a parallel development process? What obstacles might a firm face in attempting to adopt a parallel process?
2. Consider a group project you have worked on at work or school. Did your group use mostly sequential or parallel processes?
3. Name some industries in which a parallel process would not be possible or effective.
4. What kinds of people make good project champions? How can a firm ensure that it gets the benefits of championing while minimizing the risks?
5. Is the stage-gate process consistent with suggestions that firms adopt parallel processes? What impact do you think using stage-gate processes would have on development cycle time and development costs?
6. What are the benefits and costs of involving customers and suppliers in the development process?

Suggested Further Reading

Classics

Clark, K. B., and S. C. Wheelwright, *Managing New Product and Process Development* (New York: Free Press, 1993).

Cooper, R., and E. J. Kleinschmidt, "New Product Processes at Leading Industrial Firms," *Industrial-Marketing-Management* 20, no. 2 (1991), pp. 137–48.

Griffin, A., and J. R. Hauser, "Patterns of Communication Among Marketing, Engineering and Manufacturing," *Management Science* 38 (1992), pp. 360–73.

Loch, C., and S. Kavadias, *Handbook of New Product Development Management.* (Oxford, UK: Elsevier Ltd., 2008).

Recent Work

Chang, W., and S. A. Taylor, "The Effectiveness of Customer Participation in New Product Development: A Meta-Analysis." *Journal of Marketing,* 80, no. 1 (2016), pp. 47–64.

Cooper, R. G., "Agile-Stage-Gate Hybrids," *Research-Technology Management,* 59 (2016), pp. 1, 21–29

Lawson, B., D. Krause, and A. Potter, "Improving Supplier New Product Development Performance: The Role of Supplier Development." *Journal of Product Innovation Management* 32 (2015), pp. 777–92.

Piezunka, H., and L. Dahlander, "Distant Search, Narrow Attention: How Crowding Alters Organizations' Filtering of Suggestions in Crowdsourcing," *Academy of Management Journal,* 58 (2015), pp. 856–880.

Prpic, J., P. P. Shukla, J. H. Kietzmann, and I. P. McCarthy, "How to Work a Crowd: Developing Crowd Capital Through Crowdsourcing," *Business Horizons,* 58 (2015), pp. 77–85.

Endnotes

1. E. Berggren and T. Nacher, "Introducing New Products Can Be Hazardous to Your Company: Use the Right New-Solutions Delivery Tools," *Academy of Management Executive* 15, no. 3 (2001), pp. 92–101.
2. M. A. Schilling, "Technological Lockout: An Integrative Model of the Economic and Strategic Factors Driving Success and Failure," *Academy of Management Review* 23 (1998), pp. 267–84; and W. B. Arthur, *Increasing Returns and Path Dependence in the Economy* (Ann Arbor: University of Michigan Press, 1994).
3. A. Dhebar, "Speeding High-Tech Producer, Meet Balking Consumer," *Sloan Management Review,* Winter 1996, pp. 37–49.
4. M. C. Crawford, "The Hidden Costs of Accelerated Product Development," *Journal of Product Innovation Management* 9, no. 3 (1992), pp. 188–200.
5. G. Pacheco-de-Almeida and P. Zemsky, "The Creation and Sustainability of Competitive Advantage: Resource Accumulation with Time Compression Diseconomies," mimeo, Stern School of Business, 2003.
6. E. J. Nijssen, A. R. Arbouw, and H. R. Commandeur, "Accelerating New Product Development: A Preliminary Empirical Test of a Hierarchy of Implementation," *Journal of Product Innovation Management* 12 (1995), pp. 99–104; R. W. Schmenner, "The Merits of Making Things Fast," *Sloan Management Review,* Fall (1988), pp. 11–17; A. Ali, R. Krapfel, and D. LaBahn, "Product Innovativeness and Entry Strategy: Impact on Cycle Time and Break-Even Time," *Journal of Product Innovation Management* 12 (1995), pp. 54–69; and R. Rothwell, "Successful Industrial Innovation: Critical Factors for the 1990s," *R&D Management* 22, no. 3 (1992), pp. 221–39.

7. A. Griffin, "Evaluating QFD's Use in US Firms as a Process for Developing Products," *Journal of Product Innovation Management* 9 (1992), pp. 171–87; and C. H. Kimzey, *Summary of the Task Force Workshop on Industrial-Based Initiatives* (Washington, DC: Office of the Assistant Secretary of Defense, Production and Logistics, 1987).
8. A. De Meyer and B. Van Hooland, "The Contribution of Manufacturing to Shortening Design Cycle Times," *R&D Management* 20, no. 3 (1990), pp. 229–39; R. Hayes, S. G. Wheelwright, and K. B. Clark, *Dynamic Manufacturing* (New York: Free Press, 1988); R. G. Cooper, "The New Product Process: A Decision Guide for Managers," *Journal of Marketing Management* 3 (1988), pp. 238–55; and H. Takeuchi and I. Nonaka, "The New Product Development Game," *Harvard Business Review,* January–February (1986), pp. 137–46.
9. K. Eisenhardt and B. N. Tabrizi, "Accelerating Adaptive Processes: Product Innovation in the Global Computer Industry," *Administrative Science Quarterly* 40 (1995), pp. 84–110; and C. Terwiesch and C. H. Loch, "Measuring the Effectiveness of Overlapping Development Activities," *Management Science* 45 (1999), pp. 455–65.
10. B. J. Zirger and M. A. Maidique, "A Model of New Product Development: An Empirical Test," *Management Science* 36 (1990), pp. 867–83; R. Rothwell, C. Freeman, A. Horley, P. Jervis, A. B. Robertson, and J. Townsend, "SAPPHO Updates—Project SAPPHO, PHASE II," *Research Policy* 3 (1974), pp. 258–91; A. H. Rubenstein, A. K. Chakrabarti, R. D. O'Keffe, W. E. Souder, and H. C. Young, "Factors Influencing Innovation Success at the Project Level," *Research Management,* May (1976), pp. 15–20; F. A. Johne and P. A. Snelson, "Product Development Approaches in Established Firms," *Industrial Marketing Management* 18 (1989), pp. 113–24; and Y. Wind and V. Mahajan, "New Product Development Process: A Perspective for Reexamination," *Journal of Product Innovation Management* 5 (1988), pp. 304–10.
11. T. F. Gattiker and C. R. Carter, "Understanding project champions' ability to gain intra-organizational commitment for environmental projects," *Journal of Operations Management* 28 (2010), pp. 72–85.
12. E. Roberts, "Benchmarking Global Strategic Management of Technology," *Research Technology Management,* March–April (2001), pp. 25–36.
13. E. Rudden, "The Misuse of a Sound Investment Tool," *Wall Street Journal,* November 1, 1982.
14. M. Devaney, "Risk, Commitment, and Project Abandonment," *Journal of Business Ethics* 10, no. 2 (1991), pp. 157–60.
15. Devaney, "Risk, Commitment, and Project Abandonment."
16. F. A. Johne and P. A. Snelson, "Success Factors in Product Innovation," *Journal of Product Innovation Management* 5 (1988), pp. 114–28; and F. W. Gluck and R. N. Foster, "Managing Technological Change: A Box of Cigars for Brad," *Harvard Business Review* 53 (1975), pp. 139–50.
17. R. G. Cooper, "Selecting Winning New Product Projects: Using the NewProd System," *Journal of Product Innovation Management* 2 (1985), pp. 34–44.
18. J. E. Butler, "Theories of Technological Innovation as Useful Tools for Corporate Strategy," *Strategic Management Journal* 9 (1988), pp. 15–29.
19. M. Restuccia, U. Brentani, and R. Legoux, "Product Life-Cycle Management and Distributor Contribution to New Product Development," *Journal of Product Innovation Management,* 33 (2106), pp. 69–89.
20. A. S. Cui and F. Wu, "The Impact of Customer Involvement on New Product Development: Contingent and Substitutive Effects," *Journal of Product Innovation Management,* 34 (2016), pp. 60–80.
21. C. Herstatt and E. von Hippel, "Developing New Product Concepts via the Lead User Method: A Case Study in a Low-Tech Field," *Journal of Product Innovation Management* 9 (1992), pp. 213–21.

22. D. Mahr, A. Lievens, and V. Blazevic. "The value of customer cocreated knowledge during the innovation process." *Journal of Product Innovation Management* 31 (2014), 599–615.
23. Asmus and Griffin found that firms that integrate their suppliers with engineering, manufacturing, and purchasing gain cost reductions, shortened lead times, lowered development risks, and tightened development cycles. D. Asmus and J. Griffin, "Harnessing the Power of Your Suppliers," *McKinsey Quarterly,* no. 3 (1993), pp. 63–79. Additionally, Bonaccorsi and Lipparini found that strategic alliances with suppliers lead to shorter product development cycles and better products, particularly in rapidly changing markets. A. Bonaccorsi and A. Lipparini, "Strategic Partnership in New Product Development: An Italian Case Study," *Journal of Product Innovation Management* 11, no. 2 (1994), pp. 134–46.
24. L. Birou and S. Fawcett, "Supplier Involvement in New Product Development: A Comparison of US and European Practices," *Journal of Physical Distribution and Logistics Management* 24, no. 5 (1994), pp. 4–15; and A. Ansari and B. Modarress, "Quality Function Deployment: The Role of Suppliers," *International Journal of Purchasing and Materials Management* 30, no. 4 (1994), pp. 28–36.
25. Interview with Andy Zynga, former CEO of NineSigma, March 13, 2018
26. N. Franke and M. Schreier. "Why customers value self-designed products: The importance of process effort and enjoyment." *Journal of Product Innovation Management* 27 (2010), pp. 1020–1031.
27. W. D. Hoyer, R. Chandy, M. Dorotic, M. Krafft, and S. S. Singh, "Consumer cocreation in new product development," in *Journal of Service Research* 13 (2010), issue 3, 283–296.
28. R. Cooper and E. J. Kleinschmidt, "New Product Processes at Leading Industrial Firms," *Industrial-Marketing-Management* 20, no. 2 (1991), pp. 137–48; and R. G. Cooper, "Doing It Right," *Ivey Business Journal* 64, no. 6 (2000), pp. 54–61; and R.G. Cooper, "Stage-Gate Idea to Launch System," *Wiley International Encyclopedia of Marketing: Product Innovation & Management* 5, B.L. Bayus (ed.), (West Sussex UK: Wiley, 2011).
29. R.G. Cooper, "Stage-Gate Idea to Launch System," *Wiley International Encyclopedia of Marketing: Product Innovation & Management* 5, B.L. Bayus (ed.), (West Sussex UK: Wiley, 2011).
30. L. Y. Coyeh, P. W. Kamienski, and R. L. Espino, "Gate System Focuses on Industrial Basic Research," *Research Technology Management* 41, no. 4 (1998), pp. 34–37.
31. A. LaPlante and A. E. Alter, "Corning, Inc: The Stage-Gate Innovation Process," *Computerworld* 28, no. 44 (1994), p. 81.
32. J. J. Cristiano, J. K. Liker, and C. C. White, "Key Factors in the Successful Application of Quality Function Deployment (QFD)," *IEEE Transactions on Engineering Management* 48, no. 1 (2001), p. 81.
33. I. Bier, "Using QFD to Construct a Higher Education Curriculum," *Quality Progress* 34, no. 4 (2001), pp. 64–69; N. Eldin, "A Promising Planning Tool: Quality Function Deployment," *Cost Engineering* 44, no. 3 (2002), pp. 28–38; and W. J. Selen and J. Schepers, "Design of Quality Service Systems in the Public Sector: Use of Quality Function Deployment in Police Services," *Total Quality Management* 12, no. 5 (2001), pp. 677–87; J. A. Carnevalli and P. C. Miguel, "Review, analysis and classification of the literature on QFD—types of research, difficulties and benefits," *International Journal of Production Economics* 114 (2008), pp. 737–54.
34. K. B. Clark and S. C. Wheelwright, *Managing New Product and Process Development* (New York: Free Press, 1993); J. R. Hauser and D. Clausing, "The House of Quality," *Harvard Business Review,* May–June (1988), pp. 63–73; A. Griffin, "Evaluating QFD's Use in US Firms as a Process for Developing Products," *Journal of Product Innovation Management* 9 (1992), pp. 171–87; and A. Griffin and J. R. Hauser, "Patterns of Communication among Marketing, Engineering and Manufacturing,"

35. E. I. Schwartz, "The Inventor's Play-Ground," *Technology Review* 105, no. 8 (2002), pp. 68–73.
36. K. B. Clark and S. C. Wheelwright, *Managing New Product and Process Development* (New York: Free Press, 1993); J. R. Hauser and D. Clausing, "The House of Quality," *Harvard Business Review,* May–June (1988), pp. 63–73; A. Griffin, "Evaluating QFD's Use in US Firms as a Process for Developing Products," *Journal of Product Innovation Management* 9 (1992), pp. 171–87; and A. Griffin and J. R. Hauser, "Patterns of Communication among Marketing, Engineering and Manufacturing," *Management Science* 38 (1992), pp. 360–73.
37. S. Kumar, E. C. Aquino, and E. Anderson, "Application of a Process Methodology and a Strategic Decision Model for Business Process Outsourcing," *Information Knowledge Systems Management* 6 (2007), pp. 323–42; and J. W. Langford, *Logistics: Principles and Applications* (New York: McGraw-Hill, 1995).
38. L. P. Chao and K. Ishii, "Design Error Classification and Knowledge Management," *Journal of Knowledge Management Practice,* May (2004); and P. Valdes-Dapena, "Tagged: 10 Cars with Bad Reputations," CNNMoney.com (accessed April 23, 2009).
39. G. Barczak, A. Griffin, and K. B. Kahn, "Trends and Drivers of Success in NPD Practices: Results of the 2003 PDMA Best Practices Study," *Journal of Product Innovation Management* 26 (2009), pp. 3–23.
40. M. R. Millson, S. P. Raj, and D. Wilemon, "A Survey of Major Approaches for Accelerating New Product Development," *Journal of Product Innovation Management* 9 (1992), pp. 53–69.
41. "The printed World," *The Economist (2011),* February 10, 2011; K. Lee, "Foodini 3D printer cooks up meals like the Star Trek food replicator," www.inhabitat.com (2013): December 9th; Fitzgerald, M. "With 3-D printing the shoe really fits." *MIT Sloan Management Review* (2013), www.sloanreview.mit.edu:May 15th.
42. J. Silverstein, "Organ Printing Could Drastically Change Medicine," ABC News, February 10, 2006.
43. B. L. Goldense and J. Gilmore, "Measuring Product Design," *Machine Design* 73, no. 14 (2001), pp. 63–67.
44. T. D. Kuczmarski, "Measuring Your Return on Innovation," *Marketing Management* 9, no. 1 (2000), pp. 24–32.
45. Ibid.