The innovator's toolkit

50+ Techniques for Predictable and Sustainable Organic Growth

DAVID SILVERSTEIN
PHILIP SAMUEL
NEIL DECARLO

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PREFACE

Growing an already sizeable company isn't an easy feat, and it's even more difficult to do on a sustainable basis. Two avenues exist: you can grow from the outside through mergers and acquisitions (M&As), or you can grow from the inside through organically engineered innovation. The problem is that both approaches tend to fall short of expectations, even when used in combination.

Leaving the problem of M&As to others, we wrote this book to address and ameliorate the problems with organic growth. What are the barriers to organic growth and how can they be surmounted? Where are the pitfalls and can they be avoided? What are innovation's misconceptions?

We worked with a company in the tea business that believed in generating a lot of ideas. After numerous sessions, the company had more than 7,000 new ideas for innovation. A year later, only two of those ideas reached the implementation stage, and both failed in the marketplace.

Two-time Nobel Prize winner Linus Pauling once said, "The way to get good ideas is to get lots of ideas and throw the bad ones away."

One of innovation's misconceptions is that the more ideas you have, the more likely you are to innovate. You'll see in this book why this mentality might work for a basic researcher like Pauling but not for a corporation that needs to consistently meet growth targets. A lot of companies are good at coming up with new ideas, but few know how to vet them wisely, develop them efficaciously, and commercialize them profitably.

Success with organic growth takes a lot more than ideas, or even great ideas. It takes galvanizing leadership and a sustainable growth engine. It takes deep understanding of key concepts and a robust managerial process. It also takes a groundswell of employees who can skillfully apply all the necessary techniques and tools of innovation—not just the mind-expanding ones.

This book is for those who are interested in the big picture of organic growth and want to become innovation-elite organizations, as well as for those who need to execute a single innovation project. Read the Introduction if you want a practical framework for making innovation predictable and sustainable in your organization—and in the process discover the reasons most growth initiatives fail to produce their intended results (we want you to avoid them).

Then we've organized 55 useful techniques into four parts that follow a repeatable innovation process we call "D^4" (Define-Discover-Develop-Demonstrate). We don't cover any one of these techniques in depth, but we do provide a consistent overview of each, then spell out the steps involved in applying each, illustrating with nonproprietary examples. When what we give you is insufficient for mastery, we refer you to other books and resources.

The real inspiration for this book came while teaching innovation to clients and workshop attendees who kept asking, "Where can we get all these techniques in one place?" We listened time after time until we had something of an epiphany. The answer was "nowhere," and for good reasons.

For one, many techniques in this book are entire fields in and of themselves with their own dedicated texts and tomes. For another, they come from the opposing domains of right-brain creativity and left-brain analytics. Yet symbiotically, even paradoxically, techniques from both of these domains are needed to enable the innovation process and achieve organic growth on any scale.

Maybe pulling these techniques together doesn't make us innovation pioneers. But we do know this about ourselves: we perform the hard work of putting substance into what people say—in this case "innovate or die." We certainly hope you'll agree that there is enough substance in this book to move an innovation mountain in your organization, making rebirth and invention an everyday event, not an unexpected surprise.

Whatever you do, don't ever think that innovation is somehow uncontrollable or mysterious, or the birthright of just the gifted few. Innovation is for everyone.

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ACKNOWLEDGMENTS

Clients always ask us "Who should be responsible for innovation in an organization?" The easy answer is "Everyone!" An organization that creates a climate for innovation welcomes and values every individual's unique contributions—ideas, observations, customer insights, even constructive criticisms.

Because we like to practice what we preach at BMGI, we viewed this book as an opportunity to involve the entire company in what was, in itself, an innovative approach to writing a book. From our master consultants, many of whom contributed their expertise, to our global staff, everyone was invited to share their knowledge. As a result, we have a long list of people who we would like to acknowledge and thank for their time, counsel, and contributions.

First and foremost is Debra Jennings, who wrote and edited large portions of the manuscript, transforming a formidable variety of inputs into their final form. We can't say enough about Debra's incredible talent, tenacity, and wisdom. There is no question that without her, this book would not exist. You have our deepest thanks, Deb, for your incredible and impeccable work!

Next, we'd like to offer our sincere appreciation to several people who not only drafted or contributed to one or more techniques in this book, but who also stepped forward to help with examples and research. These individuals are (in alphabetical order) Riaan Brits, Liz McArdle, David McGee, Rishab Rao, Steven Ungvari, and Don Wilson.

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A thank you goes to graphic designer Colin Moore, whose more than 100 graphics made this book considerably more informative and stimulating. We're also grateful to illustrator Scott Stoddard, who created delightful and memorable illustrations and cartoons for several techniques. And thanks to BMGI's general counsel Marc Pappalardo for his thorough legal review of the book's many techniques and examples.

Still others contributed in additional capacities. Wendy St. Clair helped formulate the book's early outline, and Shari Cashman created the book's marketing and promotion plan along with Wendy. Then Kimberley Carrington and Melissa Madtson put their skills to work in helping format and check the manuscript for accuracy.

We'd be remiss to forget all the staff at John Wiley & Sons, especially those with whom we worked closely. Our editor Richard Narramore was an incisive guide for us, keeping us on track at just the right times in the most gentlemanly way possible. As well, editorial assistant Tiffany Groglio was delightful to work with and patient with our many inquiries, as was our production editor, Linda Indig.

Of course, our families were right there for us as they always are—not only accepting the long, extra hours working but giving us tangible support along the way. We love you and thank you for this!

Most importantly, we'd like to acknowledge the many organizations that have helped shape our understanding of innovation and our approach to making it more predictable, repeatable, and sustainable. Your trials and successes have inspired us, and we hope you continue to make innovation common and eventful in your organizations.

How to Make Organic Growth an Everyday Event—Systematizing Your Innovation Process

There are numerous factors involved in successfully applying the techniques and tools in this book, especially if you're undertaking an innovation deployment on an organizational scale. But even if you're using this book to solve one small problem—or just educate yourself about innovation techniques—the information in this introduction should be interesting and helpful.

First we'll bring some needed focus to innovation's often fuzzy front edge, making it much clearer and more actionable by exposing two revolutionary concepts that are also key techniques in this book: *jobs to be done* and *outcome expectations*. Then we'll examine the different strategic pathways for organic growth in light of these techniques and their conceptual basis.

After this, we'll provide some guidance on how to assemble a viable portfolio of organic-growth projects, making sure to demonstrate how all successful innovations translate to how people solve problems. Then to close, we'll give you a methodology (or process) you can follow to implement a single innovation project or to lead and manage a widespread organic-growth initiative.

Focusing on Innovation's Front Edge

We'll do the expected and give you our definition of innovation first. While a common definition is "introducing something new" or "coming up with the next big idea," we think of innovation as *the act of generating more value for the customer and the business by fulfilling a job to be done better than anyone else.*

A job to be done (JTBD) is the purpose for which customers buy products and services, like buying sanitizing soap to *keep hands clean and germ-free at work.* If you can fulfill this JTBD for your customers better than your competitors can, at a lower cost and with no harmful side effects, then you win market share.

It's as simple as that.

Meantime, most corporations are preoccupied with cataloging and improving their inventory of products and services. Instead of seeing customers who need to *stay warm in winter* (a JTBD), they are focused on their offerings—*gas furnace heaters, space warmers, electric heaters, winter jackets, a more efficient heating system,* and so on. The problem with this thinking is that it's solution-centric, and it assumes that a company exists to provide better and better mousetraps, whatever those mousetraps may be.

Innovation isn't about coming up with new or better stuff; it's about solving the problem of what to come up with in the first place. Most organizations are busy filing patents and making their products and services better, but what they really need to do is better address their jobs to be done, and their customers' jobs to be done.

In the 1700s, customers told candle companies they wanted brighter, longer-lasting candles that produced less smoke and soot, and that dripped less (performance expectations). The most sophisticated customers asked for better-smelling candles in different colors (perception expectations). Candle makers listened, and many kept producing better candles along the lines of what customers said they wanted.

Still, most of them went out of business.

In reality, business success requires focus on more than just *performance and perception expectations,* which are related to the features and functionality of specific offerings (solution specific). It's also critical—especially if you want to innovate—to understand *outcome expectations,* which are less concrete and related to the jobs customers need to get done (solution neutral). For instance, if illuminating the darkness is the job to be done, then doing this with *ease and convenience* is an outcome expectation.

Don't confuse solution-specific performance and perception expectations with solution-neutral outcome expectations, or you'll end up in

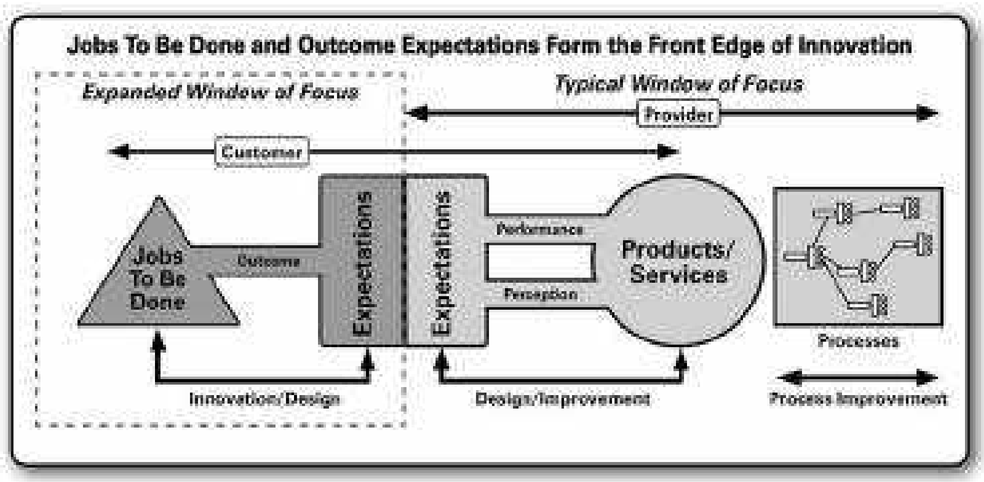

EXHIBIT I. 1

company with the storied corporations that were caught looking sideways when the wave of change came (see Exhibit I.1).

IBM was looking sideways when Microsoft envisioned a PC in the hands of every person—and 300 years earlier, candle makers were busy making better candles while others were relentlessly focused on how to differentiate themselves. Those others were more concerned with how to better achieve the job of *illuminating the darkness* in a more valuable way (with less cost and harm).

When the light bulb and electricity came along, it really didn't matter how well a company could make a candle or a kerosene lamp; these solutions didn't satisfy the outcome expectations as well as the light bulbs did. Nor did the big mainframe computers satisfy customer outcome expectations as well as personal computers did.

Exhibit I.1 shows the difference between performance and perception expectations on the one hand, and outcome expectations on the other. It's necessary to fully address both types of expectations to be successful at innovation.

Maybe the first real step toward organic growth is admitting that you're probably better at refining and improving solutions (performance and perception) than you are at cannibalizing yourself in favor of solutions that wow your customers on a higher plane (outcome expectations). This is perhaps the key reason why only about 10 percent of publicly held companies are able to reach any reasonable standard of organic growth in a consistent manner.

On the flip side, when important outcomes are poorly satisfied, or the solutions for important jobs to be done are ad hoc or nonexistent, that's a glaring opportunity for innovation. Once the opportunity is identified, any company can pursue focused ideation and solution development to provide more value than what exists today.

Adopting Organic Growth Strategies

There are at least four ways to achieve organic revenue growth through satisfying unmet JTBDs and customer outcome expectations: *core growth, disruptive growth, related jobs growth,* and *new jobs growth.* Let's briefly examine each.

Core Growth

A core growth strategy takes advantage of unmet outcomes associated with a job that customers want to achieve. For example, customers want to pour juice into a cup with greater ease (desired outcome expectation) without the risk of spilling (undesired outcome expectation), so the juice bottle is redesigned to have an indentation for easy gripping. New Balance builds running shoes that increasingly improve foot cushioning and stability. Microsoft gives customers more functionality and fewer problems with each generation of Windows.

A core growth strategy means that more value is built into core products, services, and solutions over time by fulfilling unmet customer outcome expectations.

Disruptive Growth

While a core growth strategy focuses on existing jobs for *current* customers, disruptive growth focuses on existing jobs for *new* customers. Remember when going to a dentist's office was the only way to get your teeth whitened? That was a time when many customers couldn't get the job done due to lack of money, skill, time, or access. But now the job of whitening teeth can be done by nearly everyone with Crest Whitestrips, Procter & Gamble's disruptive product.

Other examples of disruptive growth are home pregnancy tests, online stock trading, home dry cleaning, self-administered medical monitoring devices, do-it-yourself legal documents, and the $200 laptop computer for kids in developing countries (complete with software). All of these solutions make something accessible to many customers who were formerly locked out of the market for getting their jobs done.

Related Jobs Growth

The focus of this strategy is to bundle solutions or come up with new solutions that achieve the outcome expectations of more than one JTBD. Often these jobs are related as a family of jobs that need to be done before, during, or after the primary job is done. If you can offer one solution or an integrated solution that addresses a family of jobs, you can create a differentiated market opportunity.

Starbucks is an example of a solution that addresses many jobs, such as *drink caffeinated beverages*, *carry on business conversations*, *surf the Internet*, *drink healthy alternative beverages*, and *read books in a relaxed environment*.

When your customers are satisfied with your existing solutions, this is an important strategy to pursue. Customers were fairly satisfied with Sony Walkman and MP3 players to perform the job of *listening to music*. However, they were not satisfied with related jobs such as *browse music choices available for download*, *organize music*, *share music with friends*, and *discard unwanted music*. This created an opportunity for Apple to bring iPod/iTunes to the marketplace.

New Jobs Growth

At a fundamental level, society has a list of fundamental jobs to be done. Examples of these include *satisfy hunger, provide shelter,* and *travel faster.* While these jobs remain static over time, certain shift changes take place when technology is introduced to change the rules of the game—such as when we jumped from the steam to the combustion engine.

With technology as the fuel, new jobs emerge for which current solutions are ad hoc or nonexistent. The objective of a new jobs growth strategy, therefore, is to identify jobs that are unmet or poorly met.

Take the example of individuals buying from or selling goods to one another. Before eBay came into existence, this job was done through classified ads, swap meets, and flea markets—but these solutions did not adequately address the new realities of the Internet revolution. eBay took advantage of this gap and created an uncontested market space.

Many purposeful brands are created by identifying jobs to be done for which no good solutions exist. Examples include Xerox, Kleenex, FedEx, OnStar, Google, Starbucks, BlackBerry, and Lunchables. All of these brands were created by virtue of a new JTBD, or at least a major shift in outcome expectations related to a timeless JTBD.

Developing a Project Portfolio

Whatever your organic growth strategy, it always boils down to executing one innovation project at a time—even if you have hundreds going simultaneously. To manage this, think of your portfolio of projects as a well-balanced attack on the future that includes product/service innovations, process innovations, and business-model innovations.

Examples of product innovation include Sanyo's introduction of washing machines that don't use detergent, Apple's iPhone, and Procter & Gamble's Whitestrips. Service examples are Progressive Insurance's on-site claim adjustments, self-service check-ins at hotels and airlines, Skype, and Facebook.

Process innovations occur behind the scenes and provide more value to the customer in the form of expedited service and higher quality. Wal-Mart's *everyday low prices* are really a conglomeration of behind-the-scenes business process innovations, as is Amazon's *Buy Now with 1-Click* feature. At the same time, such process innovations provide great value to businesses in the form of higher productivity, lower lead times, improved employee morale, and increased profitability.

An example of a business model innovation is when Dell began selling computers directly to customers, avoiding the retail link in the chain. With minimal inventories to manage, cash up-front from customers, and delayed payment terms to suppliers, Dell redefined working capital management.

eBay also changed the business model landscape when it enabled buyers and sellers to come together outside the inefficient confines of former person-to-person venues.

A rounded innovation project portfolio should also be distributed according to degree of import (incremental, substantial, breakthrough). Obviously, the magnitude of investment, risk, and potential impact on profit increases as you move up the chain from incremental to breakthrough innovation.

Some examples of incremental innovation include improving the check-in process at a hotel or airline, or implementing an employee idea-solicitation program. A substantial innovation might be replacing an electric toothbrush with one that uses sound waves, or allowing consumers to purchase their own plane tickets online. You still need to brush your teeth and get a plane ticket, but the means by which you do this materially change.

Of course, breakthrough innovations generate tremendous value for customers and for the business. The discovery of antibiotics, the printing press, gun powder, airplanes, portable computers, and the World Wide Web are all examples of breakthrough innovation.

While it's difficult to firmly establish what constitutes incremental versus substantial versus breakthrough innovation, each company can define these terms for themselves. The chemical division of Royal Dutch Shell, for instance, said at one time it needed to generate $100 million or more in revenue for an innovation to be classified as a breakthrough. Whatever the criteria, every company needs to constantly populate and refresh its innovation project pipeline.

Exhibit I.2 shows the relative proportions of a typical innovation portfolio. Usually you will have more product, process, and service innovations—and fewer business model innovations. As well, most organizations aim for more incremental and substantial innovations—and fewer breakthrough innovations.

Of course, true competitive advantage is usually the result of making coordinated innovations on multiple fronts. Through the combination of its iPod and iPhone products with its iTunes business model, Apple created about $70 billion in shareholder value in just three years. Amazon's business model innovation of cutting out the brick-and-mortar store is coupled with service innovations such as *1-Click, Recently Viewed Items, Customer Reviews,* and *Books You Might Also Like.* This is a taste of how these companies have innovated across the board.

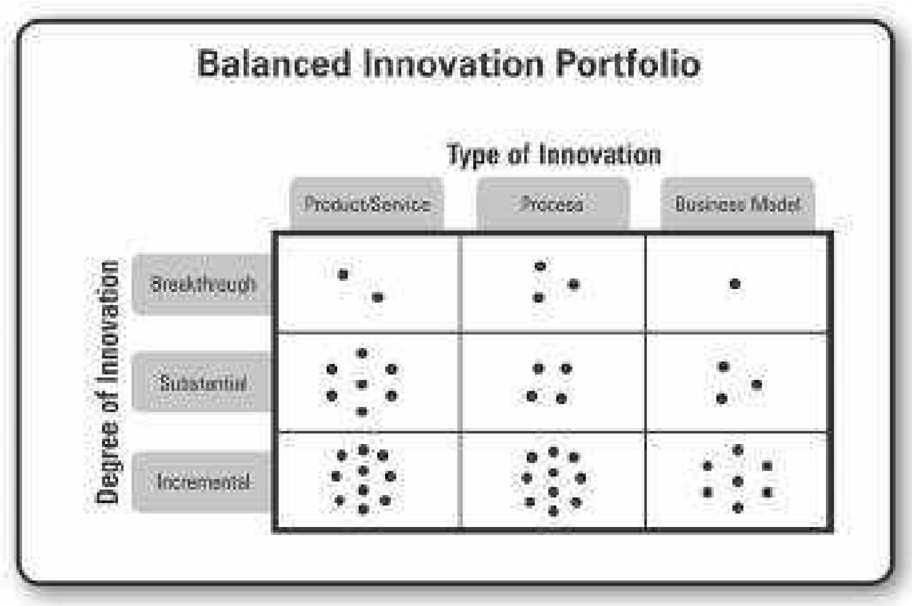

EXHIBIT I. 2

Adapted from R. B. Tucker, *Driving Growth Through Innovation,* (San Francisco: Berrett-Koehler, 2002), p. 20.

Understanding How People Solve Problems

All the identified growth projects in the world won't result in even one profitable innovation if at the end of the day you don't have the right people solving the right problems. Therefore, we'll summarize the way humans solve problems, as well as what types of problems are most appropriate to solve with the techniques in this book—and what types are not.

Every innovation is the result of solving some important problem, like how to get an army across an ocean (naval ship), or how to put a man on the moon (rocket). Even simpler problems lead to simpler but no less important innovations, like using a net to catch fish and secure a food supply. Still other problems lead to solutions that save lives: vaccines, medicines, surgical procedures, and the like.

In all of these diverse cases the underlying problem-solving dynamics are the same: people either converge in their thinking to solve a problem or they diverge in their thinking to solve a problem—or they do both.

Another way to look at problem-solving styles is in terms of *exploitation* versus *exploration.* Guided by convergent thinking, exploitation is when you solve problems using what you readily know inside a known paradigm. Guided by divergent thinking, exploration is when you move beyond known paradigms and existing knowledge to solve a problem. Some business problems require mostly exploitation, while others require mostly exploration, but all problems require some mixture of the two.

Thomas Edison is often called an inventor, but he mostly developed basic discoveries into better solutions for commercialization. Often credited with inventing the light bulb, Edison really conducted extensive experimentation and analysis to find the optimal conditions under which the tungsten wire in a bulb would glow continuously without interruption. While Edison did his own share of exploration, his basic strength and passion was in taking what was already known and refining it until he could solve some problem.

Alternatively, Einstein thought mostly outside the box of the prevailing wisdom of his day, or what was known at the time, and such exploration is the essence of solving problems in untried and untested ways. His theory of relativity questioned key assumptions of Newtonian physics. Einstein even characterized himself as a little strange—but strangeness is what it takes to solve ill-defined problems, or to solve fairly well-defined problems in new and unusual ways.

People in your organization, including you, are either more like Edison or more like Einstein. You might tend to solve problems through convergent thinking and such exploitation-oriented actions as study, analysis, and working within known domains. Or you might tend to think divergently and explore new domains, question assumptions, and generate many harebrained ideas until you solve your problem.

Different types of innovation problems require different degrees of exploitation and exploration to solve (see Exhibit I.3).The solid boxes and lines represent the convergent exploitation of established paradigms and known knowledge, and the dotted boxes and lines represent the divergent exploration of new paradigms and fields.

Understanding each of these four problem-solving classes will enable you to characterize any problem in your organization. From there you can select the best and most appropriate techniques for solving your particular problem:

1. **Class 1:** The problem and the solution space are both well-defined. This dictates mostly exploitation and convergent activities within the current paradigm. Defects on a production line are a good example of Class 1 problems, which are usually solved with such process-improvement

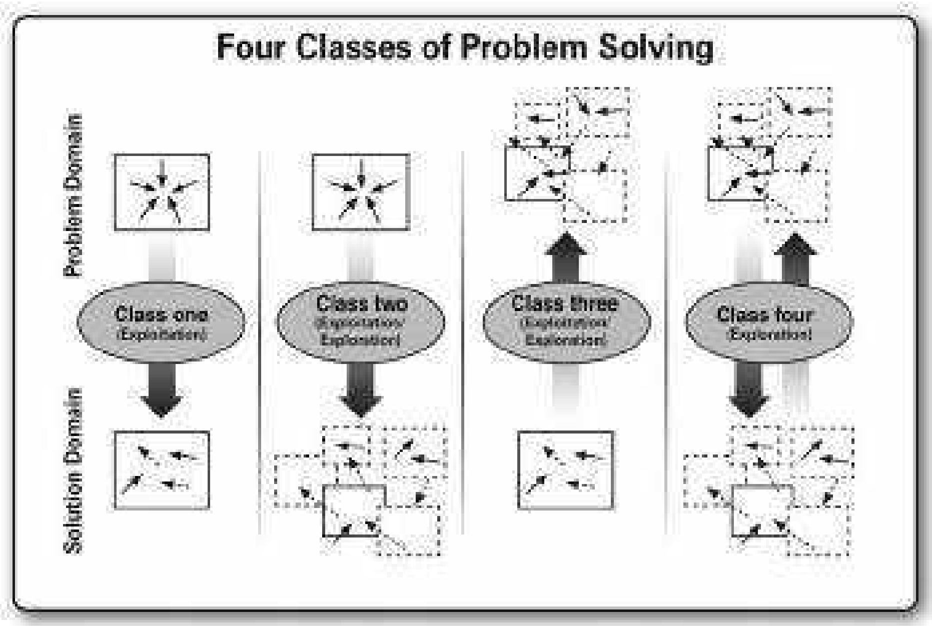

EXHIBIT I. 3

methods as Plan-Do-Check-Act (PDCA), Six Sigma, Lean, and the like. In this book, techniques in the *develop the solution* and *demonstrate the innovation* parts can help you solve Class 1 problems.

2. **Class 2:** The problem is well defined but the solution pathway is not so clear or directly discoverable. Therefore, the task is to explore new ideas and realms, searching for better solutions, while also exploiting known knowledge when necessary. For example, the job of illuminating a room in the dark was once accomplished with a candle, but candles have drawbacks, like dripping wax. Candles did not meet some important customer expectations very well, so this opened the door for better solutions.

   When your customers tell you they are largely satisfied with your product or service, you have a Class 1 problem: just optimize. However, if customers tell you they are unsatisfied with your product or service, you have a Class 2 problem and you need to discover or invent a better solution that closes the dissatisfaction gap. Stated differently, if customers are generally happy with candles, make better candles; if they are unhappy, discover a better way to illuminate the darkness.

3. **Class 3:** These problems are the reverse of Class 2 problems: the solution is clear but the problem is fuzzy. Class 3 problems are intriguing because they force you to consider new applications for existing technologies. For instance, engineer Richard James was working with tension springs in 1943 to develop a meter for monitoring horsepower on naval battleships. One of his springs fell to the ground and gave him a new idea about a different job to be done in a different market. Thus the Slinky was born.

   Sometimes, your existing solutions can be put to a different use, thereby solving a problem and opening a new market. In effect, Class 3 problems require you to turn your ideation efforts upward—beyond where your solutions reside into the realm of higher human needs—asking what jobs your solutions could do that they don't do today.

   Class 2 and 3 problems are by far the ripest classes on which to focus organic growth efforts, and all 55 techniques in this book were chosen because they primarily solve these types of organic growth problems.

4. **Class 4:** These problems are undefined, and their solutions are undefined as well. There is no particular mandate to solve any problem, and the objective is to simply explore because both the problem and the solution reside in unknown territory. Medical researchers, for instance, are always looking for new molecules—just for the sake of finding them. Once they're found, they can always be studied, manipulated, and exploited.

   Solving Class 4 problems is what you do when you don't know what you're doing—basic research, where discoveries are made but the path to commercialization is unclear. As such they fall outside the scope of this book—although techniques like Biomimicry (Technique 26), Trend Prediction (Technique 14), Provocation and Movement (Technique 22) and Design of Experiments (Technique 50) can help the Class 4 problem solver.

Establishing a Process for Innovation

Even having a sound innovation strategy, a promising portfolio of projects, and the right people set up to execute those projects, without a process for organic growth you'll have chaos if you try to innovate on a widespread scale. Only one approach works for making innovation an everyday event in an organization: having the right people solve the right problems through an effective process.

So what would this process look like and what would it entail? We've already established that only two types of problems are worth solving if you want to make innovation common and revenue-worthy in an organization: Class 2 and Class 3 problems, which require an ambidextrous ability to diverge and converge, exploit and explore, in both thought and action throughout the innovation process.

It's relatively easy to roll out programs that either require great structure (exploitation) or that require little or no structure (exploration). But working within the paradox of structure, exploring at times and exploiting at others, can be more difficult. To do this, you need a process that enables controlled divergence and convergence, and that accommodates those who are most comfortable with exploration as well as those who are most comfortable with exploitation.

We've developed a process (or methodology) that is capable of guiding organic growth. Dubbed D^4 (Define-Discover-Develop-Demonstrate), this structured-yet-flexible process forms the basis and architecture of how we've categorized and presented the 55 techniques in this book (see Exhibits I.4 and I.5). The purpose of D^4 is to enable end-to-end innovation that involves

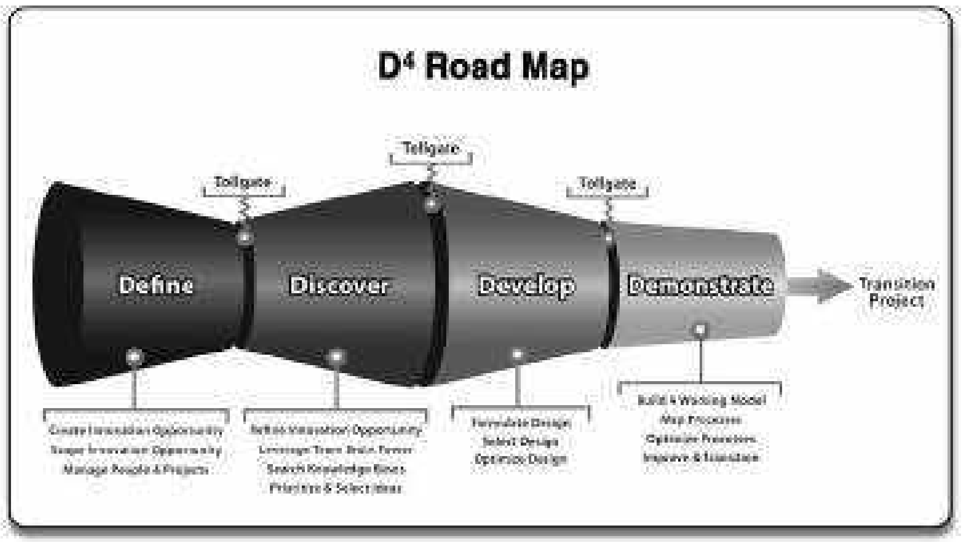

EXHIBIT I. 4

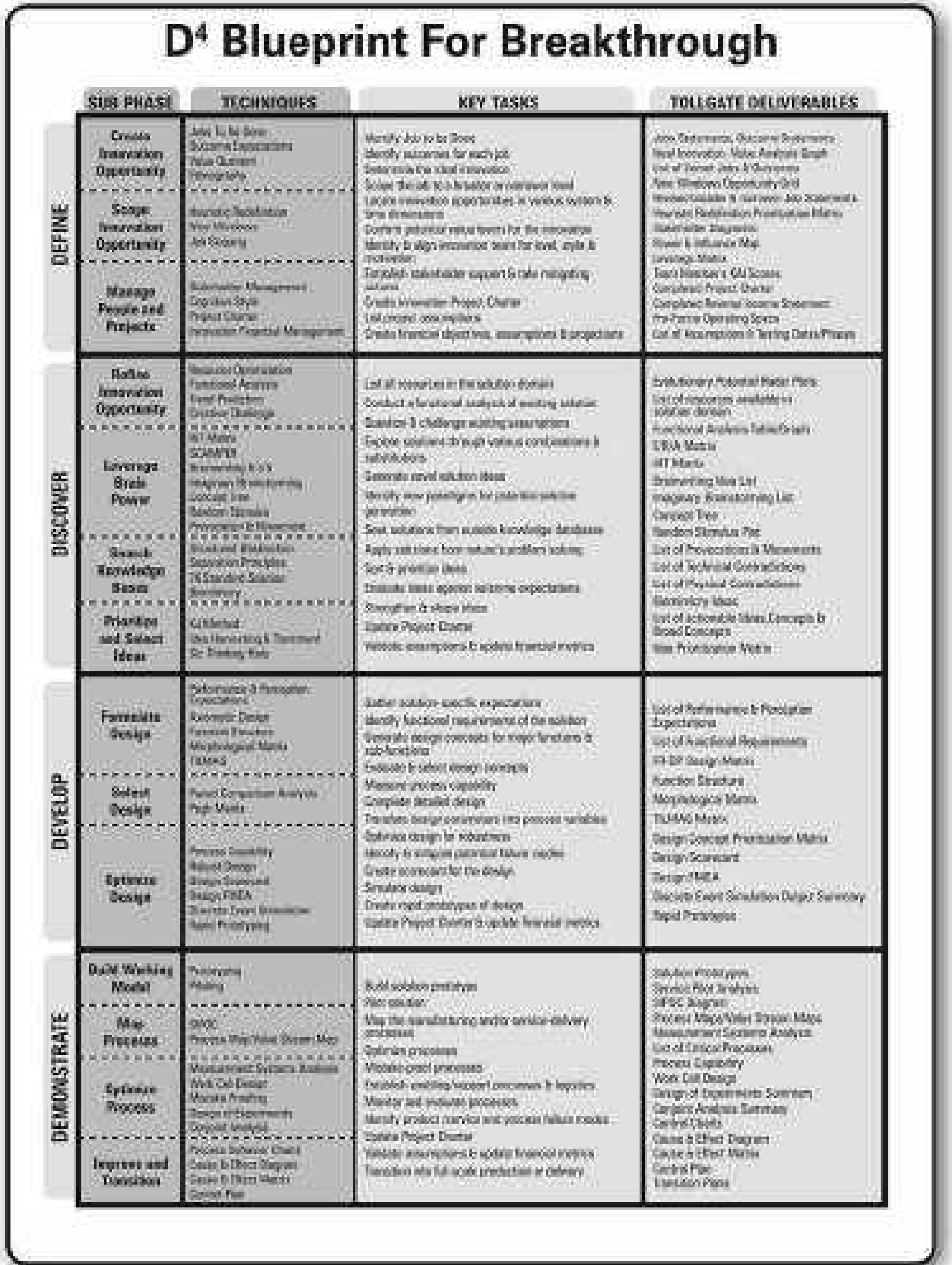
D4 Blueprint For Breakthrough
SUB PHASE
TECHNIQUES
KEY TASKS
TOLLGATE DELIVERABLES
DEFINE
Create Innovation Opportunity
Scope Innovation Opportunity
Manage People and Projects
DISCOVER
Refine Innovation Opportunity
Leverage Brain Power
Search Knowledge Bases
Prioritize and Select Ideas
DEVELOP
Formulate Design
Select Design
Optimize Design
DEMONSTRATE
Build Working Model
Map Process
Optimize Process
Improve and Transition

EXHIBIT I. 5

multiple steps of divergence and convergence along the path of ideating new products and services, then bringing those solutions into a profitable reality.

First, the innovator needs to converge on the best opportunities for organic growth; but within that convergence, there can be substantial, carefully managed divergence. This is the *define the opportunity* phase. Next, the innovator or innovation team engages in mostly divergent ideation, with the aide of powerful thinking techniques. We call this the *discover the ideas* phase. After this, the innovation process requires that you converge on your very best ideas and put them on paper, or design them. This is the *develop the solution* phase. Finally, the task of the innovator is to keep converging the design into successfully commercialized new products and services—or solutions. This is the *demonstrate the innovation* phase.

Exhibit I.4 summarizes the main phases as well as the subphases of the D^4process. Generally speaking, you move through the methodology in sequence, but only proceeding from one major phase to the next after having passed a *tollgate review* designed to mitigate financial and other risk while maximizing the probability of success, or profitability.

Of course, success with the D^4methodology depends on several factors. One, you have to create the proper organizational climate for change and innovation. Leaders can't have too much latitude to experiment and fail, which is very costly, but at the same time they need enough freedom to open and exploit the envelope of change. The right path is to create a culture that rewards risk-taking and accepts mistakes, but that also honors constraints and has controls for abandoning fruitless pursuits before they turn into financial disasters.

Another success factor is making sure you install an infrastructure through which you can govern, lead, and manage the innovation process. The infrastructure should include designations and roles for innovation leaders (executives), champions (middle managers), and practitioners (specialists). An organic growth infrastructure also will include enabling processes for: (a) monitoring financials and ensuring positive project ROI, (b) staffing the initiative and developing human competencies, (c) distributing needed information technology supports, and (d) communicating the organic growth initiative to all stakeholders.

As a final lead-in to the 55 techniques, we'd be remiss if we didn't show how they relate or map to the innovation process—especially considering that the critical hinge-point of success in any corporate initiative is the ability to apply knowledge in a directly beneficial way. We think of the techniques in this book as the innovator's core knowledge; how these techniques are applied and on what scale is a matter of leadership and management at both the project and organizational levels.

Enabling innovation leadership and management, Exhibit I.5 summarizes the D^4 system—showing each major phase, each subphase and each of the 55 techniques distributed where they provide the bailiwick of benefit. Exhibit I.5 also summarizes the key tasks you should perform and deliverables you should complete at each major phase of the process before moving on to the next. Accomplishing these tasks and deliverables with discipline is what distinguishes those who innovate with substance from those who try to innovate but don't really understand the process.

Hopefully in this introductory piece we've sufficiently articulated how you can pursue organic growth in your organization—having provided an actionable definition of innovation and pointing out why it's necessary to focus on high-order jobs to be done and outcome expectations, not on your current solutions and how they work or don't work. In addition, we hope we've provided a rich enough background to empower you in practicing and mastering the 55 techniques as you go about reinventing your products, services, processes, and business models.

Beyond this, we hope that maybe we've also inspired you to make organic growth more scalable, repeatable, and sustainable in your organization—a process everyone can follow. If you do this, it won't matter that you may not invent the next big thing (even though we hope you do). If you deploy and practice the techniques in this book on a widespread basis, you'll probably realize many profitable innovations, some smaller and some larger in their impact. Then, as a whole, you might find yourself in that unique and solitary place called market leadership.

We wish you amazing success.

PART I

DEFINE THE OPPORTUNITY

Taking thousands of shots at an undefined target (unfocused ideation) won't result in an innovation goal. Yet, the very nature of innovation seems to imply that the target is hazy and disguised—but this is a myth. Those who know how to clear the haze will see that the front edge of innovation isn't as elusive as it may seem; it's only unreachable by those who don't know how to find it and bring it into focus for their own advantage.

This first phase of innovation enables you to bring the aims of organic growth into focus and *create viable innovation opportunities*. Use the Jobs To Be Done (JTBD), Outcome Expectations, and Value Quotient techniques to identify actionable innovation gaps, or high-potential innovation projects based on the identification of unmet customer needs and new market territory. As well, use the Ethnography technique to directly observe how customers struggle with existing solutions so you can understand their unarticulated needs.

Once you've defined your opportunity, you can *scope and focus your innovation projects*. The Heuristic Redefinition technique will help you do this by identifying all the elements of your current solution and how they relate to one another. The Nine Windows technique will do this as well, adding the dimensions of time and scale to your innovation problem. Then Job Scoping is a simple but powerful technique for either narrowing or broadening your project's focus.

Also in Part I, we give you techniques to *manage people, projects, and return on innovation investment*. Specifically, the Stakeholder Management technique helps get all pertinent people lined up to support organic growth projects. The Cognitive Style technique ensures your team is staffed with the right people. The Project Charter technique is a living document used to keep the project on time and on task. And the Innovation Financial Management technique keeps you on the straight-and-narrow fiscal path, even enabling you to discontinue your project if it becomes too risky.

Jobs To Be Done

Determine the human need you're trying to fulfill.

A *job to be done* (JTBD) is a revolutionary concept that guides you toward innovation and helps you move beyond the norm of only improving current solutions. A JTBD is not a product, service or a specific solution; it's the higher purpose for which customers buy products, services and solutions.

For instance, most people would say they buy a lawnmower to "cut the grass," and this is true. But if a lawnmower company examines the higher purpose of cutting the grass, say, "keep the grass low and beautiful at all times," then it might forgo some efforts to make better lawnmowers in lieu of developing a genetically engineered grass seed that never needs to be cut.

This is the power of the JTBD concept and technique: it helps the innovator understand that customers don't buy products and services; they hire various solutions at various times to get a wide array of jobs done. You may need light survey design and sampling help from a statistician to apply this technique, but for the most part it requires no expert assistance.

Background

Harvard Business School professor Clayton Christensen and coauthors articulated the JTBD concept in a *Sloan Management Review* article (Spring 2007) as follows: "Most companies segment their markets by customer demographics or product characteristics and differentiate their offerings by adding features and functions. But the consumer has a different view of the marketplace. He simply has a job to be done and is seeking to 'hire' the best product or service to do it."

Therefore, if you understand the jobs your customers want done, you gain new market insights and create viable growth strategies. Sometimes a good solution for a JTBD, or a family of JTBDs, does not exist; when this is the case, you have a great opportunity to innovate.

There are different types of JTBDs:

- *Functional jobs* describe the task that customers want to achieve.
- *Emotional jobs* are related to feelings and perception, and as such they are subjective. One type of emotional job is a *personal job,* which describes how customers want to feel about themselves; another type is a *social job,* which refers to how customers want to be perceived by others.
- *Ancillary jobs* are other jobs that customers want to get done before, during, or after they get their main job done.

For example, brushing one's teeth is the solution to the problem or the functional JTBD of cleaning teeth and gums and removing plaque. While getting this job done, we might also achieve additional emotional jobs. While we clean teeth, we might want to feel fresh (personal job), and might want to be perceived by others as having fresh breath (social job). As well, around teeth-cleaning time, we might want to whiten our teeth, wash our face, or groom our eyebrows. In the context of cleaning teeth, these are all ancillary jobs.

You can tell when a company thinks in terms of JTBDs because the result not only fulfills a need, but is often quite innovative. Consider the recent developments in self-cleaning glass for cars and high-rise buildings, or in car paint that "heals itself" and, thereby, removes the need to paint over scratches. While you could think of *painting scratches* as a JTBD, it really isn't. Painting scratches is actually a solution for accomplishing the JTBD called *maintain a blemish-free vehicle*.

Consider the examples of new solutions for old JTBDs in Exhibit 1.1. Then, ask not how you can make your current products and services better but, instead, ask how you can fulfill your customers' JTBDs in unexpected and more effective ways.

This is the story of innovation in a nutshell: while some companies went about making better pills, or becoming better law firms, or making their flares better and brighter, others went about breaking the mold. No

Jobs To Be Done

Jobs To Be Done	Old Solution	New Solution
Ingest medicine	Pills and Shots	Skin patches
Make many products for mass market	Many craftsmen	Production line
Execute rote legal functions	Lawyers	legalzoom.com
Detect enemy at night	Flares	Night vision
Keep windows clean	Clean with squeegee	Self-cleaning glass
Clean teeth	Manual brushing	Automated with sound waves
Search for information	Library	Internet

EXHIBIT 1.1

new solution automatically or instantly makes an old solution obsolete, but change does happen as a result of finding new ways to fulfill the jobs customers need to get done.

> If you remember anything about jobs to be done, remember this: they are completely neutral of the solutions you create (your products and services). While a customer JTBD remains fairly stable over time, your products and services should change at strategic intervals as you strive to provide ever-increasing value.

Steps

1. Identify a Focus Market

Markets can be identified by considering any one of the organic growth strategies we cover in the Introduction: core growth, disruptive growth, related job growth, and new jobs growth. For example, a computer manufacturer might be interested in expanding beyond just selling computers, so it would look for related job growth opportunities in adjacent market spaces.

2. Identify Jobs Customers Are Trying to Get Done

You want to study customers and find out what they are trying to accomplish—especially under circumstances that leave them with insufficient solutions relative to available processes and technologies. What jobs have ad hoc solutions or no good solutions? When you see customers piecing together solutions themselves, these are great clues for innovation.

Several methods exist to help an innovator study customers and the way they use solutions to get their jobs done. Ethnography (Technique 4) and cultural archetype research are especially useful in this regard. Other techniques include observation, interviews, customer complaints, and focus groups.

Sometimes jobs to be done are not as straightforward as one might think. For instance, a fast-food provider found that its customers were buying flavored milkshakes when faced with a long, boring commute in traffic; they were not only looking for convenient, non-messy nourishment in the morning, but they also wanted to make their commute more interesting by entertaining themselves with a breakfast that took a while to consume.

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3. Categorize the Jobs to Be Done

Jobs can be main jobs or related jobs. Some jobs are parents of other jobs. If a person wants to self-actualize, for instance, this job could be the parent to any number of lower-order jobs having to do with a person's physical, mental, social, emotional, financial, and spiritual well-being.

There is no one way, or standardized, commonly used scheme for categorizing JTBDs—so our best advice is to use a scheme that makes sense for you and your industry. In the retail sales industry, for instance, many main JTBDs are related to how you make people feel (emotional jobs) rather than what a product or service actually does (functional jobs). Many noncustomer-facing jobs in the engineering industry are functional rather than emotional in nature.

We mentioned earlier that jobs can be functional, emotional (including personal and social), and ancillary. One family of jobs is to *organize and manage music for personal use.* An important functional job is to *listen to the music.* A related personal job is to *organize and manage music in a way that feels good;* a related social job is to *share songs with friends.* Ancillary jobs might be to *download songs from the Internet, make play-lists, discard unwanted songs,* and *pass the time.*

4. Create Job Statements

The *job statement* is used to describe a JTBD. Key components of a job statement are an action verb, the object of the action, and clarification of the context in which the job is performed. *Manage personal finances at home* is a job statement. So is *clean clothes at home,* as shown in Exhibit 1.2. *Listen to music while jogging* is also an example of a job statement.

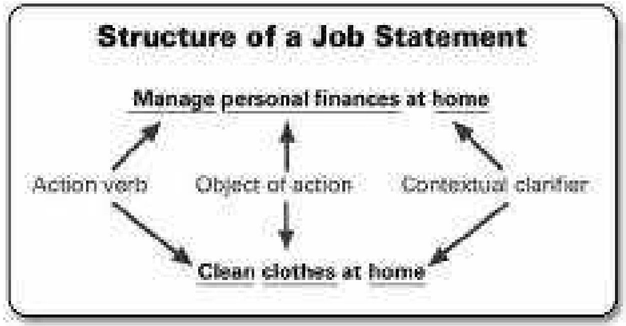

EXHIBIT 1.2 (Downloadable)

Copyright © 2009, Breakthrough Management Group. A blank version of this customized form is available for download at www.innovatorstoolkit.com/download.

5. Prioritize the JTBD Opportunities

There are hundreds of jobs that customers are trying to get done in every market. Which one of these offers the best opportunities for you? Which ones provide opportunities to create uncontested market space? In most situations, the jobs that customers want to get done for which no good solutions exist are the ones that provide the greatest opportunity for innovation.

Prioritizing JTBDs is a function of how *important* they are, how *satisfied* customers are with existing solutions, the general potential for developing new (or more ideal) solutions, and the specific potential of the provider for creating new solutions that better meet outcome expectations (see Technique 2). The importance-satisfaction dimensions establish priority from the customers' perspective, while new-solution potential forms the basis for prioritization from the provider's perspective.

You can use different assessment and rating schemes to determine which JTBDs should be a priority for innovation. One way to measure the importance of a job is by asking customers based on a Likert Scale (degree of importance to them), using sound *sampling* techniques. A Likert Scale can also work for assessing the level of satisfaction customers have with current solutions.

The priority of jobs can thus be calculated as,

$$\text{Opportunity} = \text{Importance} + \text{Maximum}\ (\text{Importance} - \text{Satisfaction})$$

with adjustments made for how likely it is that you or your competitors can come up with a commercially viable and materially better solution for priority jobs. High opportunity items are ripe for a core-growth innovation strategy (make the existing solution better); low opportunity items are ripe for a disruptive innovation strategy (remake the solution so it becomes available to those who can't afford the existing solution).

> Sometimes innovation is as simple as finding a new JTBD that your existing solution meets. Post-it Notes, for example, were developed by a 3M scientist looking for a new and better adhesive compound. The scientist didn't quite reach his goal because his adhesive was weak. Ten years later, another 3M scientist led the way in applying the adhesive for jobs that fit the solution perfectly.

6. Identify Outcome Expectations Regarding the Job

For a particular job, identify its associated desired and undesired outcome expectations. These become the drivers of further ideation activities in the innovation process. Outcome expectations are explained in Technique 2.

Resources

For more on the jobs to be done concept and technique, see:

Christensen, C. M., S. D. Anthony, G. Berstell, and D. Nitterhouse. "Finding the Right Job for Your Product," *MIT Sloan Management Review*, Spring 2007 2–11.

Christensen, C. M., and M. E. Raynor. *The Innovator's Solution: Using Good Theory to Solve the Dilemmas of Growth*. Watertown, MA: Harvard Business School Press, 2003.

Ulwick, A. *What Customers Want: Using Outcome-Driven Innovation to Create Breakthrough Products and Services*. New York: McGraw-Hill, 2005.

Ulwick, A., and L. A. Bettencourt. "Giving Customers a Fair Hearing." *Sloan Management Review*, 49, no. 3 (2008): 62–68.

Outcome Expectations

Give customers more of what they desire.

Outcome expectations are a direct outgrowth of innovation jobs to be done (JTBDs), and they lead to eventual new solutions that create more value and customer satisfaction than existing products and services. For example, the job of cleaning your clothes has many associated outcome expectations, such as *minimize the time it takes to clean clothes, increase the likelihood of stain removal,* and *increase the ease with which clothes are cleaned.*

It's important to define any outcome expectations associated with a JTBD when pursuing an innovation based on that JTBD. Understanding these expectations, and knowing how satisfied (or unsatisfied) customers are with current solutions, helps you identify unidentified market space and possibly fill that space with better solutions than what exists today. You may need light survey design and sampling help from a statistician to apply this technique, but for the most part it requires no expert assistance.

Background

There are four types of outcome expectations:

1. Desired outcomes customers want to achieve,
2. Undesired outcomes customers want to avoid,
3. Desired outcomes providers want to achieve, and
4. Undesired outcomes providers want to avoid (Exhibit 2.1).

EXHIBIT 2.1

By segmenting outcome expectations in this manner, you can look at the JTBD through the lens of what the customer wants and doesn't want, as well as what the provider wants and doesn't want. Both parties must benefit from the innovation or it will never reach viable commercialization.

Customers typically choose the solution that gives them more of the desired outcomes (benefits) and less of the undesired outcomes (cost and harm). As a provider, you want the solution that maximizes desired outcomes and minimizes undesired outcomes—for your customers and yourself. When you accomplish this, you position yourself to create high-value (innovative) solutions that address your customers' JTBDs better than competitors.

People don't buy quarter-inch drills, they buy quarter-inch holes. The drill just happens to be the best means available to get that job done.

—Ted Leavitt of Harvard Business School

We know of at least one company that was working on innovating a better detergent while another innovated a washing machine that doesn't need detergent. Whose solution will capture more market share or be more profitable? It depends on which company can better fulfill the outcome expectations for itself and its customers.

Steps

1. Identify the Job To Be Done

In Jobs To Be Done (Technique 1), we provide instructions for how to develop job statements and how to determine which JTBDs are priorities for innovation. Follow these steps to select the JTBD for which you'll develop related outcome expectations.

2. List the JTBD's Related Outcome Expectations

You can use a simple table like Exhibit 2.1 to brainstorm the four types of outcome expectations that relate to your selected JTBD. Keep asking, "What is it about this JTBD that customers want to achieve or avoid?" Think in terms of time, cost, potential errors, quality, dependability, availability, ease of use, maintainability, and any number of other satisfaction and dissatisfaction dimensions.

Do not confuse this exercise with cataloguing performance and perception expectations (see Technique 30), which are solution-specific performance characteristics, such as *candle burn time* (target = 32 hours), or *PC battery life* (target = 6 hours). Outcome expectations are solution-neutral and reside at a higher level; they are JTBD-specific desires, such as *maximize duration of illumination* (using any solution), or *maximize operating time* (in whatever way possible).

This can be tricky, but it's far from unnecessary hair-splitting. Your ability to fully delineate all pertinent outcome expectations determines how much innovation traction you'll have. Maybe more accurately, it defines the high-level pathways along which your innovation efforts will play out.

3. Create Outcome Statements

Since the job of innovation is to meet expectations to a greater extent than they are met today, they should be stated in imperative terms, using a standard structure. That structure is:

- The direction of action (minimize, increase).
- The unit of measurement (time, cost, probability, defects, errors, etc.).
- The object of control (what it is you're influencing).
- The context (where or under what circumstances).

Consider this customer outcome statement: *Increase the likelihood that clothes appear fresh after home cleaning*. *Increase* denotes the direction, *likelihood* is the unit of measure, *clothes appear fresh* is the object of control, and *at home* is the context.

Other outcome statements related to the job of cleaning clothes at home might be:

- Minimize the time it takes to clean clothes.
- Minimize the cost of cleaning clothes.
- Increase the likelihood of stain removal.
- Minimize the damage to clothes.
- Minimize the effort needed to clean clothes.
- Increase the likelihood that clothes look fresh.
- Increase the likelihood of an appealing smell from clothes.
- Minimize the likelihood of any wrinkles in clothes.
- Increase the likelihood of removing all foreign particles, germs and bacteria from clothes.
- Increase the ease of cleaning clothes.
- Minimize the use of resources (water, energy, detergent) in cleaning clothes.

Some example outcome statements from the provider's perspective include:

- Increase the revenue growth from innovations.
- Increase the likelihood of maximum profit from innovations.
- Increase customer loyalty from using solutions.
- Increase the likelihood of deriving new products from current innovations.
- Minimize the cost of developing and providing solutions.
- Minimize the likelihood of product liability litigation.
- Minimize the likelihood of imitation products or services.
- Minimize damage to the environment.

Provider-related outcome statements tend to be similar with little variation due to the commonality of why companies exist. All corporations, public or private, exist to provide valuable products and services, to make a profit, and to do so safely and without harm.

The outcome statements improve the consistency and reliability of collecting useful information regarding the job to be done. It is very important to follow the outcome statement structure to enhance repeatability and avoid confusion.

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4. Determine Priority Outcome Expectations

Examine the list of outcome statements in light of how important they are to customers, and how satisfied they are with the extent to which existing solutions meet these statements. To prioritize outcome statements, you should also examine how likely it is that competitors will implement new solutions to fulfill them better, and how likely it is that the provider (you) will fulfill them better with new solutions.

On the customer side, a Likert Scale (self-report) assessment approach can be effective, making sure to use sound sampling techniques. An *importance score* can be derived for each outcome statement by calculating the percentage of customers who rate the outcome statement as very important or extremely important; likewise a *satisfaction score* can be derived by calculating the percentage of customers who are very satisfied or extremely satisfied with the extent to which current solutions address each specific outcome expectation, or outcome statement.

The priority of outcome statements can then be calculated as:

$$\text{Opportunity} = \text{Importance} + \text{Maximum}\,(\text{Importance} - \text{Satisfaction})$$

with adjustments made for how likely it is that you or your competitors can come up with commercially viable and materially better solutions for priority outcome expectations.

In general, high-priority outcome expectations are your guides for ideating superior products, services, and solutions; they provide needed focus at the front end of innovation, which mitigates the risk of generating and pursuing big ideas that really aren't so big because they aren't grounded in market sweet spots. Generating new solution ideas for the sake of new solution ideas is one thing; using high-priority outcome expectations as a basis and guide for ideation is quite another.

You can plot outcome expectations (or JTBDs) on an XY graph, with *importance* on the Y-axis and *satisfaction* on the X-axis. Based on the location in the graph, you can then determine opportunities for the various categories of organic growth: disruption, core growth, new job growth, and related jobs growth.

Resources

Christensen, C. M., and M. E. Raynor. *The Innovator's Solution: Using Good Theory to Solve the Dilemmas of Growth*. Watertown, MA: Harvard Business School Press, 2003.

Ulwick, A. "Turn Customer Input into Innovation." *Harvard Business Review*, January 2002.

Ulwick, A. *What Customers Want: Using Outcome-Driven Innovation to Create Breakthrough Products and Services*. New York: McGraw-Hill, 2005.

Ulwick, A., and L. A. Bettencourt. "Giving Customers a Fair Hearing." *Sloan Management Review* 49, no. 3 (2008): 62–68.

Value Quotient

Identify opportunity gaps in the marketplace.

Value quotient is the ratio of a solution's desired outcomes to its undesired outcomes—relative to some job to be done (JTBD). For example, if one key desired outcome for a driver is to *increase visibility at all times,* then a car window that cleans itself has a higher value quotient than a window you have to clean—assuming the self-cleaning window can be purchased for about the same price with no additional drawbacks (undesired outcomes).

The purpose of this technique is to assess the value of your current solutions against those of your competitors—and relative to an ideal state in which a theoretical solution could fulfill all desired outcomes and avoid all undesired outcomes. Such an idealized solution (ideal innovation) would meet all expectations, cost nothing, and have zero chance of harming the user, anyone else, or the environment.

Understanding the Value Quotient technique enables the innovator to identify opportunities—or value dimensions—that are ripe for exploration and exploitation (Exhibit 3.1). The extent to which you can increase value along these dimensions determines the extent to which you will be successful with an innovation project.

Steps

Scenario: An appliance maker is looking to develop a better solution for the job of washing clothes in the home environment, but doesn't fully understand

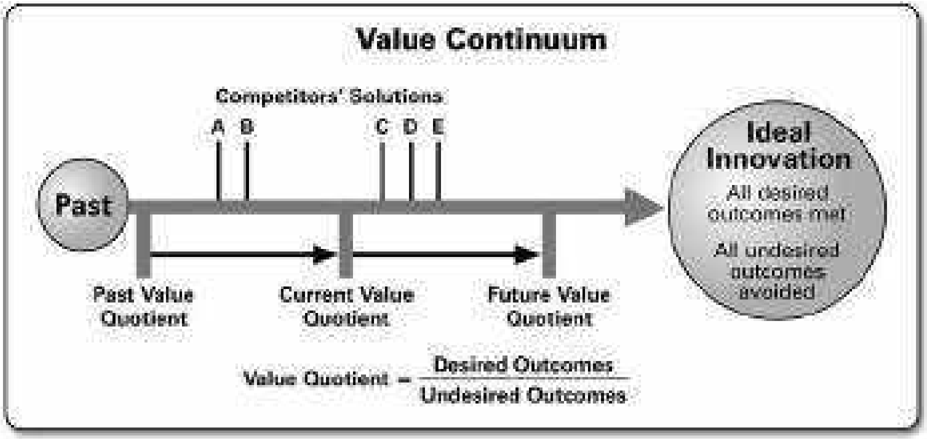

EXHIBIT 3.1 Every product, service, or solution in the marketplace contains a certain degree of value relative to others. The goal is to fulfill desired outcomes to the greatest extent possible and avoid undesired outcomes to the greatest extent possible.

how to do this or where to begin—or if any real opportunities for innovation exist. Before delving too deeply into ideation, the innovation team wants to understand the opportunity space using the Value Quotient technique.

1. Agree on and Document the Job to Be Done

The appliance company decides the JTBD is to *clean clothes at home*. See Jobs To Be Done (Technique 1) for more guidance on how to formulate and prioritize jobs for innovation.

2. Identify the Desired and Undesired Outcomes

For the job of cleaning clothes at home, Exhibit 3.2 lists a sampling of expected outcomes, desired and undesired, from both the provider's and customers' perspective. See Outcome Expectations (Technique 2) for more guidance on how to identify and document desired and undesired outcomes, as well as how to determine their relative importance.

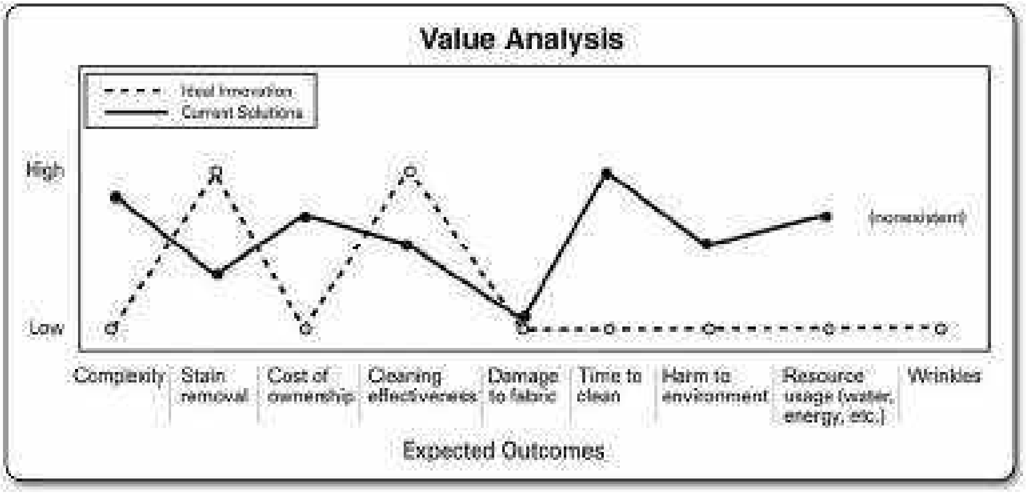

EXHIBIT 3.2

3. Plot the Ideal Innovation

For each important outcome expectation, plot the *ideal innovation* on a *value graph* using a scale from low to high as shown by the dotted line in Exhibit 3.2. This hypothetical exercise helps you imagine a state in which all desired outcomes are met and all undesired outcomes are avoided.

This state then becomes your innovation baseline; rather than starting from what you have (existing solution), you start with the perfect solution in mind and work backward. If you were to discover and develop a perfect solution for the JTBD, what would it be?

Coming back to our example, could a cleaning appliance wash all types of clothes in only one simple mode? Could all stains be removed from all clothes every time? Could clothes be cleaned without detergent? Could clothes not only be washed, but come out of the system free of wrinkles?

Even beyond this, why wash clothes at all? Some have experimented with nano-particles of titanium dioxide, a substance that can be coated onto clothes in a thin layer; the substance then reacts with sunlight to break down dirt and other organic material. Others have proposed infusing clothing fibers with bacteria that eat dirt, in essence enabling the clothes to clean themselves.

There is a huge difference between starting an innovation discovery process with these ideals versus starting with whatever you do or offer customers today. The mind is like a rubber band, and the notion of the ideal innovation can only help stretch it. Therefore, if you are designing an innovative way to clean clothes, start with the perfect solution in mind and work backward from there.

The ideal innovation concept is borrowed from the Theory of Inventive Problem Solving (TRIZ), which calls this perfect state the *ideal final result*. As a ratio, the value quotient approaches infinity, or a state where all benefits of a solution are achieved at zero cost and zero harm. In TRIZ terminology, this is called working *backward from perfect,* which forces the innovator to break through his or her *psychological inertia* into new, less limiting domains of thinking.

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4. Plot Existing Solutions

After plotting the ideal innovation, the task is to plot existing solutions in the same manner according to the expected outcome dimensions. The key is to make plots in as many different ways as you want or need. You can plot your solutions against the ideal innovation or different competing solutions, or you can make your plots using different outcome expectations, or dimensions.

Play around with this tool (but seriously) to teach yourself with whom and what you are really competing, and to make yourself swallow the bitter pill of how your current solution really stacks up.

Exhibit 3.2 illustrates the representative current state of all solutions based on using a machine and detergent to wash clothes at home—the existing standard. Our depiction of this state for each outcome dimension is based on back-of-the-napkin estimations for illustration purposes only. Note that current solutions usually fall short on outcome dimensions relative to the ideal.

5. Identify Opportunity Value Gaps

While every gap between what exists today and the ideal is an opportunity for innovation, it is most intelligent to determine which outcome dimensions are ripe for exploration and exploitation. In doing this, look for any of the following three conditions based on an importance-satisfaction assessment; see Outcome Expectations (Technique 2) for details.

- *Condition 1:* Customers report the dimension is very important but their satisfaction is low. This is an opportunity to raise the bar of desired benefits or outcomes offered.
- *Condition 2:* Customers report that the dimension is not very important and are satisfied. This is an opportunity to lower the bar of desired benefits or outcomes offered and, thereby, lower cost and increase accessibility to more customers (low-end disruption).
- *Condition 3:* There is no good solution so the customers cannot say whether they are satisfied. This is an opportunity to introduce a new solution that exceeds customer expectations and makes them say *wow*.

In our stylized clothes-cleaning example, the outcome dimension of *time to clean* is a Condition 1 opportunity—customers find it very important but are largely dissatisfied. The dimension called *complexity* is a Condition 2 opportunity—customers are satisfied with current washing options and could even accept fewer choices or washing modes. Finally, the dimension of *wrinkles* is a Condition 3 example—customers don't expect that clothes could come out of their washing machines free of wrinkles, so if you can provide this, you will wow them.

6. Close the Value Gaps

Narrowing value gaps is a matter of ideating and developing superior solutions by moving through the innovation process and applying various techniques and tools. For example, Sanyo engineers received a patent (U.S. 7,296,444 B2) for an electric washing machine that generates water streams containing an electrolyzed liquid that cleans clothes without detergent. In doing so, this creates the potential to close several value gaps, including a reduction in the total cost of ownership, a reduction in harm to the environment, a reduction in resource usage, and a reduction in germs and bacteria left in clothes after washing.

Recognize that if you can move your solution closer to the ideal innovation and beyond any and all competitors, then you have successfully innovated. Much more importantly, recognize that if you cannot move your solution (or business model) materially closer to the ideal innovation, then you will fail at innovation.

Additional Example

As of 2007, Legalzoom.com had served more than 500,000 customers with its web-based, wizard-driven, document-preparation service. Need a will? Getting divorced? Want to change your name? Just cruise the Legalzoom web site, and for between $30 to $300 you can get just about anything done—as long as it is a commoditized, document-based legal function that doesn't really require the expertise of an attorney. This is only a small fraction of what a law firm would charge, so it certainly improves the value quotient of certain legal services.

TECHNIQUE 4

Ethnography

Observe your customers to uncover unarticulated needs.

Ethnography is a science that describes human social phenomena based on fieldwork and observation. Applied to the goal of innovation in business, ethnography is the practice of observing how customers try to get their "jobs done" by using your offerings, your competitors' offerings, or neither.

For example, before inventing Quicken software, Intuit observed people struggling to do the job of organizing and managing their personal finances. Even though professional-caliber accounting software was available at the time, many individuals were using computer spreadsheets or pencil and paper to accomplish this job. None of these approaches met the expectations of home users as well as Quicken does today.

By applying ethnography early in the innovation process, you may discover jobs and/or outcomes that customers have not articulated, especially in cases where existing solutions fail or fall short. For the best results, however, you will need to hire a trained ethnographer due to the discipline associated with collecting qualitative data in the field and accurately analyzing the findings.

Have you ever tried to complete a chore (like fixing a sink) that requires a flashlight? If you need both hands to complete the job, you end up holding the flashlight in your mouth or putting it down. Observing people in this predicament led Black & Decker to invent the snake light—a light that can hold itself.

Steps

1. Plan the Study

Planning your ethnographic study involves making a few important decisions, such as:

- *When will you observe people?* When they're purchasing your product or service, or when they're actually using it? If you're looking to uncover hidden jobs or customer expectations, then study people when they're using it. Observations at the time of purchase can be beneficial for discovering what appeals to people about the product/service price, reputation, packaging, and so on.
- *How will you observe people?* Observation can be covert—watching someone purchase a product or service without them knowing you are watching. Or it can be overt—standing in someone's kitchen watching them cook, or going with them to buy a car.
- *Who will you observe?* If possible, observe both traditional and non-traditional consumers of the product or service. You can learn a lot by watching someone try to use something for the first time, or by interviewing someone who uses a different product to get the same job done.
- *Where will you observe people?* In their homes, places of business, or a public place? Remember, the point of ethnography is to observe people in their native environment, not in a lab or conference room as part of a focus group.
- *For how long will the ethnographic study take place, and how many people will you observe?* Will an ethnographic blitz, a one-week period of observation and interviews, suffice? Remember, you're trying to understand customer needs better, not gather statistical data, so the *quality* of participants, not the quantity is what matters most.

Ethnography uncovers not only conscious, but also subconscious emotional and biological needs. As such, it cannot be replaced by focus groups where participants provide primarily cognitive opinions.

2. Identify Participants

Identify specific participants and obtain their permission to be part of the study. Be sure to clearly convey to them the purpose of your study, what type of information you will be documenting, and how the results will be used. Even if you are observing people covertly in a store or restaurant, you'll still need to approach the owner for permission.

Ethnographers for Citigroup spent time watching how subway patrons paid for their rides. Based on the preferences they observed, Citigroup designed a key chain tag that could be easily swiped by riders as they pass through the turnstile, thus avoiding the need for passengers to fumble for tokens or take out their wallets in a crowded station.

---

3. Observe Participants

When you begin the ethnographic study, your primary task is to observe and take notes on how people interact with your product or service and what they think about it (Exhibit 4.1). As you do this, ask yourself these basic questions:

EXHIBIT 4.1 This plethora of notes and images was gathered by Flow Interactive Ltd. for a client during an ethnographic study.

- Why is the person using this product/service? What's the job to be done? What are their expectations? When Kaiser Permanente set out to design a new hospital, an ethnographic study revealed that people who go to a hospital had many needs. In addition to the obvious—getting medical attention, visiting a patient—people sometimes required food, child care, or spiritual counseling.

- Are they using the product/service as designed, or in a way that is unexpected? For example, would companies who send unsolicited CDs through the mail be surprised to see that many people use them for drink coasters?
- How does the person appear to feel about the product/service? Are they pleased, surprised, frustrated, confused, indifferent? What would they tell their friends and family?
- If you're observing a process or service, do people (both customers and employees) flow easily through the process? Are customers confused about where to go? Do they have to wait in long lines? Are employees tripping over each other trying to serve customers?
- Do cultural needs, barriers, or misunderstandings affect the use of the product/service? For example, Chinese appliance manufacturer Haier found through observation that some customers used their clothes washing machine to clean vegetables. This insight enabled them to create an appliance that excels at both jobs (cleaning clothes and washing vegetables).

During the study, it is imperative that you separate observation from interpretation. Like a courtroom juror, you should only be concerned with the facts while observing. There will be time later for analyzing the data you gathered and drawing conclusions.

Here's a list of recommended items to include in your field notes:

- Date, time, and place of observation.
- Specific facts, numbers, details of what happens at the site.
- Sensory impressions: sights, sounds, textures, smells, tastes.
- Personal responses to the fact of recording field notes.
- Specific words, phrases, summaries of conversations, and insider language.
- Questions about people or behaviors at the site for future investigation.
- Page numbers to help keep observations in order.

Source: Hammersly, "Ethnographic Research." Here We Are Blog. http://wearehere.wordpress.com/home/ethnographic-reasearch/. Comment posted May 4, 2006.

4. Interview Participants

Depending on your desired level of interaction with the participants, you may choose to interview them after observation. Although the key to ethnographic discovery is impartial observation, interviewing can provide additional insight if you keep these basics in mind:

- Ask open-ended questions that cannot easily be answered with *yes* or *no*. Also, don't try to limit participant responses to preordained categories by asking questions like "How would you rate this product on a scale of 1 to 10?"
- Remain sensitive to the participant's beliefs, opinions, and concerns. If a question makes someone uncomfortable, don't force an answer.
- Ask permission to record or videotape the interview, which will allow you to review and categorize participant responses more easily.
- If you're not an experienced interviewer, practice on an associate, coworker, or friend—ideally, someone whom you don't know very well so you get a feel for what it's like to interview a stranger.

For more interview tips, see "A Synthesis of Ethnographic Research," by M. Genzuk, PhD, University of Southern California Center for Multilingual, Multicultural Research,www-rcf.usc.edu/~genzuk/Ethnographic_Research.pdf.

5. Collect Artifacts

Just as an anthropologist makes assumptions and draws conclusions about a culture via tangible artifacts, a company can draw conclusions about its products and services via the collection of behavioral artifacts. Obtain permission to take with you any items that coincide with your observations or provide additional information, including:

- Pictures or video of people using the product or service.
- Competitor or homemade items that accomplish the same job, or a tangential one, as your product or service.
- Participant-generated documentation such as homegrown manuals, cheat sheets, FAQs, and so on.
- Maps or diagrams of the process, along with notes about the flow of people or objects through the process.

Ethnographic observation often reveals ingenious solutions designed by customers in lieu of commercial solutions. In *Democratizing Innovation,* Cambridge, MA: MIT Press, 2006, MIT professor Eric Von Hippel encourages businesses to learn from user-centered innovations in their industry.

6. Analyze Data

Sort the data you gathered from the ethnographic study, including observations, interviews, and artifacts. Watch for patterns or trends that can be used to form one or more hypotheses. If you had a theory in mind before beginning the ethnographic study, review the data to see if it can be supported.

7. Verify Hypothesis

Once you have a hypothesis, follow up with the participants in a focus group or by survey to validate your theory. Alternatively, you could repeat the ethnographic study with a different group of people—just be sure to keep an open mind in case the new data doesn't support your theory.

8. Document Findings

Finally, it's helpful to prepare a written report that documents your conclusions and as much of the data as possible. This information may help others in the organization to better understand your customers, now or in the future.

Resources

If you want a primer for using ethnography to better understand customers, read:

Mariampolski, H. *Ethnography for Marketers: A Guide to Consumer Immersion*. New York: Sage Publications, 2006.

For an in-depth, but reader-friendly approach to doing qualitative research, look to:

LeCompte, M. D. and J. J. Schensul *Ethnographer's Toolkit* (7 Vols.). Walnut Creek, CA: AltaMira Press, 1999.

Heuristic Redefinition

Draw a picture of your system and its parts to focus ideation.

Heuristic Redefinition is a visual approach for focusing and scoping an innovation project at the right level in a system. For example, if you're trying to make a more fuel-efficient vehicle, you would visually identify all the elements in the total system that affect fuel efficiency, not just the elements that impact a vehicle's engine.

Use Heuristic Redefinition when your innovation job to be done (JTBD) is not well defined, or is broad rather than targeted in nature and you need more specificity to take meaningful innovation action. This technique is very helpful to innovation leaders who are assembling their innovation project portfolios.

Steps

Scenario: Let's say a team called the Patient Crusaders is trying to make dental patients more at ease. The team's innovation job is to *reduce fear and increase comfort for our patients.*

1. Visualize the Overall System and Its Elements

The team should create an illustration of the system for meeting the JTBD (see Jobs To Be Done, Technique 1), showing *all* of its major elements. Remember that any combination of functions can be considered a system or a subsystem, no matter how large or small. The waiting room at a dental office is a subsystem, and so is the dentist's tool tray.

Additional guidelines:

- Prepare your illustration in any medium, but try to keep it simple (non-electronic) and openly visual to the team. Thus, a flipchart or dry erase board is probably most effective. Artist skills are not required!
- The more system elements you identify, the more likely you'll find a viable pathway to an innovation.
- To stimulate identification of system elements, the team should ask *what, when, where, who, why,* and *how* regarding the JTBD.
- Combine this technique with Functional Analysis (Technique 13) or Nine Windows (Technique 6) to bring as much system- and subsystem-defining horsepower as you can.

The Patient Crusaders ask the following questions to help define elements of the *reduce-fear-and-make-patients-feel-comfortable* system:

- *What is happening?* Patients are afraid of dental treatment, and find it stressful and uncomfortable, if not painful.
- *When does it happen?* Primarily during treatment, but the anxiety can begin before upcoming treatment.
- *Where does it happen?* Primarily at the dental office, secondarily in the patient's own mind before treatment.
- *To whom does it happen, or who causes it to happen?* Patients and the staff.
- *Why does it happen?* Either actual fear is manifested, or uncomfortable treatment methods are used, or both. Some of this is real, and some may be patient perception.
- *How does it happen?* Experiencing treatment, remembering past treatment, or hearing horror stories about others' experiences.

The Patient Crusaders drafted a picture that incorporated as many system elements as they could define. In the process, they made many drawings, had some debates, and finally aligned their thinking.

2. Label System Elements and How Each Relates to the JTBD

The task now is to label each system element in a way that characterizes its impact on the JTBD—whether positive or negative. Ask, "How does this element impact the JTBD or its associated outcome expectations?"

Consider relationships, connections, and influences between elements by asking:

- How are the elements related?
- What are the influences between elements?
- Do any natural or scientific laws apply?

The labeling process should be detailed and lively, with debate and discussion—and with a strong facilitator. The result is a revised illustration that labels all the system elements in terms of their relationships and influences on the JTBD.

The Patient Crusaders end up with a 10-element system for reducing fear and increasing patient comfort (Exhibit 5.1), including the following areas of focus:

1. The patient during treatment, who may be scared, anxious, or uncomfortable—or calm and feeling good about the visit.
2. A potential patient anticipating an upcoming visit who may be looking forward to it, or dreading it.
3. The tangible results and benefits of a successful patient visit.
4. Dental staff and their skill level regarding pleasant, comfortable treatment.
5. Current process components (tools and techniques) that are perceived as "bad" by the average patient.
6. Current process components (tools and techniques) that are perceived as "good" by the average patient.
7. The interaction between staff and patient during treatment.
8. The waiting area at the dental office.
9. The clinical practice rooms.
10. Preventive techniques.

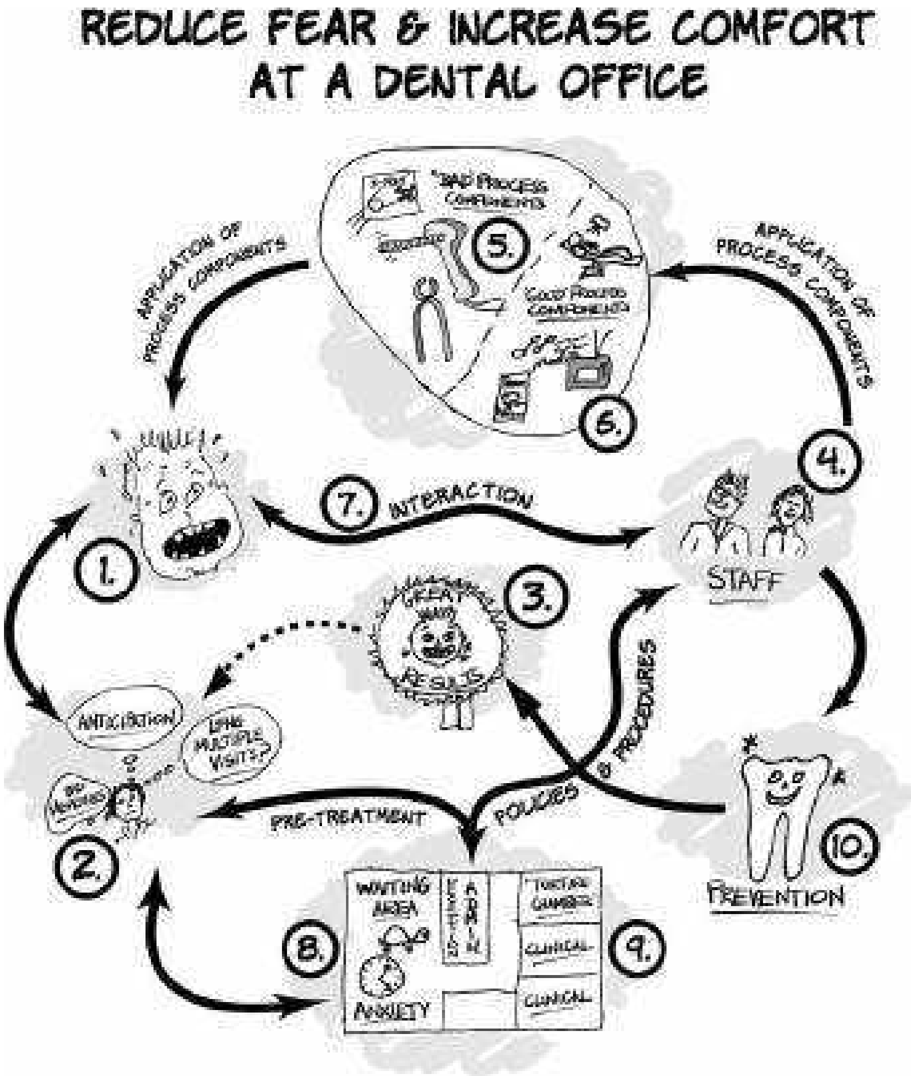

EXHIBIT 5.1

Often the big "ah ha" when applying Heuristic Redefinition is the many new problem statements, or lower-order JTBDs, that pop up as a result of dissecting the high-order JTBD. Just when you thought you knew what you needed to do, Heuristic Redefinition can help you define this in a way that enables real innovation breakthrough at an actionable level.

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3. Create Problem Statements for Each Element

Now you are ready to translate each system element into its own job statement, or *scoped JTBD*. Starting with Element 1, ask how it can contribute to fulfilling the JTBD. For each element, ask, "How can we ensure that [Problem Statement] so that [JTBD] is accomplished?"

In essence, you are scoping in or scoping out for your innovation project. As you do this work, you'll be carefully investigating the relationship between each stated system element and its parent JTBD.

These problem statements (Exhibit 5.2) now your guiding questions as you probe further about what parts of your system are ripest to yield innovation.

4. Pick the Best Elements for Innovation

This is essentially a prioritization activity using a devised rating scheme. First, enter your new problem statements into a matrix. Then rate each problem statement's impact on these three criteria:

1. Likelihood of achieving the JTBD.
2. Ease of implementation.
3. Expected impact on the JTBD.

The rating scheme is as follows:

Good/High = 3

Average/Medium = 2

Poor/Low = 1

Totals are calculated by adding the numbers in all three criteria columns of the matrix, and the results are highly considered when looking for innovation focus areas. As long as there are no conflicts with company strategy or needs, these focus areas should be your best roads to innovation.

Some questions you can ask in this regard are:

- Does the problem statement support company strategy?
- Is the risk level too high or too low?
- Is it even worth pursuing?
- Is there the will and consensus to tackle the problem?

Problem Statement Prioritization Matrix

Good/High = 3
Average/Medium = 2
Poor/Low = 1

	Problem Statement: "How can we ensure that . . ."	Likelihood of accomplishing the JTBD	Ease of Implementation	Expected Impact on the JTBD	Total
1.	**the patient** experiences relief from anxiety, minimal discomfort, and shortest duration of treatment?	2	1	3	**6**
2.	a **patient anticipating upcoming treatment** is focused on the positive benefits of dental care and attains a positive outlook?	1	1	1	**3**
3.	the patient has confirmed awareness of the **positive outcomes** of their treatment, feels satisfied, and has no anxiety toward the next visit?	1	1	2	**4**
4.	the **dental staff** is skilled and competent in specific procedures and intent toward relieving patient fear and maximizing comfort?	3	2	3	**8**
5.	the standard practice treatment **tools, equipment, and materials** are selected and applied with patient anxiety and comfort in mind?	2	2	3	**7**
6.	**additional "good" methods,** approaches, and equipment are utilized when applicable to reduce anxiety and enhance comfort?	2	2	3	**7**
7.	all **staff interaction with the patient** is conducive to elimination of anxiety, verifying comfort level, and ensuring understanding of the treatment benefits?	3	2	3	**8**
8.	the patient **waiting** time is minimal and the atmosphere is calming, encouraging, and positively instructional?	1	1	2	**4**
9.	**treatment** time is minimal and the atmosphere is calming, comfortable, and encouraging?	3	2	2	**7**
10.	posttreatment **preventative techniques** enhance treatment benefits and build patient confidence?	2	1	1	**4**

EXHIBIT 5.2 (Downloadable)

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Based on the prioritization matrix shown in Exhibit 5.2, the Patient Crusaders determined that the highest-scoring problem statements—4, 5, 6, and 7—were the best ones to pursue in coming up with an innovative solution for the JTBD. Some of the team's thinking was as follows:

- Statement 1 was really the focus of the entire effort and didn't really fit well as a problem statement. All other statements seemed to drive toward number 1.
- The team decided there was little it could do to influence statements 2 and 3 regarding the patient's anticipation of upcoming treatment and awareness of positive outcomes.
- Statements 8 and 10 seemed difficult to implement with minimal impact or likelihood of accomplishing the JTBD.
- The highest scoring statements were 4 and 7, and interestingly both involved staff. The team felt strongly that these should be pursued with rigor, and further discussion suggested that the two statements could be combined since they are closely related.
- Statements 5 and 6 were also closely related and scored similarly high. The team felt a problem statement could be assimilated from these two that would involve improving the overall application of standard good-practice tools, equipment and procedures.
- Statement 9 also scored high. However, the team felt that pursuing statements 4, 5, 6, and 7 would positively impact the issues of treatment time and atmosphere. Thus, they elected to forgo pursuing statement 9 in lieu of pursuing the others.

Before ideating further, the Patient Crusaders stopped to celebrate their success in framing their innovation challenge in a way that made it more actionable. But their work was far from over. By rolling this work forward into the next innovation phases, they ideated and refined their ideas for solving these problems until they converged on an innovative hospitality program, a set of new technologies, and a unique patient communication system. See KJ Method, (Technique 27) for more details.

The Heuristic Redefinition technique was developed by Dr. Helmut Schlicksupp, a German author and consultant who began researching and developing creativity methods several decades ago.

Additional Example

Say you want to make a house more energy efficient (a JTBD). But instead of tackling this problem as a whole, you could use Heuristic Redefinition to visually break the problem into smaller pieces. You could focus on any number of relevant system components: the house itself, its insulation, the sun outside, the surrounding trees, the windows, the shades or blinds, the awnings over the windows, major appliances, or the house's ventilation system. With this breakdown, you can see the whole system and begin to hone in on the part(s) that promise to yield the most innovation for the least amount of effort, time, and resources invested.

Resources

For more examples of Heuristic Redefinition see:

King, B., and H. Schlicksupp. *The Idea Edge: Transforming Creative Thought into Organizational Excellence*. Salem, NH: Goal/QPC, 1998.

Nine Windows

Looking at your opportunity through nine different lenses.

Nine Windows is a technique that helps you examine the innovation opportunity across the dimensions of time (past, current, future) and space (super-system, system, subsystem). For example, suppose you're designing metal utensils that can be used on an airplane to eat, but cannot be used as a weapon. Instead of innovating the utensils themselves, you could focus your efforts on the raw materials that make up the utensils (subsystem), or even on the surrounding environment (super-system).

The core of Nine Windows is a simple grid consisting of nine boxes, or windows. Filling in the boxes provides eight additional perspectives on the problem you've identified and helps you decide how and at what level to apply innovation. As such, you should leverage Nine Windows early in your project to better scope the innovation opportunity.

Steps

Scenario: To illustrate Nine Windows, let's say we want to grow Pitaya, a plant that produces the unusual-looking, but tasty and highly nutritious "dragon fruit" (Exhibit 6.1). Pitaya grows best in tropical, semi-dry environments, but we want to farm it in Colorado. So, our goal is to determine a way to cultivate the Pitaya plant in a colder climate.

1. Prepare Nine Windows Grid

On a white board or flip chart, draw nine boxes arranged in a 3 × 3 matrix. Label the bottom row of boxes (from left to right): *Past, Present, Future*. Label the far left boxes (from top to bottom): *Super-system, System, Subsystem* (Exhibit 6.2).

EXHIBIT 6.1 Dragon fruit with its antioxidant properties has captured the attention of mainstream companies including Snapple, Tropicana, and Sobe.

2. Fill in the Center Box

In the center box, put a brief description or a picture related to the innovation opportunity or JTBD (see Jobs To Be Done, Technique 1). In our example, the distinctive dragon fruit may be the first thing that comes to mind. However, since we want to make the Pitaya *plant* more tolerant to colder climates, we'll put that in the center box instead of the fruit.

You can use words or images, or a combination of both, in the Nine Windows.

---

3. Identify Super-System and Subsystem

In the present dimension (middle column), fill in the super-system and subsystem boxes above and below the center box. You can write (or draw) more than one item in each box.

- The super-system relates to how the system or object interacts with the surrounding environment. To complete this box ask, "What larger system encompasses the system or object?" For the Pitaya plant, the

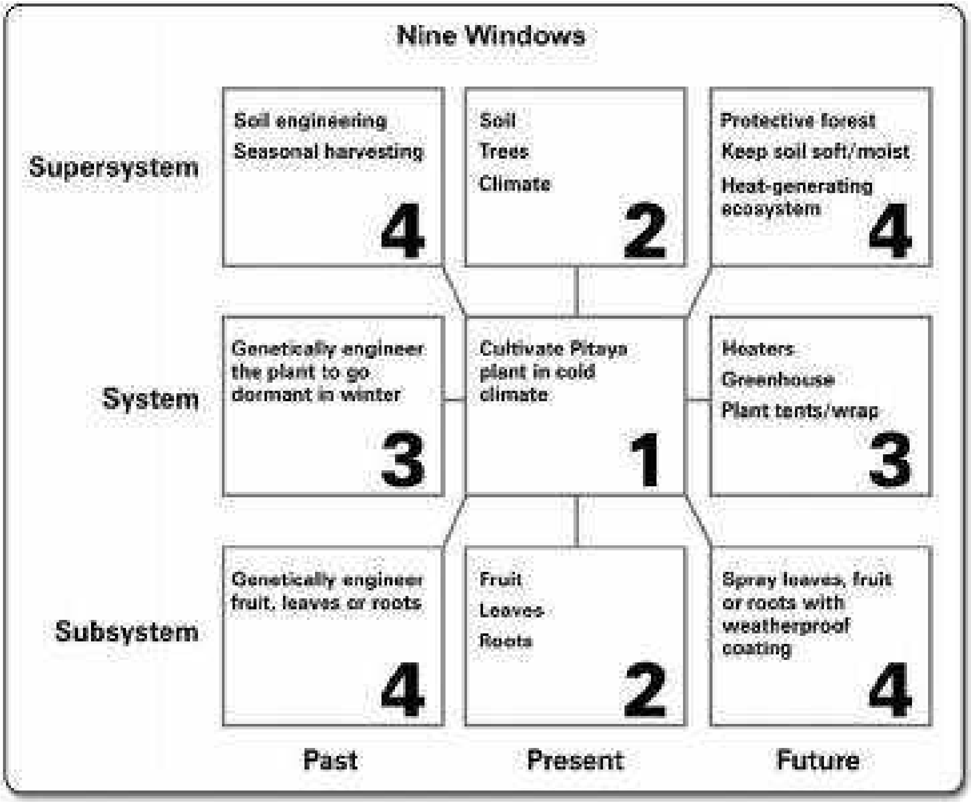

EXHIBIT 6.2 (Downloadable)

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super-system consists of the soil, the climate, and surrounding trees, which the plant often uses as support.

- The subsystem breaks the present system or object down into the components and characteristics that constitute it. To complete this box ask, "What makes up the object in its present form?" The Pitaya subsystem includes the plant's fruit, leaves, and roots.

Nine Windows is also known as *system operator* because it enables you to see how a system operates at both the macro (super-system) and micro (subsystem) levels.

---

4. Determine Past and Future

Now fill in the past and future boxes to the left and right of the center box. Don't limit yourself to just the immediate past or future. Instead, experiment with defining this temporal dimension in more than one way by asking:

- What did the system or object look like before its current incarnation, and what will it look like in the future?
- Where was the system or object before its present state, and where will it be in the future? The answer can range from a few seconds to years into the past or future.
- What happened to the system or object from its creation to its present form or function? What will happen after it ceases to function in the present?
- Before the present system or object existed, what was the previous solution for the JTBD, and what future solution could be developed to address the same JTBD?
- How can the system's inputs be modified to eliminate, reduce or prevent a harmful function, event or condition from impacting the output? Or, how can the system's output be modified in a corrective or reactive way?

In addition to enabling you to better scope the innovation opportunity, Nine Windows can be used to generate solution ideas, to determine what resources are available at each level, or to review contradictions inherent in the particular dimensions that could affect the system.

---

5. Complete the Grid

Last, fill in the four corners—the past and future states of the super-system and the subsystem. You can complete these four boxes in any order. Although you don't have to fill in all the corners, it's worth spending a few minutes trying. If you get stuck, take a short break and return to the problem with fresh eyes. The answers will depend on the specifics of the super-system and subsystem you defined in step 3, as well as the approach you took to the temporal dimension in step 4.

6. Reassess Opportunity

After filling in the Nine Windows grid, reassess the innovation opportunity to determine if you should focus your efforts at the system, subsystem or super-system level, and in which temporal dimension.

Job Scoping

Broaden or narrow your innovation focus.

Job Scoping ensures that the innovation opportunity is effectively targeted at an actionable level. If the project scope seems too broad, Job Scoping helps you drill down a level by identifying obstacles that could keep you from achieving your goal. If the scope is too narrow, Job Scoping moves the focus up a level to explore why you're working on the innovation problem in the first place.

Scoping an innovation project is important because the way you define the opportunity, or the job to be done (JTBD), can make the difference between a run-of-the-mill solution and a truly innovative approach. Although similar to Nine Windows (Technique 6), Job Scoping may take your project in a completely different direction, so it's worthwhile to apply both techniques early in the innovation project.

Steps

Scenario: Suppose you have been asked to reduce the amount of finished goods inventory in your company's warehouse. Others have tried to solve this problem in the past, but have failed. You can use Job Scoping to come up with an innovative solution that addresses the problem at the right level.

1. List Current Focus

Use the Job Scoping format (Exhibit 7.1) and write the innovation opportunity or JTBD in the center box. Use the preferred job statement format—an

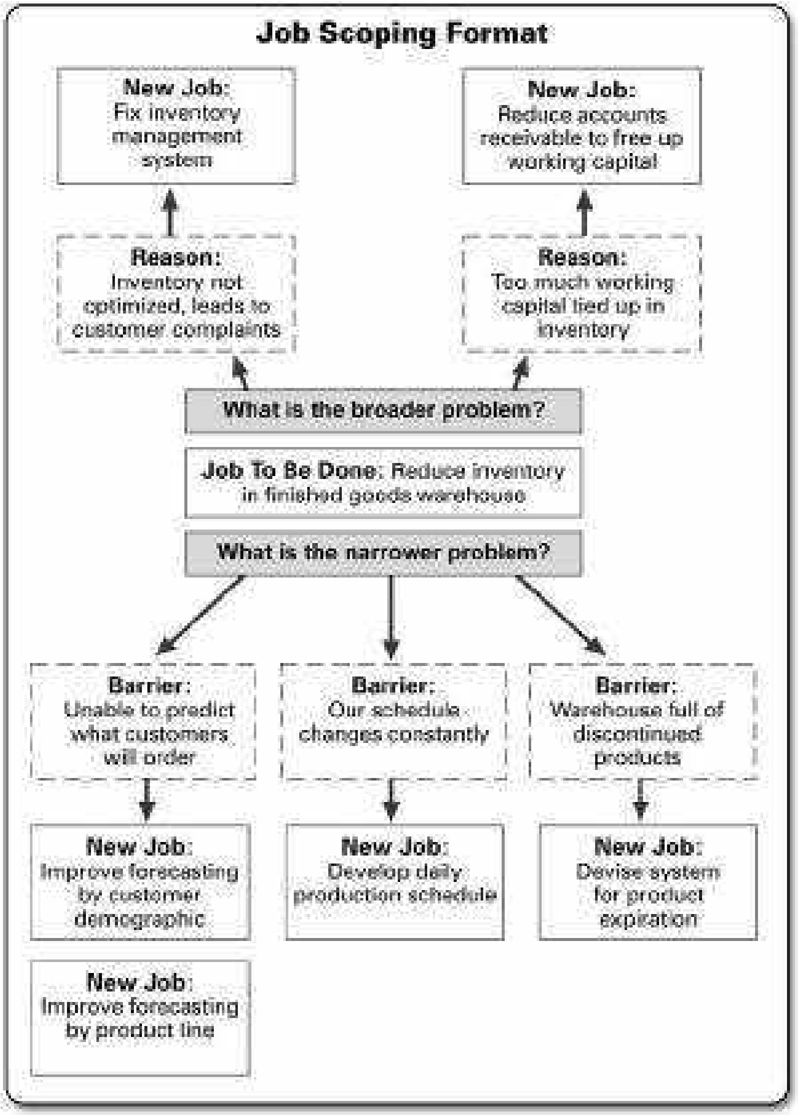

EXHIBIT 7.1 (Downloadable)

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action verb (*reduce*), followed by the object of the action (*inventory*), and a contextual clarifier (*in finished goods warehouse*). See Jobs To Be Done (Technique 1) for more information.

2. Identify Barriers

Scope the opportunity down a level by asking, "What is the narrower problem?" Write the narrower problem in a separate box below the center box.

3. Develop New Jobs

Based on the *barriers* you listed, brainstorm one or more new jobs (projects) that could address the issue at this level. Be as specific as possible. Write the new jobs below the related barrier. For instance, you might choose to reduce warehouse inventory by better managing expired products. This is a more granular, and possibly more actionable, approach than the broad original focus.

4. Identify Reasons

Next, scope the project focus up a level by asking, "What is the broader problem?" This helps the team challenge the expected benefits of the project, and provides a bigger-picture perspective of the issue. Write the broader problem in its own box above the center box.

> If you were tasked with working on the problem, instead of simply listing that as a reason, try to discern *why* you were asked—put yourself in management's shoes and figure out what they're really concerned about.

5. Develop New Jobs

Based on the *reasons* you listed, brainstorm new jobs (projects) that could address the problem at this level. Write each new job above the related reason. For example, instead of reducing inventory in the warehouse, you might discover that the real issue is customer complaints due to poor inventory management, or a lack of working capital. Addressing either of these issues would result in a much different approach than the original project focus.

6. Determine Project Focus

After applying Job Scoping, you may decide to change the focus of the innovation project to make it more actionable. Whether you do or not, just be sure the focus is clear before moving on.

Stakeholder Management

Get key influencers involved and on your side.

Stakeholder management helps you identify key stakeholders—people who have a vested interest in your innovation project—along with each person's level of support or resistance. Whether you're enhancing your existing products or services, adding something new to your offerings, or pioneering a breakthrough business model, you are in essence changing the status quo. Where there is change, there is pain, and where there is pain, there is resistance.

Resistance comes in all forms, from outright disagreement to subtle opposition, even subconscious sabotage. Stakeholder management helps you identify and understand the opposition your project may face so you can convert disbelievers into disciples—or at least minimize the damage they may cause. The Stakeholder Management technique includes three tools that will get you started, although formal change leadership training can take your skills in this area to a more effective level.

Steps

Scenario: In addition to using stakeholder management to gain support for an innovation project, you most certainly should leverage it when undertaking any large organizational initiative. For instance, imagine that your CEO feels strongly that innovation is the key to your company's growth, and charges you with leading an innovation deployment. Stakeholder management can help you identify who besides the CEO is in favor of the initiative so you can leverage supporters and move detractors in the right direction.

1. Identify Key Stakeholders

A *stakeholder diagnostic* identifies key stakeholders, along with their current level of support for the project (Exhibit 8.1). Most importantly, it documents how supportive you need each stakeholder to be to help make the project a success. As you complete the stakeholder diagnostic, keep the following in mind:

- *Key Stakeholders:* These are individuals who have direct influence over the project, or who will be directly affected by it, and who can influence other stakeholders, employees, vendors, and even customers.
- *Role in Organization:* List the stakeholder's title. Make sure that every affected organizational area is covered (including often neglected areas such as Marketing or Information Technology).
- *Impact of Project on Stakeholder:* Estimate the impact of the project on each stakeholder. How much will the project change the way they work?
- *Power/Influence Category:* This column tracks how much power the stakeholder has in the organization, relative to the influence they hold over the project. Skip it until step 3.
- *Current/Desired Level of Support:* Indicate what you perceive to be the stakeholder's *current* level of support for the project. Note: you'll determine the stakeholder's *desired* level of support in step 3.
- *Reasons for Resistance or Support:* Document why you believe the stakeholder is opposed to or in support of the project. If you're not sure why the person leans one way or the other, ask them.

Remember, the information uncovered in the stakeholder management process is confidential. It is only for use by the project leader and team.

---

2. Determine Stakeholder Power and Influence

Now that you know who your stakeholders are, and to what degree they support the project, you need to decide where to focus the majority of your stakeholder management efforts. Using a *power and influence map,* indicate where each stakeholder lies relative to their power in the organization

Stakeholder Diagnostic

#	Key Stakeholder	Role in Organization	Impact of Project on Stakeholder (H, M, L)	Power/ Influence Category	Strongly Opposed	Opposed	Neutral	Supportive	Strongly Supportive	Reasons for Resistance or Support
1	W. Sateg	CEO	M	A					●○	As CEO, believes that innovation is a key to the company's future growth.
2	K. Judge	CFO	L	A		● →	→	○		Satisfied with current product development process, believes major shift would affect profitability in short term and alarm shareholders.
3	M. Rieger	VP Business Development	H	C		● →	→	○		Believes organization is suffering from initiative fatigue, management overwhelmed with day to day, sees significant resource limitations.
4	M. Owen	CIO	L	C			●○			No obvious resistance, current IT systems are solid and can support the innovation deployment with few changes.
5	J. Stapleton	VP Research and Development	H	A		● →	→	→	○	Resistant because he sees innovation deployment as criticism of many years of R&D effort, fears loss of power and respect in organization.
6	K. Berger	VP Customer Relations	L	D				● →	○	As customer advocate, believes that any organization can always do more for the customer and innovation is one way to demonstrate it.
7	P. Smith	VP Marketing	M	B			● →	○		Limited awareness of innovation deployment vision, has solid network of grassroots team members.

Step 3

EXHIBIT 8.1 (Downloadable). This is a partial list of stakeholders for the innovation deployment example. An initiative of this type would likely have more stakeholders, depending on the size and structure of the organization.

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and their influence over the innovation project. On the map, each quadrant represents a specific power and influence ratio, as follows:

Quadrant A = HIGH power and HIGH influence

Quadrant B = LOW power and HIGH influence

Quadrant C = HIGH power and LOW influence

Quadrant D = LOW power and LOW influence

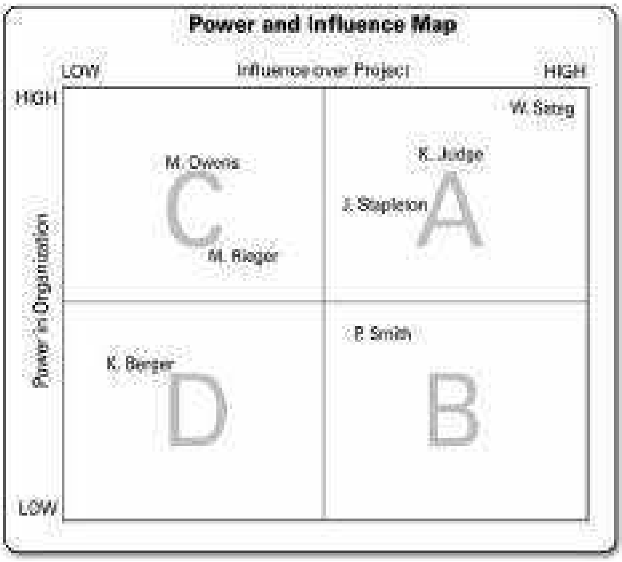

EXHIBIT 8.2 (Downloadable). Stakeholders in Quadrant A have high power in the organization and a lot of influence over the project, making them the most important to manage.

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In our example, M. Rieger has high power in the organization but less influence over the innovation deployment than most other stakeholders (Exhibit 8.2). Thus, any resistance on her part will be less consequential than those who have more control over the deployment.

3. Revisit Stakeholder Diagnostic

After filling out the power and influence matrix, return to the stakeholder diagnostic and fill in the remaining items:

- *Power/Influence Category:* Enter the corresponding quadrant letter for each stakeholder (from step 2).
- *Desired Level of Support:* In the same area where you documented the stakeholders' current level of support, indicate the desired level of support (how supportive you need each stakeholder to be). This will depend on both the impact of the project on the stakeholder, as well as

the stakeholder's level of power and influence (you'll want all the A's to be *supportive* or *strongly supportive*).

4. Develop Plan to Reduce Resistance

Now that you know whose support you must gain, there are several approaches you can use (see the list that follows) to convert the most powerful and influential naysayers into advocates. The approach you take to move each stakeholder in the right direction will be based on many factors, including the reasons that spawned the resistance in the first place.

- *Education and Communication:* If there is a lack of understanding about the project or its objectives, focus on upfront communication and education. In our example, the vice president of marketing could attend an innovation class or read more about the benefits of an innovation deployment. This would improve her support and she would also be able to help convey the benefits to others.
- *Participation and Involvement:* If you have stakeholders with considerable power to resist, find ways for them to participate early and throughout the project. This gives them the opportunity to influence the project proactively instead of reactively. In our example, the very resistant vice president of research and development should definitely be involved early and remain a key player in the innovation deployment.
- *Facilitation and Support:* If stakeholders are resisting the project due to fear and anxiety, provide extra facilitation and support. This could mean putting anxious stakeholders in touch with others who have gone through similar efforts—an approach that might convince our fictional CFO that an innovation program, if deployed properly, will raise profitability instead of threatening it.
- *Negotiation and Agreement:* If a stakeholder or group will be negatively affected by the project, try to negotiate a compromise that will please both sides. For instance, you could work with the vice president of business development to prioritize and possibly reduce some of the daily workload so the innovation deployment resource needs can be met.

Common Reasons for Resistance

- *Misunderstanding:* Based on communication failures and inadequate information.
- *Low Tolerance to Change:* Based on job insecurity or lack of organizational stability.
- *Different Assessments of the Situation:* Based on disagreement over the advantages and disadvantages of the project or resulting change.
- *Parochial Self-Interest:* Based on concern over how the project or change will impact an individual's own interests.

5. Complete a Leverage Matrix

A *leverage matrix* is used to rank the level of influence stakeholders have on each other. This comes in handy when, for instance, you need to move a stakeholder's support level from *opposed* to *supportive,* and you realize that another stakeholder can help move this person in the right direction.

Next to each name on the matrix, there is a number to the left. Corresponding numbers appear across the top of the matrix. For each stakeholder, move from left to right across the matrix and indicate how much influence the stakeholder in that row has on the other stakeholders (H = high; M = medium; L = low). For example, our fictional CEO (W. Sateg) has medium influence over stakeholders #2 (CFO) and #4 (CIO), but high influence over everyone else (Exhibit 8.3).

Leverage Matrix

		Who They Influence						
#	Key Stakeholder	1	2	3	4	5	6	7
1	W. Sateg, CEO	X	M	H	M	H	H	H
2	K. Judge, CFO	M	X	H	M	H	L	L
3	M. Rieger, VP Bus. Dev.	M	M	X	L	M	L	L
4	M. Owens, CIO	M	H	L	X	M	L	L
5	J. Stapleton, VP R & D	L	L	M	L	X	L	M
6	K. Berger, VP Cust. Relations	L	L	M	L	L	X	M
7	P. Smith, VP Marketing	L	L	L	L	L	M	X

EXHIBIT 8.3 (Downloadable)

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6. Update Documents as Needed

Stakeholder management is not a one-time check in the box. As you move through your project, it is important to update your approach based on new stakeholders and shifts in stakeholder support.

Resources

To learn more about stakeholder management and change leadership, read:

Kotter, J. *Leading Change*. Watertown, MA: Harvard Business School Press, 1996.

TECHNIQUE 9

Cognitive Style

Leverage the diversity of your exploiters and explorers.

Cognitive style is an individual's preferred approach for solving problems and can be measured along a continuum from *adaptive* to *innovative*. While adaptors are more prone to inside-the-box thinking and tasks, innovators are more prone to outside-the-box thinking and tasks. To run an innovation project from end to end, you always need some mix of both innovators and adaptors.

When all team members understand their own cognitive style, as well as the styles of other team members, the process of working together becomes much smoother and more productive—and you avoid unnecessary conflicts and delays. For example, a more adaptive team member who would ordinarily be frustrated with a more innovative team leader can, instead, understand the differences and use them to the team's advantage.

Background

Several factors affect a team's chemistry and success with innovation. *Motivation* is one factor, and there are known approaches for managing this. *Level* is another success factor, and it refers to (a) a person's current knowledge and/or skill and (b) a person's potential capacity for problem solving. We also have sound and established instruments (tests and IQ measurements, for example) for assessing these dimensions. Then there are *resources*—such as materials, money, machines, and tools—and these are typically well known.

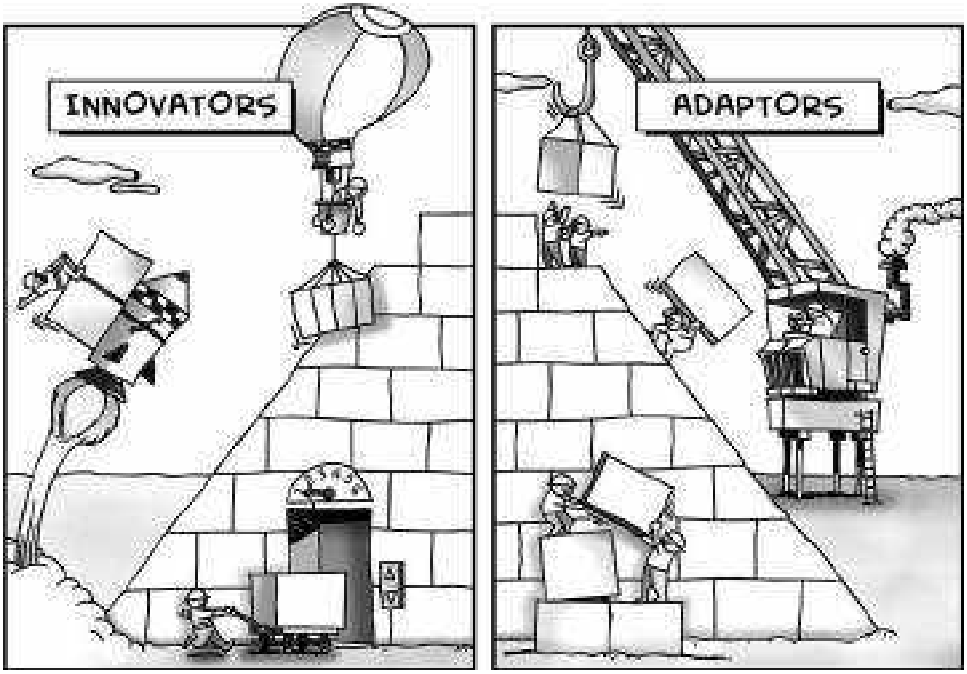

EXHIBIT 9.1 Adaptors and innovators have different approaches to solving problems.

What's not typically known or understood is the critical aspect of team members' respective cognitive styles. Cognitive style researchers have proven that people who are more adaptive prefer to accept and work within the given paradigm; those who are more innovative prefer to solve problems by looking at them from new angles and perspectives (Exhibits 9.1, 9.2, 9.3, and 9.4).

It's also important to realize the relationship between preferred style and behavior. Actual behavior is a combination of preferred style and learned *coping behavior.* If you have a more adaptive style and you have to perform tasks that have few guidelines or established structures, you will need to resort to coping behavior, and this will create stress in the long term. The converse is also true.

All innovation projects have steps that are adaptive and others that are innovative in nature. Therefore, you need a collaborative team with the appropriate motive, resources, cognitive level, and diversity of cognitive style. But research shows that people with differing cognitive styles struggle to get along—creating communication, trust and productivity issues. Therefore, make sure team members know and understand each others' cognitive styles so they can leverage each others' advantages and supplement each others' disadvantages at all stages of the innovation project.

Steps

Scenario: Let's assume you're assigned to a new cross-functional team tasked with developing a car that consumes carbon monoxide instead of producing it. Given the magnitude of the breakthrough innovation required, it's advisable to select team members with diverse backgrounds, a variety of different skills, and a range of different cognitive styles.

1. Identify Potential Team Members

Choose team members with a variety of technical and nontechnical skills, experience, and motivation related to the specific job statement or JTBD (see Jobs To Be Done, Technique 1).

2. Examine the Cognitive Style of Each Team Member

To determine the best fit for the task at hand, given the pool of potential candidates, be aware of the cognitive style that each team member brings to the task. You can do this in one of two ways:

1. Ask the following questions about the team members (in comparison to a reference person):
   - Does this person tend to question established rules, assumptions, and structures?
   - Does this person become frustrated or annoyed with details?
   - Does this person tend to have a steady stream of ideas without too much concern about how they're implemented?

   If the answers to the above questions are "yes," then this person is more innovative than adaptive. If the answers are "no," then the person is more adaptive.

2. If you want a more sophisticated way to determine cognitive style, use the *Kirton Adaption-Innovation (KAI) Inventory*, a highly validated and reliable psychometric instrument developed by psychologist Dr. Michael Kirton. Available at www.kaicentre.com, the KAI inventory works like this:
   - An individual responds to a series of 33 statements by marking responses on a range from very easy to very hard.
   - The KAI instrument is then scored by a certified facilitator to determine a primary KAI score and three KAI subscores. Primary KAI scores range on a normally distributed numerical scale from 32 (most adaptive) to 160 (most innovative), with a mean of 96. However, the observed range from worldwide data is 45 to 145 with a mean of 95. All scores are relative; there are no pure adaptors or pure innovators, so we often use the terms "more adaptive" and "more innovative" to describe the relationship between two people (Exhibit 9.2).

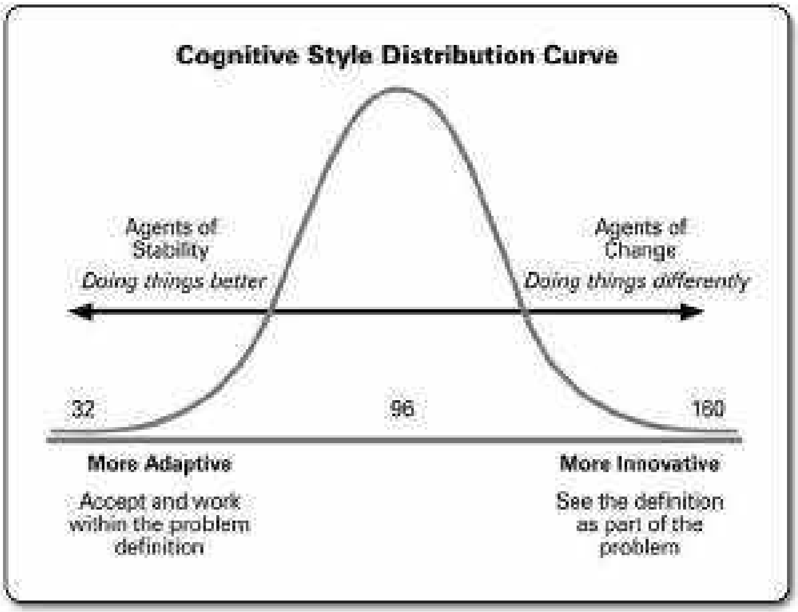

EXHIBIT 9.2

- A KAI facilitator then provides feedback to the individuals about the KAI instrument and highlights key insights about the scoring.
- The group is divided into smaller teams of participants with similar KAI scores; each team spends 15 minutes developing solutions to a specific problem that will be reported back to the group.
- Each team delivers a brief report summarizing their approach and the solutions generated.
- The facilitator highlights the differences between the different teams' styles, showing how the more adaptive team's approach differs from the more innovative team's approach.

Cognitive Style Insights

General

- All people are creative and solve problems.
- Cognitive *style* (adaptive or innovative) is different and unrelated to cognitive *level* (knowledge and capacity).
- There is no one best cognitive style.
- One's preferred cognitive style is genetically determined and stable over a lifetime.
- A group needs both adaptors and innovators to be effective over time.
- Forcing someone to work outside their preferred style (comfort zone) will cause stress; in the short term this might be okay, but in the long term it will lead to a breakdown in communication and reduction in productivity.

Don't mistake poor performance to always be a symptom of low problem-solving *level* or *motivation*. Instead of jumping to replace these team members, examine how you might reassign tasks to achieve better alignment with their preferred cognitive styles.

Adaptors

- The more adaptive tend to focus on doing things better, often within the problem definition or paradigm. Adaptors tend to be agents of stability.
- Adaptors seek solutions in tried and understood ways. Adaptors are seen as precise, reliable, and methodical. They look at the problem and want to solve it efficiently.
- High adaptors tend to rarely challenge the rules and usually only do so when assured of support.
- Adaptors produce fewer ideas that are more manageable, relevant, sound, and safe for immediate use. Expect a high success rate from these ideas.

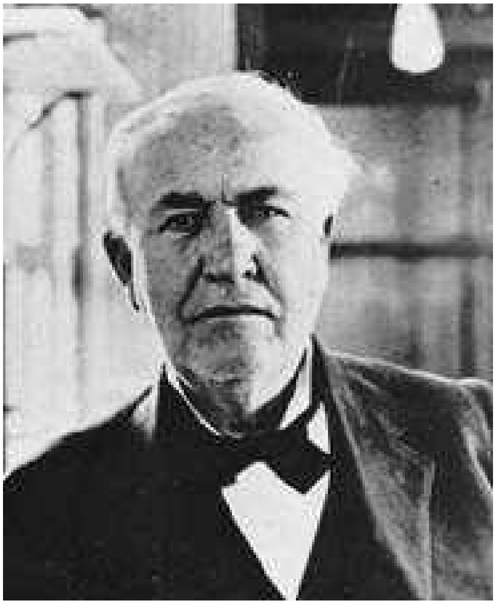

EXHIBIT 9.3 Thomas Edison borrowed new paradigms discovered by others and preferred to perfect them methodically, systematically and in a precise manner. Edison was more of an adaptor.

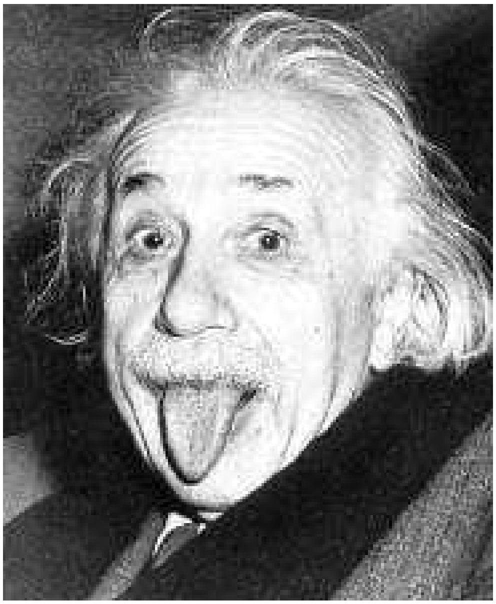

EXHIBIT 9.4 Albert Einstein questioned the existing Newtonian paradigm, which enabled him to discover the Theory of Relativity. Einstein was more of an innovator than an adaptor.

Innovators

- The more innovative tend to focus on doing things differently, often operating outside the parameters of the problem definition or current paradigm. Innovators tend to be agents for change.
- Innovators are expected to question the assumptions behind the problem at hand, and will often manipulate and redefine it. They are seen by adaptors as undisciplined and prone to tangential thinking.
- Innovators tend to view rules and structures as limiting or hindering progress, and they want to solve problems in novel ways.
- High innovators produce many blue-sky ideas that they consider exciting, and they tolerate high idea failure rates.

Teamwork and Collaboration

- The larger the gap between people's cognitive styles, the harder it will be to collaborate, communicate, and solve problems.

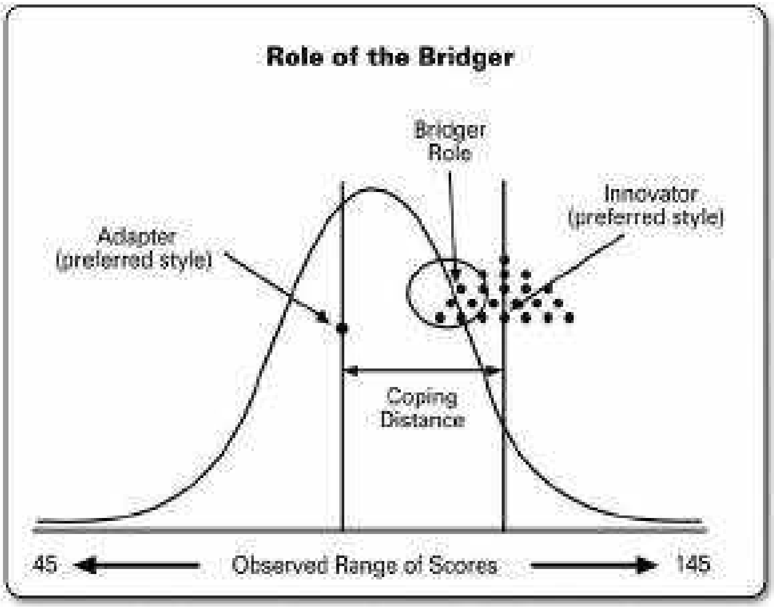

EXHIBIT 9.5 A bridger is someone whose preferred cognitive style lies in between adaptors and innovators, and who plays the role of helping overcome communication and other barriers to progress.

- A bridger is a person who helps facilitate communication and teamwork between high adaptors and high innovators (Exhibit 9.5).
- People who are more innovative can lead the opportunity-identification and ideation phases of the innovation process, while those who are more adaptive can lead the design and implementation phases.

Resources

Kirton, M. J. *Adaption-Innovation: In the Context of Diversity and Change*. New York: Routledge, 2003.

TECHNIQUE 10

Project Charter

Keep your innovation team focused and on track.

The Project Charter keeps your innovation team focused and on track, and it ensures that you manage the risks associated with innovation closely, carefully, and effectively. You wouldn't start a business without a well thought out and carefully designed plan. And you shouldn't take on something as risky as innovation without clearly documenting your objectives, your key assumptions, the projected return on investment, and many other data points that ensure your team and other stakeholders remain on the same page.

Regardless of the degree of innovation you're hoping to accomplish, you should always make time for a Project Charter. It's important to note that the Project Charter is not a static document you finalize early on, but rather a dynamic technique that should be revisited, refined, and updated throughout the life of the project.

The Project Charter and Innovation Financial Management are two of the most important techniques in this book. After all, you can generate thousands of clever ideas, but if no one needs or wants what you have to offer then your time and money is wasted. Therefore, don't overlook the value of spending time up front, and throughout the project, continually verifying that your innovation is marketable, feasible, and able to bring your organization a profit.

Steps

Scenario: Pikes Peak Coffee owns 32 coffee shops in three Western states. For the past three quarters, the company has failed to deliver the type of growth that stockholders are accustomed to seeing. One idea to spur growth is to add a healthy, fresh breakfast item to the menu. Thus, the innovation project Operation Feeding Frenzy was begun to determine what type of breakfast offering would outperform the competition. We'll use the company's Project Charter to demonstrate this key technique (Exhibit 10.1).

1. Administrative Information

Document summary information that categorizes the innovation project including:

- *Project Name:* Create a name for the project that allows people to clearly reference the effort. Instead of taking a purely literal approach, try coming up with a creative and inspiring name.
- *Type of Innovation:* Categorize the focus of your innovation project as either a product, process, or business model innovation.
- *Project Leader:* The project leader should have experience in applying innovation techniques and facilitating change teams.
- *Innovation Champion:* The champion (executive sponsor) removes organizational roadblocks and provides feedback during project tollgate reviews.
- *Methodology:* The D^4 methodology or other approach of your choosing.
- *Degree of Innovation:* Categorize the degree of innovation associated with the project (incremental, substantial, or breakthrough) based on the magnitude of the outcome or resulting change.
- *Date of Completion:* Start with your best estimate based on phase and deliverable planning.

2. Business Case

A business case is required to justify the allocation of time, money, and energy needed to make your innovation a successful venture. The business case should be a compelling summary for why the project is necessary and

Innovation Project Charter

Project Name: Operation Feeding Frenzy
Type of Innovation: Product / Service

(1)

Project Leader: T. Nichols
Innovation Champion: A. Mahoney
Methodology: D4
Degree of Innovation: Substantial
Date of Completion: Jan 1, 2009

Business Case: (2)
Pikes Peak Coffee (PPC) has consistently delivered double-digit growth since its inception, except for the last three quarters. While growth is the number-one priority, we believe the coffee market is saturated in the region. Research shows that about 35% of our competitors' sales come from food products, and 30% of these products are sold in the morning. This project will explore growth opportunities in the hot breakfast food business.

Job Statement: (3)
Eat a healthy breakfast on the go.

Customers: (4)
External: Coffee drinkers who want a hot, healthy breakfast on the way to work (primary); athletes, parents, students (secondary).
Internal: None.

Unmet Outcome Expectations: (5)
- Minimize the time needed to acquire breakfast in the busy morning.
- Increase the likelihood of eating a healthy breakfast.
- Increase the convenience of eating breakfast outside home.
- Minimize the mess generated from eating breakfast.
- Minimize the cost of buying breakfast out.

Competing Solutions: (6)
- Fast food chains that offer breakfast options.
- Microwaveable/homemade breakfast foods.
- Smoothies (breakfast through a straw).
- Restaurants that offer full-service, sit down breakfasts.
- Hotels that include breakfast in the price of a room for travelers.

Key Assumptions to be Tested: (7)
- 15% increase in revenue growth.
- Unit price of $4.95 for breakfast offering.
- Per store average volume of 80 sales per day.
- 40% contribution margin.
- Revenue from beverage sales will not be diminished by new offering.
- Customers will purchase breakfast from a coffee shop.
- Capital expenditure will be repaid in six months.
- New offering will not significantly impact coffee order cycle times.
- New offering will be distinct from competitions'.

Expected Financial Impact: (8)
- 1st Qtr: $750,000 Rev./$300,000 net profit.
- 2nd Qtr: $1.2 MM Rev./$480,000 net profit.
- 3rd Qtr: $1.3 MM Rev./$520,000 net profit.
- 4th Qtr: $1.4 MM Rev./$560,000 net profit.

(9)

Milestones/Time line:	Scheduled	Actual
Define Tollgate:	06-30-08	
Discover Tollgate:	07-30-08	
Develop Tollgate:	09-15-08	
Demonstrate Tollgate:	01-01-09	

Project Investments: (10)

Define Phase:	$5,000
Discover Phase:	$7,000
Develop Phase:	$10,000
Demonstrate Phase:	$30,000
Commercialization Phase:	$246,500

Team: (11)
M. Chew, A. Jones, D. McDonald, A. Perkins, S. Gonzalez, D. Roberts, E. Thomas

EXHIBIT 10.1 (Downloadable). This is a template for an Innovation Project Charter. As you move through the project, you will constantly revise this document.

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promising. Your business case can include any or all of the answers to the following questions:

- What's the business reason for undertaking this innovation project?
- How is the outcome aligned with or linked to strategic objectives?
- Is the idea financially viable and in what way will it contribute to profitable growth?
- Why is this an important opportunity and which customers (either internal or external) does it benefit?
- What is the expected Return on Investment (ROI) for the project?
- Why should this project be a priority for the organization?

The business case is often based on initial assumptions (customers will buy this innovative offering from us, we will recoup our investment on this project, etc.). Just be sure to test these assumptions for validity as you move through the project. Otherwise, you may find out too late that they weren't sound.

---

3. Job Statement

A job statement is the job to be done (JTBD) summarized in a specific format: *verb* (eat), *object* (a healthy breakfast), *context* (on the go). Note that the job statement should be written from the customer's point of view not the provider's (e.g., increase profits from new menu item). For more on this, see Jobs To Be Done (Technique 1).

4. Customer

To build a robust Project Charter, it is important to identify the customers who will benefit from the innovation outcome. Segment your existing and potential customers by the job they're trying to accomplish instead of demographics, product line, geography, and so on. For example, the obvious target market for Pikes Peak Coffee's new offering is coffee drinkers who want a healthy breakfast on the way to work. Other customers might include athletes after their morning workout, parents returning from dropping the kids off at school, or students on the way to class.

5. Unmet Outcome Expectations

To ensure that your innovation will provide real value to customers, it's important to understand the major outcomes that are not currently satisfied by existing solutions. Use Outcome Expectations (Technique 2) to generate a list of expectations associated with the JTBD. Then, on the Project Charter, list the key unmet expectations. Use the format: *direction* (minimize), *measurement* (time needed to acquire), *object of action* (breakfast), and *context* (in the busy morning).

> Consider using focus groups or even Ethnography (Technique 4) to identify unarticulated outcome expectations.

6. Competing Solutions

Understanding the competitive landscape is essential for developing successful, profitable innovations. The key is to identify the current solutions for the JTBD (not just a list of who you think your competitors may be). Make a list of products, services, or processes that currently fulfill this job (well, poorly, or in between).

> You can use Value Quotient (Technique 3) to compare and contrast competing solutions.

7. Key Assumptions to Be Tested

Most business endeavors evolve from a series of assumptions related to functionality, outcomes, value, process, price, and so on. To identify which key assumptions need to be tested for your innovation, start by creating a comprehensive list of assumptions that are built into your idea. You can use the approach of Innovation Financial Management (Technique 11) to help with this task. Once you have a comprehensive list, prioritize your assumptions and select ones that will have the greatest impact on the success of the innovation. List these on the Project Charter.

Common Assumption Categories

- Availability of reasonable solutions.
- Price the customer is willing to pay for the innovation.
- How the business model can support the innovation.
- Supply chain logistics.
- Operational capabilities.
- Speed to scale-up.
- Cultural acceptance.
- Other strategic considerations.

Early in the innovation project, your ratio of verified knowledge to unverified assumptions will be low (there will be much you don't know). It's important to test and validate your assumptions as the project progresses. This increases your knowledge base, allowing you to make more informed decisions—and giving you the opportunity to abandon the innovation effort, if necessary, before you've reached your full investment.

8. Expected Financial Impact

Financial projections are often one of the most scrutinized aspects of an innovation Project Charter, especially when executives are trying to select which few innovation projects to fund. Almost all financial projections include estimates of revenue. Or, you can estimate *profitability* using Innovation Financial Management (Technique 11). Either way, the financial projections listed on the Project Charter should be estimated from the point your innovation will be available to customers, and should align with the company's current accounting periodicity (monthly, quarterly, annually).

Had Motorola tested its assumptions, maybe it could have avoided the billions lost on its Iridium (satellite phone) product. Perhaps Apple Computer could have curtailed its $350 million in losses on its handheld Newton device. Test your assumptions as rigorously and often as possible if you want to avoid innovation and business failures.

9. Milestones/Timeline

Establish milestones and timelines for your innovation project by identifying key deliverables. Milestones are often mapped against your innovation methodology (with a tollgate review at the end of each phase). Or, they could represent major steps toward the end result, such as Business Case, Feasibility, Preliminary Design, Detailed Design, Pilot/Prototype, Prelaunch, and Launch.

10. Project Investments

To complete the initial project investment estimates, identify the cost of raw materials, people, training, time, capital expenditures, and other costs that will be required to bring your innovation to market. You can use Innovation Financial Management (Technique 11) to help you identify investment costs relative to your assumptions.

11. Team

To select your innovation project team members, start by identifying the combination of technical and change leadership skills that will be required to bring your innovation to market. The appropriate number of team members should be driven by the complexity and requirements of the innovation. You can also examine the candidates' problem-solving styles (see Cognitive Style, Technique 9) to ensure an effective and diverse mix.

Innovation Financial Management

Constantly improve your assumption-to-knowledge ratio.

The innovation financial management approach offers a clear advantage over traditional financial assessments. By forcing you to articulate your assumptions early in the innovation process, innovation financial management provides a systematic way to evaluate the feasibility of your innovation before putting too much time, money, and resources into it.

Consider the case of Euro Disney. When Walt Disney Company built the park, one key assumption was that visitors would spend an average of four days in an onsite hotel. The average turned out to be only two days. Alone, this inaccurate assumption does not account for Euro Disney's initially poor return on investment. But it can be coupled with a host of other unverified assumptions that cost the company nearly $1 billion in losses during its first two years.

Any innovation is risky. Innovation financial management reduces this risk by increasing the ratio of verified knowledge to unverified assumptions as the project unfolds. This learn-as-you-go approach ensures that you have the most accurate and updated information possible and enables you to confidently proceed or abandon the project at any point.

Background

Many innovation projects fail because the business lacks the right tools to understand markets, build brands, find customers, select employees, organize processes, and drive strategy. Traditional financial analysis tools, such as discounted cash flow and net present value, tend to distort the importance, the likelihood of success, and the value of investment in the innovation. These approaches build in certain assumptions that are rarely tested after the initial investment decision has been made.

Innovation financial management offers an alternative to these methods by identifying, tracking, and updating key assumptions, and linking the verification of these assumptions to the investment decision-making process.

Innovation financial management is an amalgamation of other proven financial management approaches. For more information, see:

McGrath, R. G., and I. C. MacMillan. "Discovery-Driven Planning." *Harvard Business Review,* July–August 1995.

Sykes, H. B., and D. Dunham. "Critical Assumption Planning: A Practical Tool for Managing Business Development Risk." *Journal of Business Venturing* 10, no. 6 (1995): 413–424.

Dewar, J. A., and C. H. Builder, et al. *Assumption-Based Planning: A Planning Tool for Very Uncertain Times*. Santa Monica, CA: RAND Corporation, 1993. http://rand.org/pubs/monograph_reports/MR114/.

The extent to which you can complete the innovation financial management documents early in the project depends on the level of innovation you hope to achieve. During incremental innovation, your initial ratio of knowledge to assumptions (Exhibit 11.1) will be higher than for substantial or breakthrough innovation. In either case, you should update the relevant financial documents, as well as the Project Charter, as you uncover new data throughout the project.

Steps

Scenario: To demonstrate the basics of innovation financial management, we'll continue the Pikes Peak Coffee example from the Project Charter technique (Technique 10). The company can use this approach to determine the profitability of adding a healthy, portable breakfast offering to its menu.

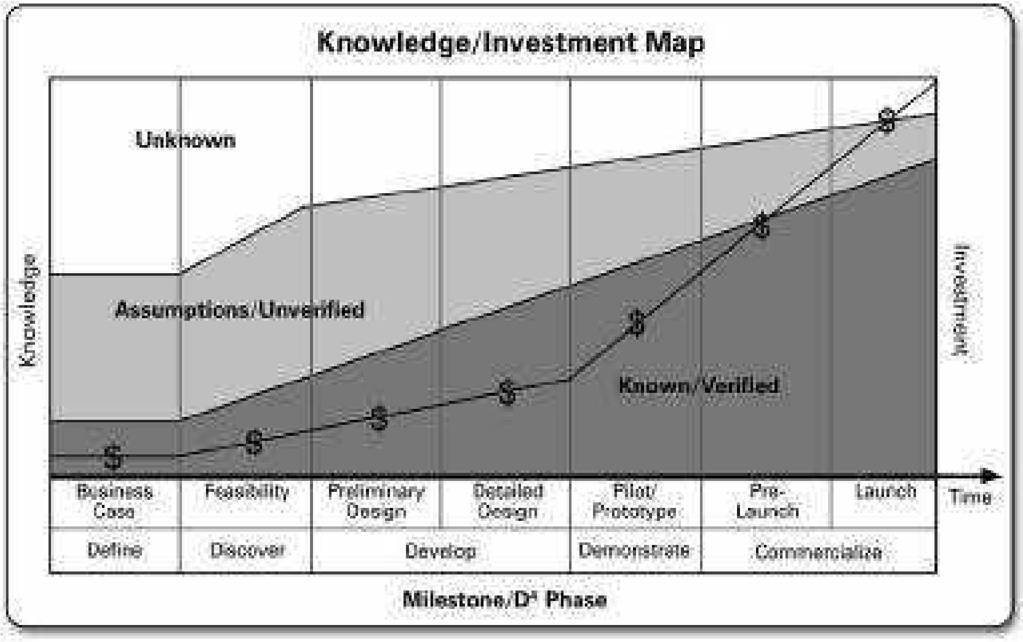

EXHIBIT 11.1 Early in the innovation project, there may be a low ratio of known/verified information compared to unverified assumptions and unknowns. Ideally, investment will also be low at this stage. As the project progresses, the level of verified knowledge should increase relative to the project investment.

1. Document Initial Assumptions

If you've completed a Project Charter, you've established the business case for your innovation. Innovation financial management takes over from here and begins with a list of what you know (verified knowledge), as well as what you need to find out (unverified assumptions and unknowns).

For example, Pikes Peak Coffee knows that it currently has 32 locations, and that if the innovative breakfast offering proves to be viable, it would be offered in all locations. What the company doesn't know yet is the details of the offering, the retail price, the demand, or the cost (materials, personnel, and new equipment). However, for each of these assumptions, innovation financial management encourages you to put forth an educated guess. The point is not to show what you know, but to learn as you go (Exhibit 11.2).

Initial Assumptions

	Per Store	All Stores
Stores	1	32
Sales Volume	29,293	937,374
Unit Price	$ 4.95	$ 4.95
Revenue	$ 145,000	$ 4,640,000
Production Days	365	11,680
Daily Production Capacity	160	5,120
Employees/Store	1	32
Employee's Wages/Store	$ 22,500	$ 720,000
Material Cost per Unit	$ 1.63	$ 1.63
Paper Cost per Unit	$ 0.17	$ 0.17
Capital Cost	$ 8,500	$ 272,000
Equipment Life (years)	5	5
Allowable Overhead	$ 9,970	$ 319,046

EXHIBIT 11.2 (Downloadable)

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Assumptions are factors you assume to be a certain way without enough evidence to prove or disprove your theory.

2. Prepare Reverse Income Statement

Now that you've articulated some basic assumptions, the next step is to determine the amount of *profit* (not revenue) you want to generate as a direct result of your innovation. Determine the profit margin and amount of profit that would make the project worthwhile. Then, use a *reverse income statement* to calculate how much revenue you would need to reach this profit after subtracting your initial investment and any ongoing costs.

Pikes Peak Coffee, for example, hopes that adding a unique, healthy breakfast offering to its menu will net them an additional $1.8 MM profit annually across their 32 locations. A reverse income statement (Exhibit 11.3) shows that to meet this goal, annual revenue from the new offering (before costs) needs to be $4.6 MM.

Reverse Income Statement

Required Profit	$	1,856,000
Required Contribution Margin		40%
Allowable Cost	$	2,784,000
Required Revenue @ 40% ROS	$	4,640,000

Revenue = Profit/Contribution Margin

EXHIBIT 11.3 (Downloadable). To determine the Required Revenue (line 4), divide the Required Profit (line 1) by the Required Contribution Margin (line 2).

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A reverse income statement models the basic economics of the proposed innovation based on projected profit, not revenue.

3. Estimate Operating Specifications

In addition to investment costs, ongoing operational costs will divert your innovation's revenue stream. Use *pro forma operations specs* (Exhibit 11.4) to identify and estimate overhead costs. Include estimates for wages and salaries, raw material and inventory cost, manufacturing costs, insurance, shipping, marketing and advertising, and whatever other annualized costs the innovation may incur above and beyond your current operating costs. Also include annual depreciation or any other factors that could impact the profitability of your innovation in an ongoing manner.

Pro Forma Operations Specs

	Per Store	All Stores
Sales		
Annual Sales Volume	29,293	29,293
Daily Sales Volume per Store	80	80
Production		
Annual Production Capacity	58,400	1,868,800
Daily Production Capacity	160	5,120
Stores	1	32
Expenses		
Workers Needed	1	32
Workers' Wages	$ 22,500	$ 720,000
Total Material Cost	$ 47,850	$ 1,531,200
Total Paper Cost	$ 4,980	$ 159,364
Marketing Cost	5%	5%
Capital		
Total Capital Cost	$ 8,500	$ 272,000
Annual Depreciation	$ 1,700	$ 54,400

EXHIBIT 11.4 (Downloadable). Pro forma operations specs document all specific and measurable costs required to implement the innovation.

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The APQC Process Classification Framework can be a useful tool when trying to articulate all the associated costs for the pro forma operations specs. You can download a copy at www.apqc.org/portal/apqc/site/?path=/research/pcf/index.html.

4. Update Income Statement

After compiling the estimated operational costs, update the income statement (Exhibit 11.5) to see if your initial profit projections are still on target. For our coffee shop example, total costs will likely be less than predicted on the reverse income statement, which increases the amount of projected profit. Of course, had the pro forma operation specs predicted higher costs than the initial estimate, Pikes Peak Coffee would need to either reduce costs or increase revenue projections.

Updated Income Statement		
Required Revenue	$	4,640,000
Direct Costs		
Additional Employee Wages	$	720,000
Food Cost	$	1,531,200
Paper & Packaging	$	159,354
Equipment Depreciation	$	54,400
Direct Costs - Sub Total	$	2,464,954
Allowable Admin., Marketing Overhead	$	232,000
Total Costs	$	2,696,954
Projected Profit	$	1,943,046
Initial Required Profit	$	1,856,000

EXHIBIT 11.5 (Downloadable)

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5. Identify Critical Assumptions

Make a list of any critical assumptions that, if left unchecked, could seriously impact your innovation financially. Many of these you have already created for the income statements and operations specs. Include the following:

- Competition, market size, retail price, average order size, up-sell potential, and other revenue-related assumptions.
- Design time line/costs, prototyping/piloting expectations, testing timeline, and other R&D cost assumptions.

- Production schedule/timeline, sales cycle, material cost, shipping costs, inventory costs, salaries, wages, and other operating cost assumptions.
- Marketing, advertising, packaging, redesign, and other promotional cost assumptions.

Avoid These Dangerous Inherent Assumptions

- Customers always prefer technologically superior products and services.
- Customers don't know how to articulate their needs.
- "Build a better mousetrap and the world will beat a path to your door."
- When customers hear about our new solutions, they will quit using existing solutions in favor of our solutions.
- Our solution is so superior that it will sell on its own without any extra effort.
- Distribution channels will promote our products and services over existing products and services they sell.
- We have the expertise and resources needed to create the solution and get it right the first time.
- Our competitors have no capability to match our plans.
- All stakeholders in our company will rally behind our new idea.
- We are the leader in our industry.

6. Link Assumptions to Milestones

Milestones are checkpoints that help you determine whether to continue on course or redirect your innovation effort. Make a list of milestones for your innovation. Include significant targets both during the innovation project and after. Then associate each milestone with the critical assumptions that must be verified before the checkpoint can be completed (Exhibit 11.6).

7. Test and Validate Assumptions

For each critical assumption, design a test that will prove it right or wrong. You could target the assumptions at each milestone before moving on to the next. Or, you may need to take a more granular approach and design a test that validates each assumption. Either way, make sure the assumption

Milestones and Assumptions		
Milestone	**Assumption**	**Test Plan**
Business Case	15% increase in revenue growth Unit price of $4.95 for breakfast offering Per store average volume of 80 sales per day 40% contribution margin	Benchmark competition
Feasibility	Production capacity per store per day Capital cost of equipment Equipment life Production days Additional employees per store Additional employee wages Food cost Packaging cost	Identify availability and cost for capital, materials and people
Design	Capital expenditure will be paid within 6 months New offering will be distinct from competition's	Explore alternatives
Pilot	Unit price Volume Food cost Packaging cost Revenue from new offering Test marketing costs New offering will not diminish revenue from beverage sales Customers will purchase breakfast from a coffee shop New offering will not significantly impact coffee order cycle times During pilot, operating costs will be offset by incremental revenues	Measure performance of new offering
Pre-launch	Unit price Revenue Profit margin Marketing and advertising costs	Analyze collected data and update business plan
Launch	Marketing and advertising costs Success of pilot replication Growth rate Market size	Continuously improve operating methods

EXHIBIT 11.6 (Downloadable)

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is clearly stated and understood, and the data and method used to verify the assumption is sound.

Don't wait for the pilot or prototype phase to validate all your assumptions. Although many of Pikes Peak Coffee's assumptions will be tested during a three-month, three-store pilot of their new breakfast offering, many other key assumptions need to be tested both before and after the pilot (Exhibit 11.6).

8. Revisit Financials

As you proceed through the project milestones, testing your assumptions along the way, your knowledge increases regarding the innovation's potential. Thus, you should recalculate the income statement at each milestone. Depending on what you learn, you may also need to revisit the operations specs. Your critical assumptions list will also change as you validate your initial assumptions and develop new ones during the process.

If you're following the D^4 innovation process, verify that your assumptions have been validated during each tollgate review.

PART II

DISCOVER THE IDEAS

Successful innovation is about capitalizing on an opportunity to fulfill unmet customer expectations in a superior way. But finding that superior way is far from easy, because at the core of most opportunities lies a difficult problem. Customers, for instance, want wrinkle-free clothes but no current solution meets their expectation very well. This is an innovation problem as well as an opportunity.

In this second phase of the innovation process, your goal is to generate substantive ideas for closing customer-expectation gaps (or innovation opportunities) within the confines of a smartly scoped organic-growth project. But first you'll want to *refine the opportunity* using the Resource Optimization, Functional Analysis, Trend Prediction, and Creative Challenge techniques—along with their associated tools.

Then you need to bring out the best of what's in your mind and accelerate the creative process using the techniques of HIT Matrix, SCAMPER, Brainwriting 6-3-5, Imaginary Brainstorming, Concept Tree, Random Stimulus, and Provocation and Movement. Each of these techniques is designed to leverage *latent brainpower* beyond what resides in your immediate consciousness, or what can be surfaced with only classic brainstorming.

Still, the power of your team's collective mind might not be enough to ideate a sufficient innovation. The prescription is to *search knowledge bases* that exist outside yourself, finding clues and direction. One knowledge base is the collective experience of all inventors, as catalogued inside such techniques as Structured Abstraction, Separation Principles, and 76 Standard Solutions. Another knowledge base is the adaptive miracles of nature and nonhuman species; the Biomimicry technique should be your source for exploring how nature's miracles can be put to use for innovation.

This phase of the innovation project ends by filtering ideas and narrowing them down to the few that are the best candidates for further development. See the KJ Method, Idea Harvesting and Treatment, and Six Thinking Hats to help you converge on the concepts that are ripest for commercialization.

Resource Optimization

Make sure you use all available resources.

Resource optimization is the use of existing resources to solve an innovation problem and increase the value of a solution relative to existing options. For instance, when food-makers came up with reverse bottles (spout on bottom instead of top) for ketchup, shampoo, and other liquid substances, they used the free and available resource of gravity to solve the problem of getting every last drop out with ease and no frustration.

Use resource optimization when you need to come up with solution ideas that provide higher value than those in existence today—or when you need to refine and optimize a specific solution design. The key is to make sure you list as many resources as possible within and outside your immediate system or sphere of focus. After this, you can use any number of idea-generation techniques to figure out how your available resources can be applied to your inventive problem.

Background

In the vast majority of problematic situations where a creative idea is sorely needed, resource optimization is seldom if ever seriously considered. Most of the time, it never even makes the radar screen, because the typical approach is to throw money at a problem and fix it through adding complexity.

It's always easier to solve a problem through additive approaches rather than through elegant solutions that utilize readily available resources.

So what really is a resource? Machines, people, equipment, money? Yes. But what about the resources of gravity, air, vacuums, and even waste? This is where the creative part starts: using resources you never thought were available to position your innovation ahead of your competition.

Think of resources that are just hanging around waiting to solve a problem without a large outlay of time, effort, or expense. Heat from a car's engine is harnessed to keep passengers warm on a cold day. An empty wine bottle is used as a rolling pin. Gravity provides the centripetal force needed to keep a satellite in orbit.

This means you'll identify your system's immediately recognizable resources, but you'll also identify resources outside the system (super-system), inside the system (subsystem) and even resources in the environment at large (like humidity for instance).

An innovator also should consider resources that were available in the past or will be available in the future. For example, NASA engineers spent a lot of money trying to come up with a headlight for a lunar module. They had trouble creating the perfect interface between the glass light bulb and the metal body holding it—until they realized they could use a future resource: since the moon's atmosphere has vacuum properties, the engineers eradicated the need for a glass bulb at all.

Some resources to consider in solving innovation problems include:

- *Material resources,* such as waste, raw materials, modified materials, and inexpensive materials.
- *Time resources,* such as parallel operations and prefunction and post-function work.
- *Information resources,* such as data usage, computer networks, public data, and information.
- *Field resources,* such as energy in the system (mechanical, thermal, chemical, electrical, magnetic, etc.) or energy in the environment (gravity, vacuums, light, wave movement, wind, geothermal, etc.).
- *Space resources,* such as empty spaces, nesting components, or dimension reconfiguration.

- *Function resources,* such as harmful functions that can be converted to good functions, or enhancing the secondary effects of functions.

Engineers participate in the activities which make the resources of nature available in a form beneficial to man and provide systems which will perform optimally and economically.

—L. M. K. Boelter, engineer, educator, and innovator

Steps

Scenario: Some resource optimization experts have proposed that every life on the Titanic could have been saved with the use of existing resources on the ship (Exhibit 12.1). That may very well be true, but clearly the crisis conditions prevented that from happening. Hopefully you won't find yourself in the middle of a crisis with your innovation project, and you'll always have time to explore how you can optimize your unused but available resources.

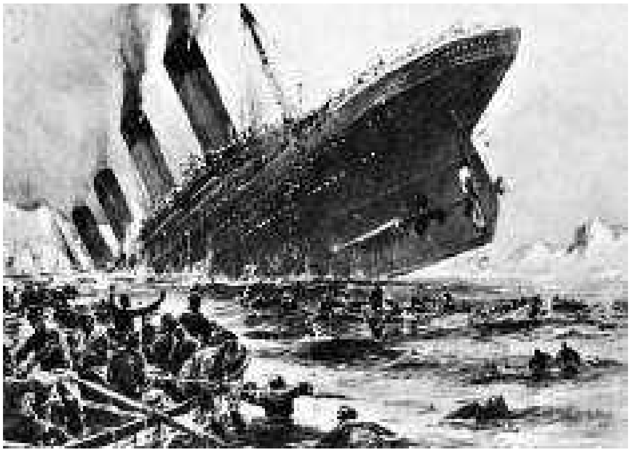

EXHIBIT 12.1 The Titanic.

1. Formulate the Problem

What job, problem, or task creates the focus for your innovation effort? What are its associated customer and provider outcome expectations? Have you already created a project statement or job statement? See Jobs To Be Done, Outcome Expectations, and Project Charter (Techniques 1, 2, and 10 respectively).

For the Titanic scenario, the job is to save all 2,223 people on board, even though there are only 1,178 available lifeboat seats. A rescue ship is on the way in approximately four hours, but the ship will sink in two hours if left to its own devices. Also, people will freeze in four minutes if exposed to the icy cold waters of the Atlantic Ocean.

2. Compose a List of Resources

Make an inventory of all resources at hand, leaving no stone unturned. First list all the resources that are internal to your system; then list all resources that are external or outside of your system; then list all resources that are by-products of your internal and external resources. For the Titanic, we'll only list pertinent resources for illustration purposes (Exhibit 12.2), because we don't have the space to list every available resource on the approximately 883-foot long, 93-foot wide, 60-foot high, 46,328-ton ship.

3. Analyze the Resource List

The key to this step is to narrow the list of resources down to only those that have the most leverage or potential to change the system in a way that

Some Resources Aboard the Titanic

Time Resources	Rescue ship	Ship's architect
Two hours to sink	Bed mattresses	Ship's captain
Four hours to rescue	Wood	
Four minutes to freeze	First aid kits	**Information Resources**
	Life preservers	Knowledge/skill sets
Material Resources	Bathtubs	Communication equipment/radio
Life rafts	Deck chairs	
Ship	Band instruments	
Tools	Garbage containers	**Field Resources**
Water	Blankets	Chemical (from coal)
Axes	Maps	Thermal (engine heat)
Cooking lard		
Steel	**Natural Resources**	**Space Resources**
Coal	Salt water	Deck
Clothes	Whales/other fish	Empty spaces in bathtubs, suitcases, furniture, etc.
Kitchen utensils	Iceberg	
Band instruments		
Suitcases	**Team/People Resources**	
Rope		**Function Resources**
Furniture	Passengers	Engine
Canvas	Crew	Navigation system
Food	Engineers	Steering system
Cars	Doctors	
Car Tires	Ship's chief engineer	

EXHIBIT 12.2

solves the inventive problem, without creating any unwanted side effects. When wanted changes are made in any system, those changes tend to create ancillary unwanted changes—so the fertile ground of innovation lies in those areas where you can make changes, or better utilize resources, without creating drawbacks elsewhere.

When looking for free resources to use, or looking to better utilize certain resources as a pathway to an innovation, complete the following equation: $Y = f(x)$, substituting the desired outcome for the Y variable and the proposed resource for the X variable. To achieve the expected outcome (Y), the X resource must perform the function without added complications, cost or undesired effects.

Some options for working with resources are:

- *Resource Utilization:* Convert existing resources into new resources through the application of inventive fields (burn fuel to generate heat).
- *Resource Accumulation:* Use a device or substance to increase the amount of a resource, and then release it (use a dam to accumulate water).
- *Resource Combination:* Add one resource to another (add salt to water to affect buoyancy).
- *Resource Concentration:* Use a field to concentrate a resource to an effective level (microwave oven, laser for eye surgery).
- *Resource Evolution:* Envision the evolution of a system—what resources might evolve and how (using plants to generate oxygen).
- *Resource Scaling:* Change the scale or magnitude of a resource property (concentrated vaccine dilutes after injection).

Several uses of resources could be employed to possibly save all the lives on the Titanic. Teams of people could be organized to perform various functions, such as blocking the hole in the ship with clothes, garbage, mattresses, canvas, and so on to delay the water flooding rate. Also teams could be formed to transport people from the ship to the iceberg, where they could stay warm enough until the rescue ship arrives. Other teams might create various floating devices using the ship's resources.

Additionally:

- Use lifeboats to shuttle people back and forth to the nearby iceberg.
- Use ropes and kitchen utensils to secure people to the iceberg.

- Keep people warm with mattresses and blankets.
- Use life preservers as a buffer between passengers and the iceberg to keep people warm and safe.
- Coat people's bodies with cooking lard to protect them from the icy cold waters and prevent hypothermia.
- Use empty suitcases and wooden furniture as mini lifeboats.
- Use car tires as flotation devices.
- Use engineering experience to devise and implement the rescue system.

Additional Examples

- Perhaps the most brilliant use of available resources was when the ground and flight crew of Apollo 13 devised a way to overcome severe electrical power and oxygen limitations to keep three astronauts alive and safely return them to earth. They did this by using the lunar module as a lifeboat in space, and rigged an adapter system using materials in the spacecraft.
- General Electric's Jenbacher engines produces power for greenhouses, businesses, and homes using patented technologies. The same Jenbacher can run on a variety of gases, including natural gas but also gases from coal mines, sewage, and landfills. The Jenbacher was designed to harness these available resources that might otherwise be wasted.
- A power plant was emitting selenium, which is harmful if swallowed or breathed (waste). After the plant's engineers designed an expensive system for separating selenium, they realized something: ragweed and cattails absorb selenium. With nature as their teacher, they created a pond and populated it with ragweed and cattails; then they dumped the selenium into the pond, where the ragweed and cattails absorbed it and bound it to their tissues. After this, the plants were harvested and sold as fertilizer to cotton and tobacco farmers.

Functional Analysis

Scrutinize your system for innovation.

Functional Analysis is a process for assessing and improving system value—with a focus on retaining or increasing all useful functions, mitigating or eliminating all harmful functions, and improving inadequate functions. For example, a health care provider currently gives medicine to a patient at a clinic using a syringe-and-needle system; breaking these functions down into their parts (piston, cylinder, medicine, nurse, needle, patient) and functions (moves, guides, positions, penetrates) provides an opportunity to rethink and innovate the system.

Use Functional Analysis upstream in your ideation efforts to identify opportunities for improving the value quotient of your future solutions (see Technique 3). A simple Functional Analysis can be performed without the help of an engineer or expert. But for the details involved in complex systems, a value engineer or expert with experience is advisable if not necessary—especially when dovetailing this technique with such other formidable techniques as Axiomatic Design (Technique 31) and Function Structure (Technique 32).

Background

Every system is composed of hundreds if not thousands of interfacing elements. Changes in any one subsystem, component, or even a process parameter can reverberate and set off a chain reaction of positive and/or negative consequences throughout the system. Without a thorough understanding of how all of the causal linkages impact each other, it's likely that any change will create a number of unintended consequences.

The work and value of Functional Analysis revolves around an information-rich *function diagram* that shows all the causal linkages in a system and indicates whether they are desired, undesired, or insufficient. Once the function diagram is complete, the following advantages accrue:

- It's easier to clarify the functions of an existing or proposed system, which feeds directly into solution ideation and development.
- It's easier to figure out where available resources can be employed to improve a system or solve a problem (also using Resource Optimization, Technique 12).
- It's easier to pinpoint and eliminate any *physical or technical contradictions*. See Structured Abstraction (Technique 23) and Separation Principles (Technique 24) for more.
- It's easier to flag any unneeded elements, or functions through *trimming,* thereby reducing cost and moving the system closer to an ideal innovation.

> The formulation of a problem is far more often essential than its solution, which may be merely a matter of mathematical or experimental skill.
>
> —Albert Einstein

Steps

Scenario: Most people are familiar with the real-estate transaction system whereby two agents facilitate a number of functions, including property listing, advertising, showing properties, offer and counteroffer negotiation, contracting, home inspection, title insurance, closing and so on. How could this system become more value-oriented (innovative) and thereby increase desired outcomes and/or decrease undesired outcomes?

1. Gather Information and Define the Problem

Before creating a function diagram and performing a Functional Analysis, gather as much information about the system and problem as possible. The following questions can help:

- What is the primary useful function (the design intent) of the system, or the main job to be done (JTBD)?
- How do the elements of the system interact with each other?
- What resources are available to solve the problem?
- What constraints are there on the system? Are they necessary?
- What solutions have been attempted in the past and to what degree were they successful or not; if not successful, why not?

For our real estate example, we would like to complete the real estate transaction process more efficiently, especially pertaining to the services provided by agents working within a proprietary database (Multiple Listing System).

Use this technique to help assess system implications when applying Axiomatic Design (see Technique 31) to translate functional requirements into design parameters.

---

2. Develop a Functional Model of the System (Function Diagram)

What is a function? For our purposes, a function is defined as an activity, action, process, or condition that operates between two variables, one the input (independent) variable and the other the output (dependent) variable. In between the input and output is a *value transformation,* because the function creates a more valuable output using a less valuable input. By virtue of the function, value is added.

While many functions are desired, some are undesired—or costly or harmful. Further, all functions in a system are either sufficient or insufficient in performing their duties, or value transformations. As well, functions are performed by elements or entities that reside either inside the system or

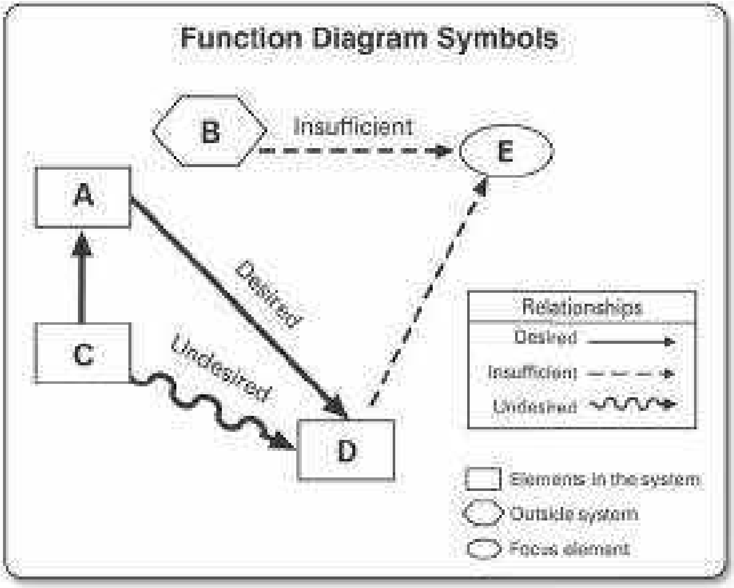

EXHIBIT 13.1

outside the system, yielding certain results. Exhibit 13.1 summarizes the basic symbols and architecture involved in creating a function diagram.

The goal of a function diagram is to depict all pertinent functions in the system in a cause-and-effect style (using Y = f(x) to guide your thinking). The key agents in the system, inputs (x) and outputs (Y), interact (f) to accomplish the system's objective.

Start by identifying the primary desired functions of the system, asking two questions with subsequent follow-on questions:

1. Does this function produce another function? If so, is the resulting function desired (and sufficient), undesired (harmful), or insufficient (needed but not good enough)?
2. Is this function produced by another function? If so, is the producing function's impact desired, undesired, or insufficient?

These control questions then serve as the guide for linking the functions with the desired, undesired, or insufficient arrows as illustrated in Exhibit 13.1.

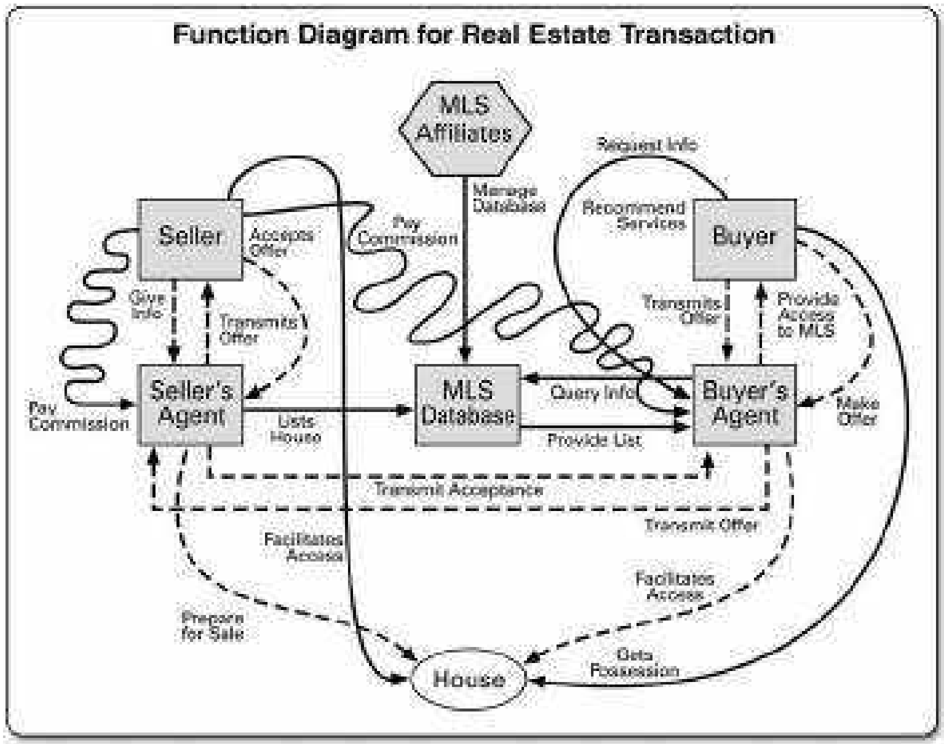

EXHIBIT 13.2

We've created a stylized, rough function diagram for the real-estate transaction process (Exhibit 13.2). The diagram identifies some functions but leaves others out, such as appraisal, title insurance, home inspection, contract preparation, advertising, county recording, securing a mortgage, obtaining mortgage insurance, obtaining homeowners insurance, and closing.

Looking at Exhibit 13.2, we see that some functions are desired, some are insufficient, and some are undesired. Real estate commissions, for example, are an undesired function because they do not represent the ideal innovation and because they add significant and unnecessary cost to the process.

3. Perform the Functional Analysis

Analyzing the model in a group setting is the best way to proceed with Functional Analysis. Essentially, the task is to review the function diagram and modify it in ways that will make the system more value-added. What desired functions can we increase? What undesired functions can we remove? What insufficient functions can be made sufficient? This requires exploratory use of any number of ideation techniques in this book.

Use a Cause & Effect Diagram (Technique 53) to document all the important causal relationships in the system. Then prioritize these relationships using a Cause & Effect Matrix (Technique 54). These then become the initial focus of an attempt to trim the system using a trimming worksheet.

One way to generate immediate ideas is to use a *trimming worksheet* (Exhibit 13.3). Populate the worksheet as shown:

- For all key functions, ask what the function is and identify its input and output.
- Indicate if the function is desired (and sufficient), undesired (harmful), or insufficient (needed but not good enough).
- Ask if the function is necessary. If so, then it becomes a candidate for trimming by asking two questions: Could Y do the function by itself—how? Could some other X or resource perform the function—how?

The trimming questions are very important because they facilitate reducing the complexity of the system through elimination of unnecessary elements. This reduces system cost and improves value.

If the function isn't necessary, then it becomes a candidate for elimination.

By trimming certain elements of the real-estate transaction system, we can envision a cleaner, simpler, and less expensive system, depicted in Exhibit 13.4. Of course, this innovated system is stylized and simplified; in reality, the Functional Analysis would be much more detailed, showing all aspects of the real estate transaction, not just the listing, negotiation, and other functions shown.

In this envisioned agent-less system, many resources could be available in the Central Listing Authority to sellers and buyers, not just information about and pictures/video tours of available properties. Attorneys, title

Functional Analysis and Trimming Worksheet
(Real estate transaction system)

State each function as "X does this to Y" (or input does this to Output)			Is function desired, undesired or insufficient?	Is function necessary?	Trimming Questions (to simplify the system or reduce cost)	
X	Does this to	Y			Could Y do it for itself?	Could some other X or resource do it?
Seller Agent	Enters data	MLS	Desired	yes	Possibly - using county records	Yes - Seller could enter into public Central Listing Authority, with controls
Buyer Agent	Shows house	Buyer	Desired	yes	Yes - buyer could show house	Yes - Buyer and seller can arrange showing
Buyer	Transfers offer	Buyer Agent	Insufficient	yes	No	Yes - Offers can exchange directly between seller-buyer, maybe with Internet
Buyer Agent	Transfers offer	Seller Agent	Insufficient	yes	Yes - could have only one agent involved	Yes - Offers can exchange directly between seller-buyer, maybe with Internet
Seller Agent	Transfers offer	Seller	Insufficient	yes	No	Yes - Offers can exchange directly between seller-buyer, maybe with Internet
Seller	Transfers counter	Seller Agent	Desired	yes	No	Yes - Offers can exchange directly between seller-buyer, maybe with Internet
Seller Agent	Transfers offer	Buyer Agent	Insufficient	yes	Yes - could have only one agent involved	Yes - Offers can exchange directly between seller-buyer, maybe with Internet
Buyer Agent	Transfers counter	Buyer	Insufficient	yes	Yes - buyer could get from Seller Agent	Yes - Offers can exchange directly between seller-buyer, maybe with Internet
Seller	Pays commission	Seller and Buyer Agents	Undesired	No	No	No comissions paid; only fees for advertising, contract, etc.

EXHIBIT 13.3

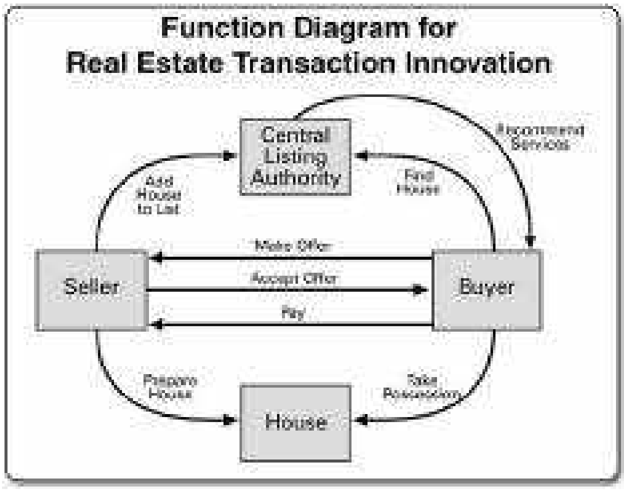

EXHIBIT 13.4

companies, appraisal companies, insurance companies, and lenders could advertise their services; at the same time they could provide information about how to accomplish related functions. For example, as a self-serve customer you could download an instruction set for doing a title search and for hiring a title company. Or, download a contract template that you can customize and use to exchange offers and counter-offers. Or even hire a home-based real estate specialist who can coach you through the process for a small fee.

Trend Prediction

Learn from evolution's genetic code.

Trend prediction is a powerful knowledge-based technique that extrapolates how current systems will evolve in the future. Using this extrapolation, you can plan your own innovations. For instance, all systems are trending toward *decreased human involvement*—robotic functions in factories, automated information systems, the need for only one human (the customer) to be involved in trading a stock or booking an airline ticket online.

To apply this technique, you'll need an extensive understanding of 35 universal technology trends, each of which progresses toward increasingly valued and ideal innovation. While the knowledge and time required to apply this technique is formidable, it reveals the trends that underlie all product and service innovations, thereby vaccinating against the tendency to innovate insufficient solutions, or to innovate a new product or service at the wrong time.

Background

There are many ways you can predict trends in an industry, and there are numerous trend gurus whose work could be helpful. We like the work of Genrich Altshuller, the founder of the Theory of Inventive Problem Solving (TRIZ), because it's one of the most empirical approaches. We also favor the work of U.K.-based author Darrell Mann, who has built on Altshuller's paradigm of *systematic innovation* to refine it for further use.

The basic idea behind trend prediction is that evolution is not random but follows certain patterns and stages that can be predicted. If you know what these patterns and stages are, then you can solve difficult innovation problems and define technology-related strategic opportunities.

The basis for applying trend prediction is to understand the concept of *S-curves* as they operate in time, one giving way to the next as the new eclipses the old. Each S-curve moves slowly from conception to birth, then rapidly from birth to maturity, then slowly again from maturity to retirement. After this, the system or solution of focus tends to taper off and decay in value (Exhibit 14.1).

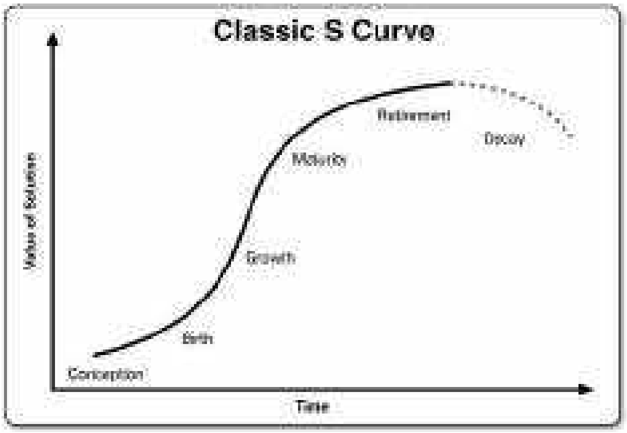

EXHIBIT 14.1

This retirement/decay inflection point is determined by the market force generated by a newly developing system or solution—one that is clearly fueled by a breakthrough technology, process, or business model (Exhibit 14.2). Note that the target, or expected outcome, is beyond what the current system can deliver, so an innovation is required.

> The legitimacy of trend prediction is derived from studying system dynamics contained in worldwide patent databases. When you understand the dynamics and principles involved in why and how systems, products, and services change over time, you have a secret weapon in ideating innovations.

There are thousands of examples of one S-curve eclipsing another. Employing new technologies along the way, we moved from the horse and buggy to the train to the car to the airplane to the rocket ship. We moved from writing on stone to writing on paper to large-scale printing to all forms of digital communication. From the macro systems level to the smallest micro level, the trajectory of S-curves tells the story of an evolving world.

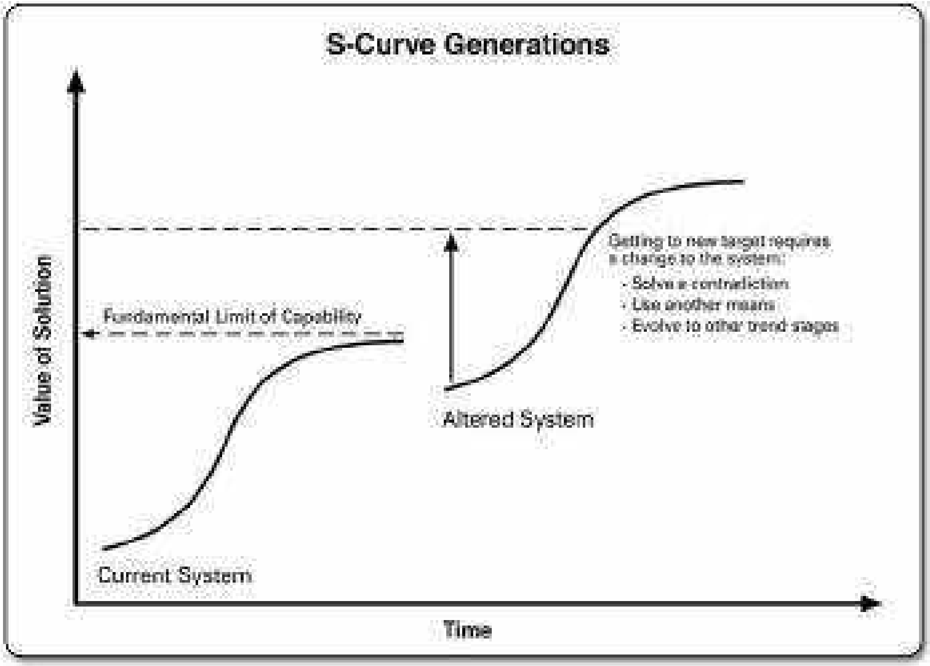

EXHIBIT 14.2

It's possible to examine a product, service, or system (solution) within the context of the 35 universal, generic evolutionary trends—call them the chromosomes of innovation. Such an examination enables you to gauge your idea-generation efforts against established and undeniable historical patterns. It also enables you to:

- Avoid costly innovation missteps and consistently provide a superior customer experience.
- Prevent new disruptive shifts in technology from blindsiding your organization.
- Determine when it's necessary to shift your product strategy to a new technology platform.
- Create critical patent umbrellas under which to protect yourself against competitive attacks on your company's intellectual property.

The 35 trends of trend prediction are classified into three main categories as shown in Exhibit 14.3. These are the signposts of innovation,

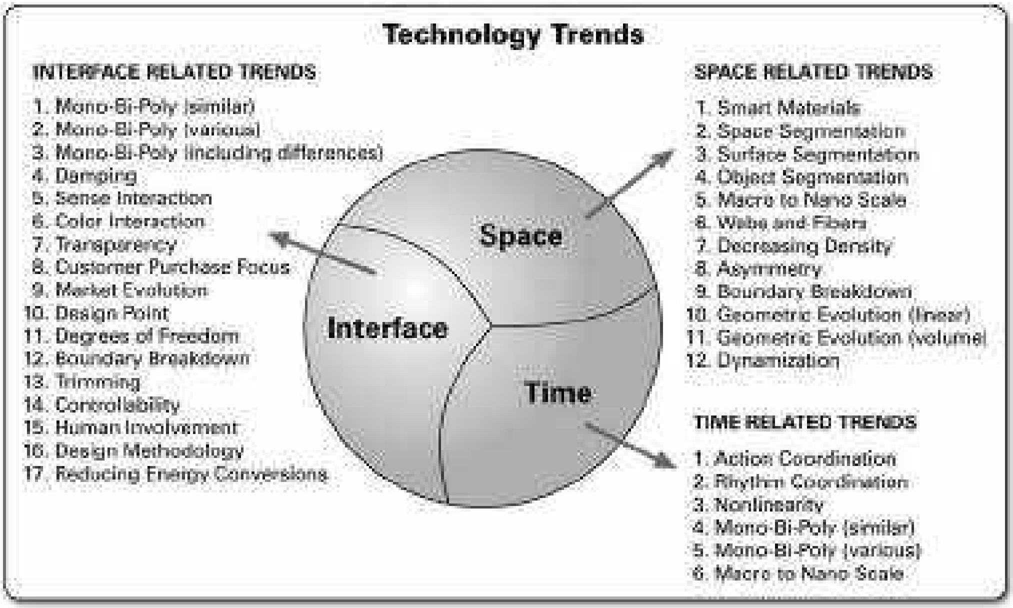

EXHIBIT 14.3

Source: Hands-On Systematic Innovation, by D. Mann, Clevedon, United Kingdom: IFR Press, 2007, www.systematic-innovation.com.

whether it involves pushing a solution along the continuum of a particular S curve (incremental innovation), or replacing one S curve with the next (breakthrough innovation).

If an organization can fix its position on the life cycle curve (S curve), and it has a sense of the slope of the curve, it has an excellent mechanism for determining where its technology is headed, and it can also determine the relative rapidity of that movement. Understanding this dynamic yields unique insights on how to direct product/service development and R&D processes, as well as how to proactively align core competencies with new technology imperatives.

In addition to *technology trends,* which operate at the product, service, and solution level, Altshuller, Mann, and others have also developed 36 *business trends*—but these still represent a relatively new body of research and are yet to be rigorously validated.

Steps

1. Become Familiar with Technology Trends

Once you understand each of the 35 technology trends, you are ready to examine any of your products, services, or solutions from the lens of these established evolutionary patterns. The key is to know that each trend progresses along a scale of evolutionary potential, from a less evolved state into a more evolved state. One space-related trend is *dynamization,* which says that over time a system, product, or part will evolve from a rigid state to a flexible one, moving through several stages as shown in Exhibit 14.4.

Another universal trend is the tendency for systems to evolve from the *macro* to the *nano* scale. We see this trend in action when looking at the first early computers, which weighed about 27 tons and contained 17,468 vacuum tubes, 70,000 resistors, 10,000 capacitors, and around 5 million hand-soldered joints. IBM's ENIAC computer measured 8.5 feet by 3 feet by 80 feet. By comparison, today's notebook computers are quite small.

For an in-depth description of each evolutionary trend with examples, read *Hands-On Systematic Innovation,* by D. Mann, Clevedon, United Kingdom: IFR Press, 2007, www.systematic-innovation.com.

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2. Determine Evolutionary Potential

You can use *radar charts* to set the stage for ideating better products and services. A radar chart is a visual way of depicting the state of a system,

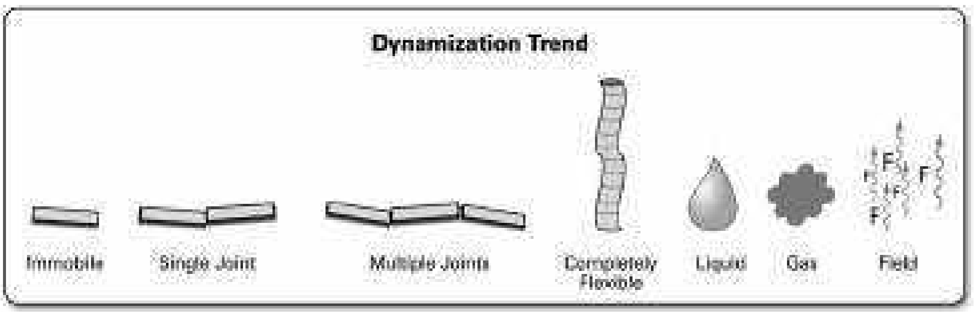

EXHIBIT 14.4

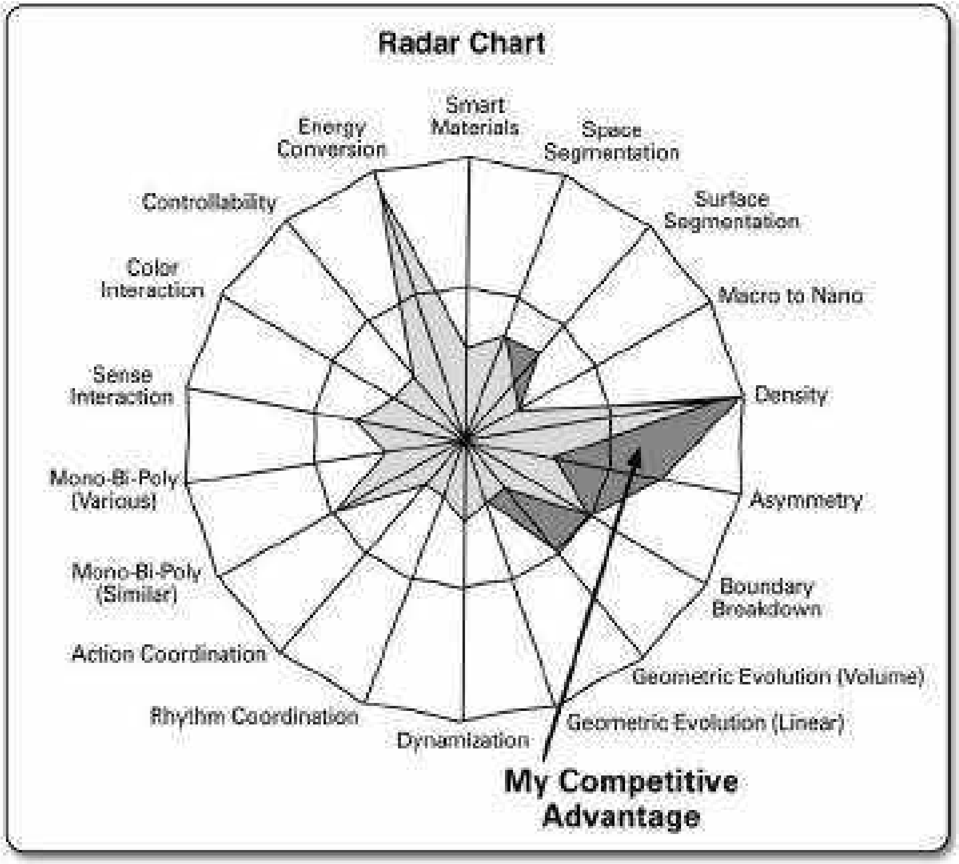

EXHIBIT 14.5

product, service, or solution relative to some other one, as shown in Exhibit 14.5. Note that we have constructed a sample radar chart using 18 of the 35 technology trends. Each spoke of the radar chart represents evolutionary movement along the S-curve at progressive stages starting from the center point. The darkly shaded area represents the evolutionary potential of a solution that extends the current competitive reality more toward the ideal innovation (for more on this concept, see Value Quotient, Technique 3).

Predicting such evolutionary developments entails many technical or scientific considerations, as well as considerations related to feasibility, cost, time to invent, and anticipated customer reaction. This is when other techniques such as Innovation Financial Management (Technique 11) and Outcome Expectations (Technique 2) come in handy.

3. Close Evolutionary Gaps

Although you can use trend prediction alone to carry an innovation idea through to a viable design, the difficult job of closing evolutionary gaps is made easier by using other ideation techniques in this book. This enables the innovator to make sure the very best ideas are surfaced and tested before spending time and resources developing new solutions.

Example

Scenario: An innovative pizza delivery chain has the job of keeping pizza hot during delivery. The task is to find the evolutionary trends that might apply to this challenge or problem. Then, ultimately, the pizza chain would want to design and implement a better solution, or better way of fulfilling this job and its related customer expectations.

After much research and scientific due diligence, the team converges on the trends of *surface segmentation* and *geometric evolution of linear constructions.* Both trends are shown in Exhibit 14.6, which depicts their progression through standard evolutionary stages.

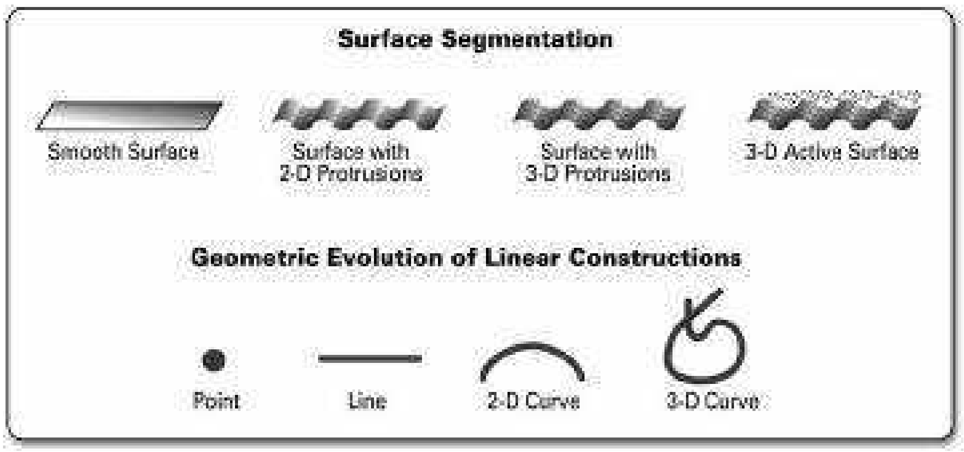

EXHIBIT 14.6

Using all pertinent evolutionary trends, the team prepares a radar chart to depict its planned innovation. In doing so, the team expects it can move up one notch on the evolutionary scale for each of the two identified trends. In the case of surface segmentation, the new design will move from a line to a two-dimensional curve. As for the geometric evolution of linear constructions trend, the team calculates that it can move from a surface with two-dimensional protrusions to one that displays three-dimensional protrusions.

These planned evolutionary steps are depicted in Exhibit 14.7 relative to the space occupied by existing solutions. The additionally shaded area shows the planned extent of evolutionary expansion.

Traditionally, the pizza oils soak into the box and tend to cool the pizza off and make it soggy. Looking at the two identified trends, the

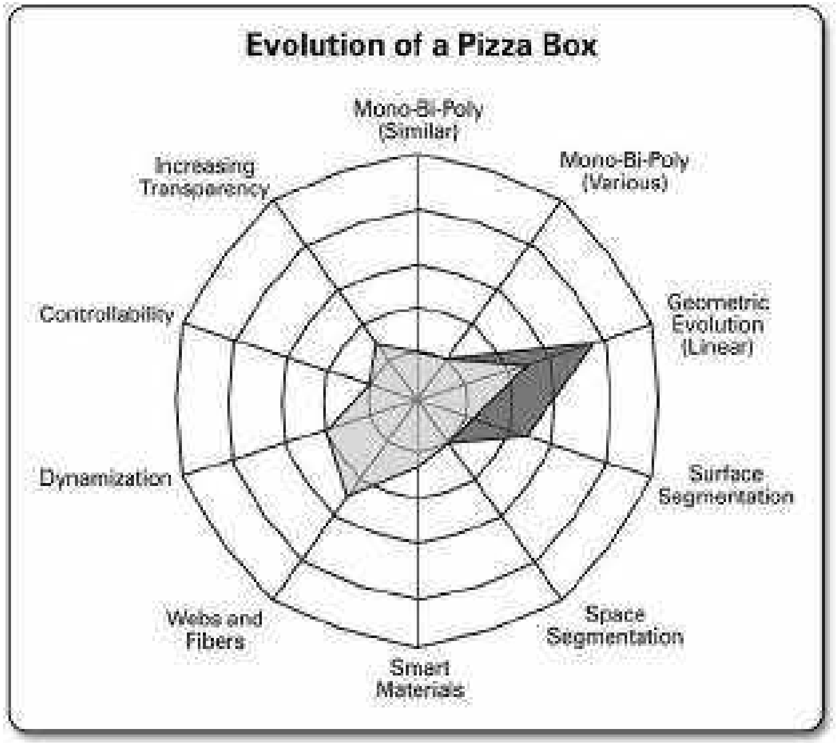

EXHIBIT 14.7

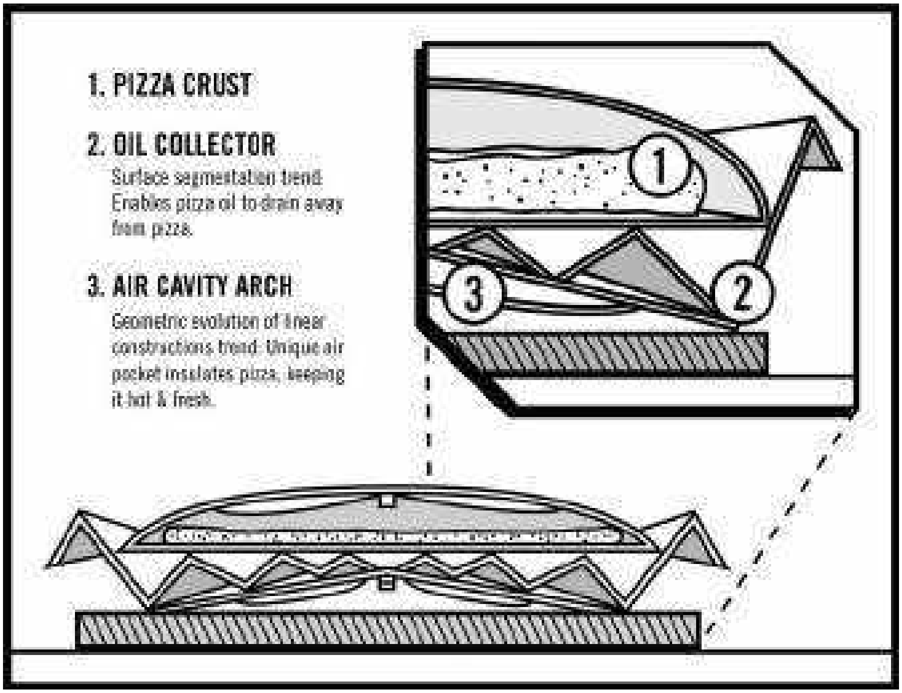

EXHIBIT 14.8

pizza-maker innovated a new, arched box bottom with air pockets. This created an insulation barrier and enabled oils to drain away from the pizza, thus meeting the expectation for "hot and crisp" better than any existing solution. Exhibit 14.8 shows the newly designed pizza box and its innovative elements.

Creative Challenge

Sacrifice the sacred cows.

The goal of Creative Challenge is to question the current solution for a particular focus area. If you think about it, the world is full of solutions that challenge the status quo. Electronic airline tickets are quickly replacing traditional paper tickets. E-mail and Internet marketing are threatening to usurp direct mail. Downloadable MP3s are making CDs unnecessary, just as CDs made cassettes and albums obsolete.

Creative Challenge helps you investigate the necessity, validity, and uniqueness of the current solution or approach. As such, this technique can be extremely helpful during the idea-generation phase of your innovation project—and can give you the impetus you need to discard your current solutions in favor of ones that are more ideal.

Background

Creative Challenge is not a rapid-fire brainstorming technique. Rather, it leverages a different approach called *E/R/A:*

- **E:** Can we *eliminate* some element of the current approach?
- **R:** What are the *reasons* for the current approach?
- **A:** Are there *alternatives* to the current approach?

Using E/R/A, you challenge the reigning beliefs, assumptions, and limitations relative to the status quo to create a list of innovative ideas that will increase your innovation's value quotient (see Technique 3).

You can follow-up Functional Analysis (Technique 13) with Creative Challenge to improve insufficient functions or eliminate undesirable ones.

Steps

Scenario: Credit cards are arguably easier to carry and safer to use than cash, but they can still be lost or used by unauthorized parties. As a result, credit card lenders have accumulated millions of dollars in fraudulent charges, and consumers are at great risk of identity theft. But what if credit card lenders challenged the status quo in search of a new, fraud-free method of payment? Let's see how Creative Challenge could help them accomplish this job.

1. Select a Focus Topic

This can be an innovation opportunity, product, service, system, process, or business model. It can be anything you want to change or challenge. For our example, the goal is to create a type of credit that is easy to use but virtually impossible for identity thieves to steal.

You can creatively challenge any part of a process or system. Some hotels, for instance, now ask guests to reuse their towels rather than replacing them every day. The hotels did not challenge the entire maid service, just the part that uses excessive water and energy.

---

2. Investigate Current Solution

Create a SIPOC and/or Process Map (see Techniques 45 and 46) to document the current solution's inputs, outputs, customers, and suppliers, and any associated processes. Use this information to make a list of the process steps, systems, subsystems, or components that are linked to the focus topic. For example, part of the process of using a credit card is carrying a physical card, which can be lost or stolen and subsequently used by identity thieves.

3. Identify Assumptions

Add to the list from step 2 all assumptions you take for granted about the current solution. Include factual data, physical characteristics, supporting ideas or philosophies, and limitations of the current solution. For the credit card example, some of our assumptions include:

- All credit cards are plastic, sized 85.60 × 53.98 mm, and have a magnetic strip or chip that holds data.
- Credit cards can be used in person, over the phone, or on the Internet to pay for goods and services.
- Consumers expect to have multiple credit cards, and to carry balances on more than one credit account.
- Extending credit must remain profitable for credit lenders.

Creative Challenge is never an attack or criticism, but a method that questions current thinking to discover new ideas and directions.

---

4. Apply E/R/A

Apply the E/R/A challenge process (Exhibit 15.1) to each item on the list:

- *Eliminate:* Challenge the necessity of each process step, element, or assumption. Is it still necessary, or can it be eliminated without incurring any negative side effects?

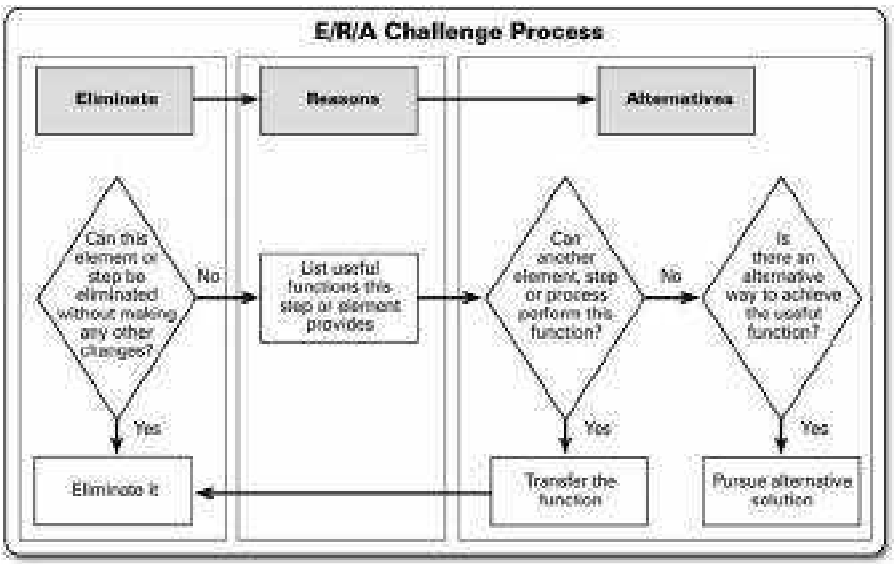

EXHIBIT 15.1

Creative Challenge Matrix			
Process Step, Element, or Assumption	**Eliminate** Can this item be easily eliminated without negative consequences?	**Reason** Why can't we eliminate this item? What is the function or feature it provides?	**Alternatives** Are there alternative ways to provide this function or feature?
Credit cards must be carried with you in order to make purchases in person.	NO	Credit card possession and signature on card and receipt used to verify authorized use.	Use retinal scan or fingerprint to verify identity and availability of funds in credit account.
Credit cards are plastic, sized 85.60 x 53.98 mm, and have a magnetic strip or chip that holds data.	NO	Industry standard.	RFID chip in keychain or other small device that securely carries credit account information.
Credit cards can be used in person, over the phone, or on the Internet to pay for goods/services.	NO	Easier to carry and use than alternative forms of payment (cash, checks).	
Consumers expect to have multiple credit cards and to carry balances on more than one credit account.	NO	Lenders only extend a certain amount of credit per person to spread default risk across multiple borrowers.	Assign everyone a single credit account at birth, funded jointly by multiple lenders.
Extending credit must remain profitable for lenders.	NO	It's a business.	

EXHIBIT 15.2 (Downloadable)

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- *Reason:* If the step, element, or assumption is necessary, what function or feature does it provide?
- *Alternatives:* Challenge the uniqueness of the solution. Is this the only way to provide the needed feature/functionality, or are there alternatives?

Use a Creative Challenge matrix (Exhibit 15.2) to track your ideas and decisions for each item.

> Never assume the current way is the only way. If you do, you'll never innovate a thing.

5. Compile Alternatives

After the E/R/A challenge process, make a list of the alternative ideas that you want to investigate further.

HIT Matrix

Compare existing solutions to spark new breakthroughs.

A HIT Matrix compares the characteristics of two seemingly unrelated products or services to develop new ideas. What do you get when you combine the characteristics of a telephone and a computer? The Internet.

HIT, short for Heuristic Ideation Technique, was developed by marketing professor Edward M. Tauber, who found that *new* products are typically a combination of characteristics from two or more *existing* products. HIT Matrix is a simple but beneficial tool to jumpstart your team's creativity in search of innovative ideas.

Steps

Scenario: In the very competitive travel industry, most businesses target a high volume of low-paying customers through cheap, no-frills service. However, Innovative Railways hopes to catch the attention of fewer, high-paying customers by offering a luxury experience for mid-distance business travelers. A HIT Matrix will help Innovative Railways develop ideas for an innovative solution that fulfills customer expectations.

1. Select Existing Items

Choose two products, services, or brands that seem to have no apparent connection and are not already overtly combined. These could be offerings from your company, or from a competitor or another industry. Avoid items that are too close in meaning; coffee cup and drinking glass will produce fewer innovation ideas than drinking glass and bicycle (think Camelbak). The Innovative Railways team chose *luxury conference services* and *international first class travel.*

The opposite of heuristic ideation is *backward ideation,* which looks at the characteristics of *unsuccessful* products and brands to generate new ideas and solutions. For more information, see "Backward Ideation Technique for Generating New Product Ideas," by O. A. Mascarenhas, *Vikalpa,* 8, no. 2 (1983), www.vikalpa.com/pdf/articles/1983/1983_jan_mar_95_113.pdf.

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2. List Characteristics

Brainstorm a list of characteristics related to the two items you selected in step 1. Ask yourself what the features or components are that make up the item. Also how, when and why is the item used? Generate the same number of characteristics for each item (typically 5 to 7 per item). If you have too many characteristics, use a Pugh Matrix (Technique 36) to narrow down the list.

Don't get too granular in your thinking. For example, if you're listing the features of a first class airplane seat, some characteristics might be *ample leg room* or *reclines to a bed.* This leaves more opportunity for creativity than specifying that the seat has 10 inches more leg room than a coach class seat, or that the seat reclines to a 160 degree angle.

You don't have to be an expert on the items you select. However, it is important to understand the customer expectations associated with each item. For more information, see Outcome Expectations (Technique 2).

---

3. Populate HIT Matrix

In a HIT Matrix (Exhibit 16.1), list the characteristics from one item across the top, and the characteristics from the other item down the side. Then, pair one characteristic from each item until all cells are filled.

HIT Matrix		Luxury Conference Accommodations				
		Wireless Access	Spa Services	Personal Chef	Dedicated Concierge	Executive Lounge
Int'l. First Class Travel	Reclining Seats	Wireless Access Reclining Seats	Spa Services Reclining Seats	Personal Chef Reclining Seats	Dedicated Concierge Reclining Seats	Executive Lounge Reclining Seats
	In-seat Chargers	Wireless Access In-seat Chargers	Spa Services In-seat Chargers	Personal Chef In-seat Chargers	Dedicated Concierge In-seat Chargers	Executive Lounge In-seat Chargers
	Gourmet Meals	Wireless Access Gourmet Meals	Spa Services Gourmet Meals	Personal Chef Gourmet Meals	Dedicated Concierge Gourmet Meals	Executive Lounge Gourmet Meals
	Personal Attention	Wireless Access Personal Attention	Spa Services Personal Attention	Personal Chef Personal Attention	Dedicated Concierge Personal Attention	Executive Lounge Personal Attention
	Expedited Service	Wireless Access Expedited Service	Spa Services Expedited Service	Personal Chef Expedited Service	Dedicated Concierge Expedited Service	Executive Lounge Expedited Service

EXHIBIT 16.1 (Downloadable)

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4. Qualify Ideas

Review each cell in the matrix and discuss the merits of joining the two characteristics. Eliminate cells that contain existing ideas or don't make sense (such as *spa services* and *in-seat chargers*). However, don't immediately discard ideas because they contain technical or physical contradictions; you may be able to get past the contradictions using Structured Abstraction (Technique 23) or Separation Principles (Technique 24).

5. Select Ideas

Identify all the paired characteristics that could become a potential solution. For instance, *personal chef* and *gourmet food* has potential, as does *dedicated concierge* and *personal attention.* Also look for ideas that combine more than one characteristic, such as *executive lounge, wireless access, in-seat chargers,* and *personal attention.* Make a list of ideas for further exploration.

SCAMPER

Ask eight important questions.

The SCAMPER technique uses a set of directed questions to help you evolve your existing product, service, or solution into one that is superior (more ideal). For example, SCAMPER led to the combining of two shaving solution elements—the razor and the shaving cream—into a razor that holds cream in its handle and dispenses it as a person shaves. SCAMPER is most powerful when you have an idea or set of ideas, and you need to make them even better. It is especially helpful in mature markets where there are many competing solutions.

The SCAMPER acronym stands for:

- **S**ubstitute
- **C**ombine
- **A**dapt
- **M**odify/Mirror/Distort
- **P**ut to other purposes
- **E**liminate
- **R**earrange/Reverse

Steps

Scenario: A team was tasked with innovating the sales approach in an organization with 50 locations, keeping each abreast of the company's latest products, technologies, policies, and procedures. The existing approach was to perform on-site training at each location once a quarter using several trainers. The team used the SCAMPER technique to generate ideas for improving the knowledge-transfer process.

1. Define the Job To Be Done

Before you use this tool, it's best to make sure you have clarity on how the current process or product is used to achieve the job to be done (JTBD). Articulate the JTBD and the current approach for delivering its solution. Remind the team to stay focused on the JTBD, so that innovative solutions (with higher value quotients) can be generated, not just incremental improvements to current solutions. (For more information, see Jobs To Be Done, Technique 1.)

> Another variation of SCAMPER is SCAMMPERR (the double M to indicate Magnify and Minify and the double R to indicate Reverse and Rearrange).

2. Apply SCAMPER

As a group, discuss the SCAMPER questions one at a time, and list the team's ideas. Keep these tips in mind:

- Involve team members by using the simple rule of one idea per person per question.
- Use the questions as a trigger to generate ideas and don't get bogged down in answering each question. No one should criticize ideas or evaluate ideas during the exercise.
- It's not important that the ideas are associated directly with the question that originated the idea.
- Ideas may be repeated if they fit with several questions.

Exhibit 17.1 shows the ideas the team came up with for improving the sales training process.

SCAMPER
Guidelines & Example (Innovate the sales approach)

S	**Substitute**	Think about substituting part of your product/service or process for something else. By looking for something to substitute, you can often come up with new ideas. **Typical questions:** What can I substitute to make an improvement? What if I swap this for that, and see what happens? How can I substitute the place, time, materials, or people? **Example:** Online training, Chat sessions with the trainer, Conferences (video, audio), Computer-based training, Library (eLibrary, physical library), Self Study by employee, On-the-job training, Recorded classroom (available 24X7, divided in slots), Anyone can attend any module twice, Group discussion, Mail based training.
C	**Combine**	Think about combining two or more parts of your problem to create a different product/process or to enhance synergy. **Typical questions:** What materials, features, processes, people, products, or components can I combine? Where can I build synergy? **Example:** Combine classroom training with On-the-job training, Library studies and trainer/conferences, Self study and online trainer/conferences, Combine locations (Reduce number of locations), Combine induction and training wherever possible, Combine work with training, Mix people (trained and untrained) then trained people will train untrained people
A	**Adapt**	Think about which parts of the product/service or process could be adapted to remove the problem, or think how you could change the nature of the product/process. **Typical questions:** What part of the product could I change? And in exchange for what? What if I were to change the characteristics of a component? **Example:** Notes exchange between participants, Convert training material to drawings/flip charts, Mix people (trained and untrained) - then trained people will train untrained people, Video of one-training/one-trainer then replicate and distribute (reuse).
M	**Modify**	Think about changing part or all of the current solution to distort it in an unusual way. By forcing yourself to come up with new ways of working, you are often prompted into an alternative product, service, or process. **Typical questions:** What happens if I warp or exaggerate a feature or component? What will happen if I modify the process in some way? **Example:** Change training delivery media, Classroom to computer-based training, Classroom to audio/video training, On-the-Job Training, Change mode of training, Paper/pencil to Web-based learning, Classroom to audio/video training, Reduce locations of training, Increase batch size, Intensive training, Anytime training.
P	**Put to other purposes**	Think of how you might be able to put your current solution to other purposes, or think of what you could reuse from somewhere to solve your innovation problem. You might think of another way to meet your Job To Be Done or find another market for your product. **Typical questions:** What other market could I use this product in? Who or what else might be able to use it? **Example:** Use training material as reference in library, Training in auditorium, Training in movie/drama format, Training in game/puzzle format, Part training to set of people - then each set becomes internal trainer for the part it learned and trains others.
E	**Eliminate**	Think of what might happen if you eliminated various parts of the product/process/problem, and consider what you might do in that situation. This often leads you to consider different ways of tackling the problem. **Typical questions:** What would happen if I removed a component or part of it? How else would I achieve the solution without the normal way of doing it? **Example:** No classroom, Training without classroom, No trainer, Virtual trainer, Eliminate time constraint, Anytime training, Video of one-training/one-trainer reuse - replicate the same.
R	**Reverse**	Think of what you would do if part of your problem/product/process worked in reverse or was done in a different order. What would you do if you had to do it in reverse? **Typical questions:** What if I did it the other way around? What if I reverse the order it is done or the way it is used? How would I achieve the opposite effect? **Example:** Learner is trainer, Create trainer, Create library, Prepare training and trainer in-house.

EXHIBIT 17.1 (Downloadable)

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3. Review Ideas

Once the team has completed ideating after all the questions, review the list for duplications. Combine similar ideas, but don't discard any at this point. You can use a technique such as KJ Method (Technique 27) or Idea Harvesting and Treatment (Technique 28) to evaluate the feasibility of each idea.

Resource

Michalko, M. *Thinkertoys: A Handbook on Creative-Thinking Techniques*. 2nd ed. Berkeley, CA: Ten Speed Press, 2006.

Brainwriting 6-3-5

Encourage equal opportunity ideation.

Brainwriting 6-3-5 is a modified form of classic brainstorming that encourages equal participation from all team members using written rather than verbal idea generation. For instance, if half of your team wants to launch a new product line and the other half is resistant, Brainwriting 6-3-5 would give team members a chance to express their ideas without commentary or criticism.

This technique is particularly helpful when the group is in danger of domination by certain participants, or when team members may hold back because of the group makeup. However, if you're looking for more outside-the-box ideas, other ideation techniques may be more powerful, such as Provocation and Movement (Technique 22) or Creative Challenge (Technique 15).

The name "Brainwriting 6-3-5" comes from the practice of *six* people writing down *three* ideas in *five* minutes. In reality, the tool works fine with a slightly larger or smaller number of people.

Steps

Scenario: Say you have a web site where customers can register for your company's online training courses. One problem you've noted is that 35 percent of the people who begin the registration process fail to complete it before leaving the site. Your team can use Brainwriting 6-3-5 to list possible reasons for this behavior, and discover ideas to alleviate it.

1. Choose Participants

If you have more than eight people, split them into equally divided groups. If you have less than four participants, use a different idea-generation approach such as Imaginary Brainstorming (Technique 19) or Random Stimulus (Technique 21). Either way, select a mixed team that includes people who are familiar with the issue at hand as well as outsiders who can promote a new perspective.

> If there are tensions within the group you can use Brainwriting 6-3-5 to diffuse the emotional situation and encourage participation.

2. Generate Ideas—Round 1

Distribute a Brainwriting 6-3-5 worksheet (see Exhibit 18.1) to each participant. In the first row of the worksheet, participants should write three potential ideas that might fulfill the JTBD (for more on this topic, see Jobs To Be Done, Technique 1). Each person takes five minutes to write their ideas in silence (although it may take less time during the first few rounds). Remind team members to write legibly so that others can read their contributions.

> Remember that Brainwriting is conducted in silence, so no talking is allowed until all ideas have been recorded. This allows participants to interpret other ideas solely from what is recorded on the worksheet.

3. Generate Ideas—Round 2

When everyone completes three ideas, the worksheets are passed to the next person who can add three new ideas or build on the ideas listed. Either way, new responses should be written in the second row. Again, the allotted time is five minutes.

Brainwriting 6-3-5	Job To Be Done: Reduce number of booking transactions not completed on our web site	Date: 30-Oct-07 Team: 1 Member: Elizabeth
1	2	3
Provide login before starting the process so customer can restart at the appropriate point.	Provide paper catalog with quick codes to identify course and use with client profile to make booking.	Send automated e-mail to find out why transaction wasn't completed and offer help.
Store user details locally so the system recognizes them.	Make web site search function more accurate and user friendly.	Follow up with phone call on incomplete transactions.
Allow multiple customers to book the same course with minimum effort.	Allow customers to amend their course selection details rather than having to start again.	Provide a way to hold course bookings for 24 hours until payment is made.
Reduce the number of fields customers must complete.	Make web site easier to use.	Provide customers with incentives (bonus materials or special pricing).
Allow customers to book multiple courses during the same transaction.	Simplify online ordering process.	Give discounts for bookings completed with a single transaction.
Provide user with booking history and list of incomplete transactions when they login.	Add a pop-up window to alert users that they are closing the browser without completing the transaction.	Recommend courses based on the user profile.

EXHIBIT 18.1 (Downloadable)

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Instead of passing the sheets in a circle, participants can put completed sheets in the center of the table, and team members can pull from the center stack at their own pace.

4. Continue Idea Generation

Repeat the idea generation cycle until every participant has written three ideas on every worksheet. If your team has six people, you should have generated 108 ideas. You can take time now to discuss, clarify, refine, and combine similar ideas, then make a list of ideas for further analysis.

Imaginary Brainstorming

Get silly for the sake of creativity.

Imaginary Brainstorming helps distance you from practicalities that may be hindering your creativity. Say you are trying to *gain market share in Southeast Asia.* With Imaginary Brainstorming, you could replace "market share" with "exotic animals" and concentrate instead on *gaining exotic animals in Southeast Asia.* After brainstorming solutions for this imaginary scenario, you would come full circle and retrofit the resulting ideas to the original problem.

When you're struggling to develop innovative ideas around a particular area, Imaginary Brainstorming encourages a fun atmosphere where wild and crazy ideas can be put forward, and people can participate without intimately understanding the technicalities of the problem.

If you conduct classic brainstorming before Imaginary Brainstorming, you'll identify the most obvious and common ideas. Then you can encourage the team to go beyond these ideas during Imaginary Brainstorming.

Steps

Scenario: Pretend you're a professor in the history department of a local college. You and your colleagues are having difficulty getting students to submit their assignments on time. It's a topic at every weekly meeting, where the same ideas come up but never seem to work. Let's see how Imaginary Brainstorming can help your group generate new ideas for solving this dilemma.

1. Identify Real Problem Elements

Review the problem, or job to be done (see Technique 1), and identify the following key elements:

- What is happening? [action]
- Who or what is the recipient of the action? [object]
- Where is the action occurring/what is the scope? [context]
- Who is performing the action? [subject]

Looking at our history department example (persuade students to submit assignments on time), we can identify an action (persuade), an object (students) and a context (submit assignments on time). The subject (professors) is implied. Document your answers on an Imaginary Brainstorming worksheet (Exhibit 19.1).

2. Brainstorm Imaginary Elements

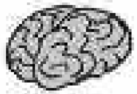
For each real element you identified in step 1, generate a few imaginary replacements. For instance, we could replace *students* with *gorillas, cyclists,* or *aliens. Submit assignments on time* could become *take out the trash* or *wash behind their ears.*

> Classic brainstorming typically uncovers ideas near the surface of our consciousness. Imaginary Brainstorming digs deeper by leveraging make-believe situations to trigger subconscious creativity.

3. Create an Imaginary Problem Statement

Choose the *one* element you're having the most difficulty with and replace it to create an imaginary statement. In our example, we could replace *submit assignments on time* with an imaginary element and the problem becomes *get students to* ***wash behind their ears*** *on time.*

> Only replace one element at a time so you can more readily translate your ideas back to the original problem statement.



Imaginary Brainstorming

1. Real JTBD				
Persuade students to submit assignments on time				
2. Real Problem Elements			**5. Imaginary Problem Ideas**	**6. Application to Real Problem**
ACTION	What is happening?	Persuade	Have a public ear inspection	• Call out students by name to hand over assignments in front of class
OBJECT	Who or what is the recipient of the action?	Students	Each student checks another students' ears for cleanliness	• Get students to complete assignments in groups • Have students "grade" each other's work
CONTEXT	Where is the action occurring & what is the scope?	Submit assignments on time	Provide attractive soap	• Start an assignments after school group in the school cafe with free refreshments • Reduce number of assignments
SUBJECT	Who is performing the action?	Professors	Have a clean ear competition	• Feature the best work in the school magazine • Have competitions aligned with specific assignments • Replace assignments with exams
3. Imaginary Elements			Provde awards to students who wash their ears regularly	• Give extra credit for work submitted on time
ACTION	What is happening?	Entertain, bribe, prevent	Show pictures of extremely dirty ears	• Explain to students the consequences of not completing work (fail course, name posted on poor performing list in main hall)
OBJECT	Who or what is the recipient of the action?	Gorillas, cyclists, aliens	Provide synthetic examples of the smell and texture of dirty ears	•Invite speakers who can show the value of a college education
CONTEXT	Where is the action occurring & what is the scope?	Take out the trash, wash behind their ears		
SUBJECT	Who is performing the action?	Singers, cats, soccer players		
4. Imaginary JTBD				
Persuade students to *wash behind their ears* on time				

EXHIBIT 19.1 (Downloadable)

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4. Solve the Imaginary Problem

Now brainstorm ways to solve the imaginary problem. For instance, if dirty ears were really an issue on campus you could *hold public ear inspections, provide scented soap in the bathrooms,* or *give awards to students with the cleanest ears.*

5. Apply Imaginary Ideas to the Real Problem

When you've thought of as many ideas as you can, try to relate each idea back to the original problem. It may help to sort your ideas into three categories:

1. Ideas that can be applied directly to the original problem without making any changes.
2. Ideas that need to be modified or altered before they are applied to the original problem.
3. Ideas that cannot be used or modified but may contain an element that could spark a new idea. Spend a few minutes on every idea no matter how unlikely it may seem.

If you don't end up with enough viable ideas, create another imaginary statement by replacing a different element and go through the steps again. Or try another idea generation approach such as Creative Challenge (Technique 15) or Random Stimulus (Technique 21).

Concept Tree

Leverage current ideas to generate many ideas.

Concept Tree starts with an idea and uses that idea to identify concepts, or connecting points, from which alternative ideas can be derived. For example, a perfume designer could explore the concept behind a new fragrance idea and subsequently create a way to naturally enhance a person's pheromones.

By using an existing idea as a source of inspiration for untapped ideas, Concept Tree can lead you to a unique approach to an old problem. It's also valuable if your original idea is too general, has too many limitations, or is not actionable.

Some call this technique a Concept Fan, or Concept Abstraction and Alternatives. For more information, see "Generation of Alternatives" in *Lateral Thinking: Creativity Step by Step,* by E. de Bono, New York: Harper Paperbacks, 1973.

Steps

Scenario: Let's say we want to improve our company's image. We have a few broad ideas along these lines, but we can use the Concept Tree technique to generate many actionable ideas.

1. Agree on the Job To Be Done

On a white board or flip chart, write the JTBD (see Jobs to Be Done, Technique 1). In our example, we are tasked with the rather broad job of improving the company's image. We could use Job Scoping (Technique 7) or Nine Windows (Technique 6) to better define this job, but since we have a few general ideas for meeting this JTBD, let's see where Concept Tree takes us.

2. List Ideas

Next list your ideas for fulfilling the JTBD. So far in our example we have: *reduce environmental impact, give back to the community,* and *launch a PR campaign* (Exhibit 20.1).

> Although the terms *idea* and *concept* are often used interchangeably, in the context of this technique they have different meanings. Concepts represent a general way of achieving your goal, while ideas are more specific and actionable.

3. Generate Concepts

For each original idea, brainstorm related but nonspecific concepts. Make sure that none of the concepts is the same as the original idea. For instance, if you're trying to *reduce environmental impact,* someone may suggest the concept of *going green,* which is really just another way of restating this idea.

4. Generate Alternative Ideas

For each concept you brainstormed, list new ideas that come to mind. This can be done in typical brainstorming fashion, but each idea must be related to a concept. If you need to add more concepts, do so. These, in turn, may generate new ideas.

> Concepts are the connecting points between your original idea and the alternative ideas that the Concept Tree helps you generate.

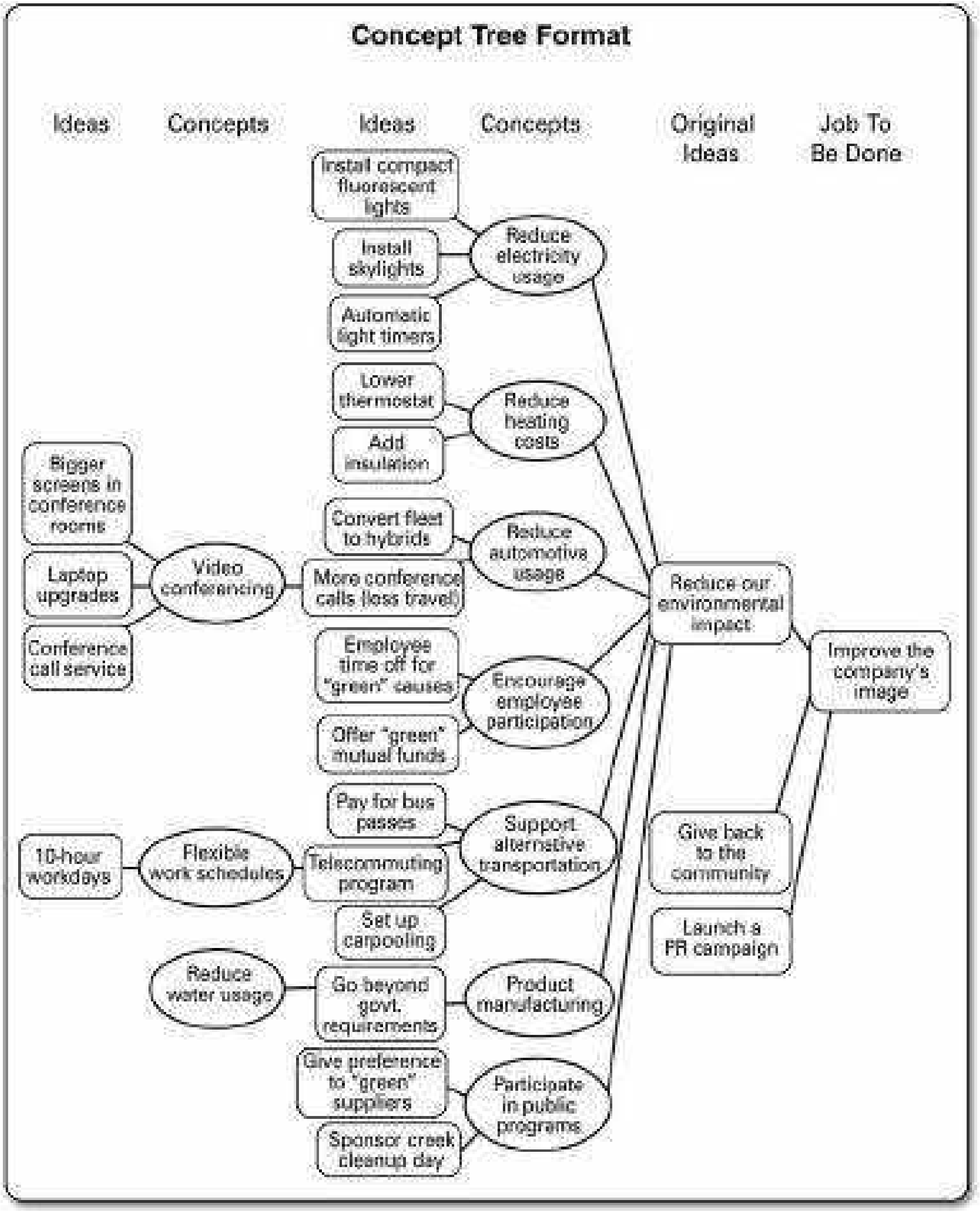

EXHIBIT 20.1 In this example, we started with three general ideas for *improving the company's image*. Using Concept Tree for only one of these ideas (*reduce environmental impact*), we generated 19 ideas that are more specific and actionable than our original ideas.

5. Keep Going

Repeat steps 3 and 4 until the team runs out of concepts and ideas. If you started with more than one original idea (as in this example), don't forget to apply Concept Tree to your other ideas. When you're finished, you should have a long list of ideas you can organize using a technique like KJ Method (Technique 27) or Idea Harvesting and Treatment (Technique 28).

Random Stimulus

Use an unrelated picture or word to spawn new ideas.

During Random Stimulus, participants use free association in connection with an arbitrary word or image to generate new ideas. For example, looking at a picture of a racecar could bring to mind a race track, which in turn could help you think of a new way to desalinate water.

Techniques like Random Stimulus initially might seem too disconnected in the way they lead to new ideas, but this disconnection from one's mental inertia is exactly what is needed. Humans naturally establish logic patterns as they process information over time, so creative thinking actually becomes unnatural. The only way to spark it is to move away from these patterns, and using Random Stimulus is one way to do that.

A *random stimulus* can be any kind of signal—a word or image, even a sound or smell—that forces you to move your thoughts to a new place outside of your current focus and associations.

Steps

Scenario: Fueled by an expanding population of recreational runners, manufacturers and retailers in the running equipment and apparel industry have introduced many innovative solutions aimed at both short- and long-distance runners. Let's see how Random Stimulus could help a company in this realm generate new ideas.

1. Identify Job To Be Done and Outcome Expectations

As a group, agree on the JTBD (see Jobs To Be Done, Technique 1) and any associated outcome expectations (see Technique 2). For instance, if you were trying to better serve recreational runners, one job could be to *increase running speed during training*. For this job, the desired customer expectations for the solution might include: *relatively low cost, easy to use,* and *lightweight or portable;* undesired customer expectations might include *harmful side effects* and *interference with other running equipment*. These outcomes set the boundaries for the Random Stimulus idea-generation session.

You can use the Random Stimulus technique to generate solution ideas for a JTBD, or even for an outcome expectation (see Exhibit 21.3 for an example of the latter).

---

2. Select Random Stimulus

Choose a random word or image that is not directly related to the JTBD. If you select a *word,* choose a noun using one of these common methods:

- Use a dictionary or thesaurus and randomly choose a page number and entry number (e.g., page 169 and entry 10, which would become your random word.) Or, use a magazine or newspaper, randomly choosing a page number, paragraph, and word number.

EXHIBIT 21.1

- Refer to a random word list (Exhibit 21.1), choose a number and then count down to that word on the list.
- You can also use random word generating software, such as the one at www. randomwordgenerator.com/websoftware.html.

Use the list of 150 words in Exhibit 21.1 to spawn new and great ideas. But don't just pick your favorite word or image—randomness is key. The further the random stimulus is from the JTBD, the higher the chance of generating outside-the-box ideas.

If you want to use an *image,* choose one that clearly conveys an action and inspires positive emotions. Also remember the following tips:

- Use real photos, preferably in color; color brings more emotions to mind. Don't use clip art or cartoons. These are already characterizations and, thus, may limit free association creativity.
- Avoid content that may be controversial, offensive, or depressing (e.g., pictures of war, nudity, funerals). Don't use embarrassing pictures of the participants.
- Good sources of photos are magazines and books on travel, movies, sports, current events, and nature.

For an automated random picture generator, visit www.brainstorming.co.uk/onlinetools/randompicture.html.

3. Brainstorm Associations

When you've chosen a random word or image, ask the team what associations the random stimulus brings to mind. For example, the random word *ingredient* might be associated with *recipe, food,* or *list*. Record each association on a separate line radiating from the random word or image (Exhibit 21.2). Welcome every answer without judgment and without stopping to explore the idea further.

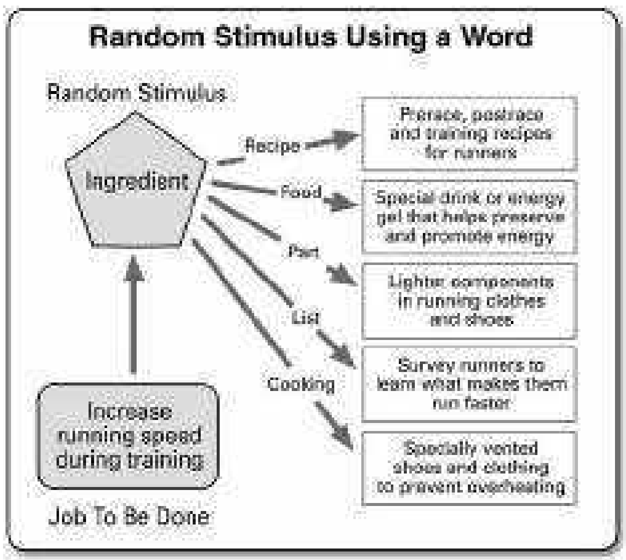

EXHIBIT 21.2

If you're using an image, ask participants what they see happening in the picture, as well as who, when, where, why, and how.

4. Generate Ideas

Discuss each association to determine how it could be realized as a tangible idea related to the JTBD (keeping the associated outcome expectations in mind). For instance, the association *recipe* might lead to the idea of new components in running shoes; *list* might result in the notion of surveying recreational or professional runners to see what they do to run faster. It may seem difficult at first to see any connection between the association and the JTBD. The trick is to keep trying. In most cases someone will start the associations rolling. If not, choose another random stimulus and try again.

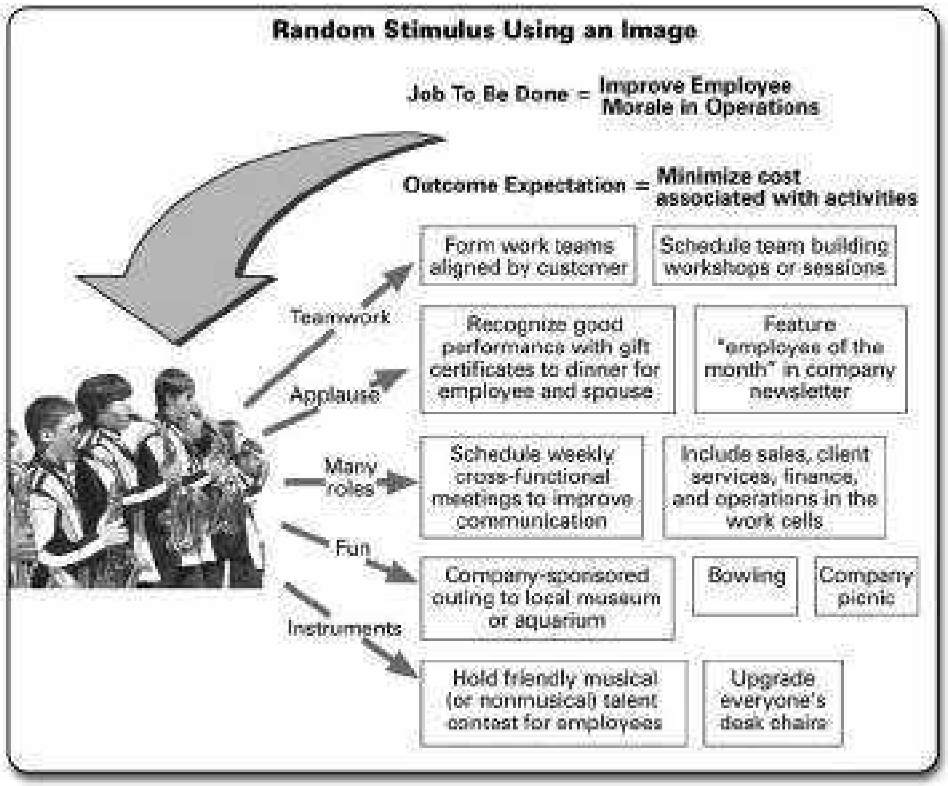

EXHIBIT 21.3

5. Review Ideas

When you're finished generating ideas, review the list. If you need additional ideas, repeat the steps with a different random stimulus. Or, try another idea generation technique such as Provocation and Movement (Technique 22).

Exhibit 21.3 shows another example of Random Stimulus using an image to generate new ideas for *minimize cost associated with activities,* which is an outcome expectation for the JTBD of *improve employee morale in operations*.

Provocation and Movement

Step over the roadblocks in your thinking.

The overall idea of Provocation and Movement is to create a shocking statement that is strong enough to move people out of their *psychological inertia*—their tendency to think the way they've always thought. For example, "We need customers to generate revenue" is a statement one might take for granted. However, if we said, "We *don't* need customers to generate revenue," this provocation would certainly generate discussion that would point us in a different direction and generate new ideas.

As such, Provocation and Movement is one of the best tools for generating outside-the-box ideas—*if* you're open to questioning the status quo, imagining "what if," and shocking yourself into a new reality.

Often frustration is the initial force that creates a provocation and spurs movement toward a better product, service, or solution. The Diner's Club card, precursor to all credit cards, was born out of the frustration of always having to pay for a meal with cash.

Steps

Scenario: The Private Pools company designs and builds Olympic-sized swimming pools for homeowners. Recently, the company has watched its profits plummet, thanks in part to an economic downturn in the housing market. A cross-functional team hopes to use Provocation and Movement to discover an innovative way to expand the company's market share.

The goal of Provocation and Movement is to improve the satisfaction level of an outcome, or generate a solution that allows you to better fulfill a job to be done.

1. Select a Focus

Choose a focus topic—a product, service, process, or business model for which you need ideas. Make a list of the current features, characteristics, and aspects of the focus topic. To create the list, you can use brainstorming, or an approach like Creative Challenge (Technique 15).

If at first the idea is not absurd, then there is no hope for it.

—Albert Einstein

2. Create Reality Statement

Choose one item from the list of features and craft a statement that represents the current reality. Often, this statement reflects a poorly satisfied customer expectation, or a job the solution has trouble fulfilling. Or it could be something taken for granted or rarely questioned. The Private Pools team, for example, chose the statement: *private swimming pools require a large outdoor area.* Bypassing this traditional notion could extend the reach of the company's product to people who don't have large backyards, or who live in a climate with cold winters.

Provocation is the stepping stone that allows you to carve out useful ideas from illogical thoughts, while keeping an eye on your innovation's value quotient (see Technique 3 for more on this concept).

3. Develop Provocation

Based on the current reality statement, generate several Provocative Thought (PT) statements that depart from the current reality in an unusual, fanciful, absurd, or otherwise illogical manner (Exhibit 22.1). Just remember to take

Provocation and Movement

Current Reality	Provocation		Movement		Ideas
Private swimming pools require a large outdoor area.	Negation	A private swimming pool does not require a large outdoor area.	Extract a Concept	Pools do not have to cover an area on the ground.	Develop a small pool with big pool functionality. Create a "tube" of water to swim in. Have a conversion kit to make a swimming pool an ice rink in winter. Design a water tub that allows for practice of specific strokes. Design roof pools.
	Reversal	A large outdoor area requires a private swimming pool.	Extract a Concept	Build pools in large outdoor areas such as front yards, rooftops, and parks.	
	Exaggeration	A private swimming pool only requires as much space as a bathtub.	Focus on Differences	Outdoor vs. indoor Large area vs. small area Deep vs. shallow Standing water vs. flowing	
	Dream	What if every home in America had a private swimming pool?	Moment to Moment	Market for pools would expand dramatically; price would be significantly reduced; use of public pools would decrease.	

EXHIBIT 22.1 (Downloadable)

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this *provocation* at face value and suspend judgment. This is not the time to question the validity of the statements, or to block the free flow of radical creativity. In general, PT statements fall into four categories:

1. *Negation:* Counteracts the current reality with an opposite statement.
2. *Reversal:* Reverses the action of the current reality statement.
3. *Exaggeration:* Takes the current reality to an incredible or extreme state (in either direction).
4. *Dream:* Imagines how the current reality would be different "if only . . ."

In psychological circles, extreme negation is considered a form of insanity (Cotard's syndrome). In the world of innovation, however, a little insanity can be a good thing if it leads you in the direction of never-before-imagined solutions for your job to be done.

---

4. Generate Ideas from Movement

The Provocative Thoughts you generated in step 3 should have the team thinking outside its normal frame of reference. The next step is to make these PT statements more realistic and feasible by applying one or more *movement* techniques to each statement. Movement techniques can be categorized as follows:

- *Moment to Moment:* Visualize what would happen if the Provocative Thought were put into effect. For example, if every home in America had a swimming pool (Dream PT), then the market for pools would expand dramatically and the price would be significantly reduced. Correspondingly, the use of public pools would decrease.
- *Extract a Concept:* Determine the concept behind the Provocative Thought and use this as the basis to generate new ideas. For instance, the team could use its Reversal PT (a large outdoor area requires a swimming pool) to extract the concept of building pools in large outdoor areas such as front yards, rooftops, and parks.
- *Focus on Differences:* Make a list of differences between the Provocative Thought and the current reality. For instance, the differences between

a private swimming pool and a bathtub (Exaggeration PT) include outdoor versus indoor, large area versus small, deep versus shallow, standing water versus flowing (from the faucet). One or more of these differences could lead the team to think about swimming pools in a completely new way.

Provocative Thoughts will always sound impossible, stupid, crazy, or ridiculous if not attached to some operative movement that can achieve the proposed radical idea.

5. Review Ideas

As a result, of applying movement to the PT statements, you should have a list of innovative ideas to explore further. Your ideas may be ready-made solutions. More than likely, however, Provocation and Movement may have pushed you to the boundaries of what is possible. In this case, you may need to leverage Structured Abstraction (Technique 23) or Separation Principles (Technique 24) to help you overcome any physical or technical contradictions inherent in your ideas.

Once Bill Gates provoked the world when he suggested that every household could own a personal computer. Today we're close to realizing the $100 laptop—an idea that would have seemed absurd just a few years ago.

Resource

For more on the Provocation and Movement approach, see:

deBono, E. *Serious Creativity Using the Power of Lateral Thinking to Create New Ideas*. New York: HarperBusiness, 1993.

Structured Abstraction

Guide your innovation using 40 proven principles.

Structured Abstraction is used to resolve a *technical contradiction*—two variables that are in conflict with each other. For example, you want to produce a car with more horsepower (A), but doing so entails a loss of fuel efficiency (B). You want to improve critical system factor A, but the actions involved in doing that cause factor B to degrade, and you need to avoid the tradeoff.

The Structured Abstraction technique comes in handy when you've identified a functional contradiction that stands in the way of an innovation—and when other ideation techniques have fallen short. Because Structured Abstraction is deeply grounded in science, engineering, and the Theory of Inventive Problem Solving (TRIZ), it's best to seek the help of an expert when using this technique.

Steps

1. Identify the Contradiction

How do you identify a technical contradiction? More often than not, technical contradictions are evident and well known within any field of endeavor or technology. Engineers and technicians familiar with a system understand the conflicting dynamics that give rise to technical contradictions.

To identify and characterize a technical contradiction, think in terms of two related variables, or parts of a system or process. When you improve one of the variables, say *increase the speed of a car,* that action causes another variable to deteriorate, like *lower gas mileage*. Whatever your innovation challenge, it is likely to entail at least one, if not many technical contradictions.

2. Abstract the Problem

After the contradiction and its improving and degrading elements have been identified, your next step is to translate each element into its associated problem parameter (make the problem generic). There are 39 such parameters in the TRIZ system, as shown in Exhibit 23.1.

In making your translations, ask this: What is the fundamental nature of each side of the conflict? This is an exercise in abstract thinking because you have to reframe each of your contradictory elements in terms of one of the 39 problem parameters.

For example, let's say you need more heat in a system, but that heat makes the system less safe. Referencing the 39 problem parameters, you can translate the need for heat into the parameter of *temperature* (number 17), and you can translate the negative impact on safety into the generalized parameter of *harmful side effects* (number 31).

Or maybe your system needs more airflow, but more airflow undesirably cools the surface. The need for more airflow references to general

39 Problem Parameters

1. Weight of moving object
2. Weight of nonmoving object
3. Length of moving object
4. Length of nonmoving object
5. Area of moving object
6. Area of nonmoving object
7. Volume of moving object
8. Volume of nonmoving object
9. Speed
10. Force
11. Tension, pressure
12. Shape
13. Stability of object
14. Strength
15. Durability of moving object
16. Durability of nonmoving object
17. Temperature
18. Brightness
19. Energy spent by moving object
20. Energy spent by nonmoving object
21. Power
22. Waste of energy
23. Waste of substance
24. Loss of information
25. Waste of time
26. Amount of substance
27. Reliability
28. Accuracy of measurement
29. Accuracy of manufacturing
30. Harmful factors acting on object
31. Harmful side effects
32. Manufacturability
33. Convenience of use
34. Repairability
35. Adaptability
36. Complexity of device
37. Complexity of control
38. Level of automation
39. Productivity

EXHIBIT 23.1

parameter number 7, *volume of a moving object,* while the cooling of the surface references to parameter number 17, *temperature.*

You can get a good run down and explanation of the 39 problem parameters at www.triz-journal.com/archives/1998/11/d/index.htm.

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3. Converge on Inventive Principles

This step entails using a *contradiction matrix* (Exhibit 23.3), which cross-references the 39 problem parameters against themselves, yielding a total of 1,521 cells in the matrix—or 1,521 different types of contradictions ($39 \times 39 = 1{,}521$). After taking away the 39 instances in which a problem parameter conflicts with itself, you are left with 1,482 usable cells in the contradiction matrix.

All you have to do is identify your generic useful feature (parameter), as well as your generic harmful feature, then go to the contradiction matrix cell that resides at their intersection. Inside that cell, you'll find any of *40 inventive principles* (Exhibit 23.2) by which you can solve your contradiction.

40 Inventive Principles

1. Segmentation
2. Taking out
3. Local quality
4. Asymmetry
5. Merging
6. Universality
7. 'Nested doll'
8. Anti-weight
9. Preliminary anti-action
10. Preliminary action
11. Beforehand cushioning
12. Equipotentiality
13. 'The other way around'
14. Spheroidality
15. Dynamics
16. Partial or excessive actions
17. Another dimension
18. Mechanical vibration
19. Periodic action
20. Continuity of useful action
21. Skipping
22. 'Blessing in disguise'
23. Feedback
24. 'Intermediary'
25. Self-service
26. Copying
27. Cheap short living
28. Mechanics substitution
29. Pneumatics and hydraulics
30. Flexible shells and thin films
31. Porous materials
32. Color changes
33. Homogeneity
34. Discarding and recovering
35. Parameter changes
36. Phase transitions
37. Thermal expansion
38. Strong oxidants
39. Inert atmosphere
40. Composite material

EXHIBIT 23.2

Contradiction Matrix Cross Section

Problem Parameters (39 Total)

Harmful Feature / Useful Feature	17 Temperature	20 Use of energy by standard objects	25 Loss of time
7 Volume of a moving object	2, 10, 18, 34	—	2, 6, 34, 10
14 Strength	30, 10, 40	35	29, 3, 28, 10
36 Adaptability or versatility	27, 2, 3, 35	—	35, 28

Problem Parameters (39 Total)

Inventive Principles (40 Total)

EXHIBIT 23.3 (Downloadable). This is a very small cross-section of the larger contradiction matrix, showing the problem parameters and inventive principles associated with our stylized example (volume of a moving object versus temperature). It also shows other parameters and principles chosen at random.

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The key to the 40 inventive principles is that they were derived from an extensive analysis and categorization of more than 2 million patented innovations. In each and every case, the patented innovations employed at least one of the 40 inventive principles to solve some identified technical contradiction. This is why some call these 40 principles the genetic code of innovation, and why TRIZ experts will tell you that someone else in another field at another time has already solved your contradiction.

For more specific examples of the 40 inventive principles, see *Simplified TRIZ: New Problem-Solving Applications for Engineers and Manufacturing Professionals,* second edition, by K. Rantanen and E. Domb, Boca Raton, FL: Auerbach, 2007, or go to www.triz-journal.com/archives/contradiction_matrix.

The contradiction matrix typically displays anywhere from one to four inventive principles that can help you solve your contradiction. If you're in the consumer products business, for instance, the solution you need may have been already found and applied in the space industry, or in agriculture, or in any number of other fields. All you have to do is navigate your way through the technical contradiction algorithm to the inventive principle(s) you need.

For example, if you need the volume of air flow to go up but the surface temperature to stay constant, what do you do? According to the contradiction matrix, you go to inventive principles 2, 10, 18, and 34, because when you cross-reference these parameters, that's what the contradiction matrix gives you.

When you look up inventive principles 2, 10, 18, and 34 (see Exhibit 23.2), you get the following, in respective order: *taking out, preliminary action, mechanical vibration,* and *discarding and recovering*. You now have four important clues for solving the air-flow/surface temperature contradiction.

There are certain instances in the contradiction matrix where no numbers appear, as you can see in Exhibit 23.3. This indicates that there are no data to suggest the benefit of any one or more principles over any other principles. In these instances, you can apply any or all of the 40 inventive principles versus any particular subset. Or you can consider reframing your contradiction using different problem parameters.

---

4. Apply the Inventive Principles

Now comes the moment of truth—actually applying the inventive principle to solve your technical contradiction. This requires good analogical thinking skills because you have to consider the identified inventive principles as a guide for coming up with a specific solution to your original specific problem, or technical contradiction.

This is obviously an exercise that not only requires analogical thinking, but also requires deep and intimate subject matter expertise. As always, the danger is in becoming a victim to your own psychological inertia by dismissing any inventive principle as preposterous before giving it serious consideration. If you're skilled at abstract thought, and you put your existing mindset aside, you just might find the innovative solution you seek.

Resources

Large portions of material in this technique have been reprinted with permission from:

Silverstein, D., N. DeCarlo, and M. Slocum. *Insourcing Innovation: How to Achieve Competitive Excellence Using TRIZ*. Boca Raton, FL: Auerbach, 2007.

We recommend this book because it displays the entire contradiction matrix, Structured Abstraction case studies, and additional information about this and other TRIZ-based methods and techniques.

If you need the help of a TRIZ expert, contact:

Breakthrough Management Group International (www.bmgi.com).

Or you can find other experts at:

Real Innovation (www.realinnovation.com).

TRIZ Journal (www.triz-journal.com).

Separation Principles

Split your innovation problem in four ways.

Separation Principles helps when some *physical contradiction* stands between you and an innovation, and you need to resolve the conflict with minimal or no tradeoff. For example, you need the water in the system to be hot for some functions but cold for others. Or you want all the information to make a good management decision, but you don't want all the information because you don't have time to sift through it.

Use the Separation Principles technique when you've identified a physical contradiction, and when other ideation techniques may have fallen short of resolving it. You may need the help of an expert to apply Separation Principles, depending on the nature of your innovation project and its difficulty level.

The Separation Principles come from the Theory of Inventive Problem Solving (TRIZ), and they are defined a little differently by different experts. For simplicity, we characterize the Separation Principles by separating contradictory properties in *time, space, scale,* and *condition.*

Steps

1. Identify the Physical Contradiction

The key action here is to figure out which variable, system, or part of a system conflicts with itself. If this is not readily apparent, identify what you want to maximize and why you also want to minimize or eliminate that factor as well. Here are some examples of physical contradictions:

- We need tire rotation to provide steering and to avoid skidding under icy or wet conditions that require extreme braking to stop the vehicle. But we don't want tire rotation because the vehicle must stop.
- We need landing gear on planes for easy take off and landing, but we don't want landing gear because it causes drag.
- Engineers want a large window in a spaceship to see out, but they don't want the window because it adds extra weight to the spaceship.
- We want options when searching for flights online, but we don't want options because they consume too much time to review.

2. Consider Separation Heuristics

The four Separation Principles—time, space, scale, and condition—can be applied in an endless number of circumstances. To help you determine which principle could resolve your physical contradiction, consider the following:

- *Separation in time:* The strategy for this principle is that at Time 1, the variable has property (+P), and at Time 2 it has property (−P). For example, a modern fighter jet has to be maneuverable during landing as well as in combat situations. The requirements of the wing geometry are radically different in each scenario. At low speeds (Time 1) the best wing geometry is unswept (+P), while at high speeds (Time 2) it is swept (−P). These contradictory requirements are resolved through the invention of variable sweep wing geometry (Exhibit 24.1).

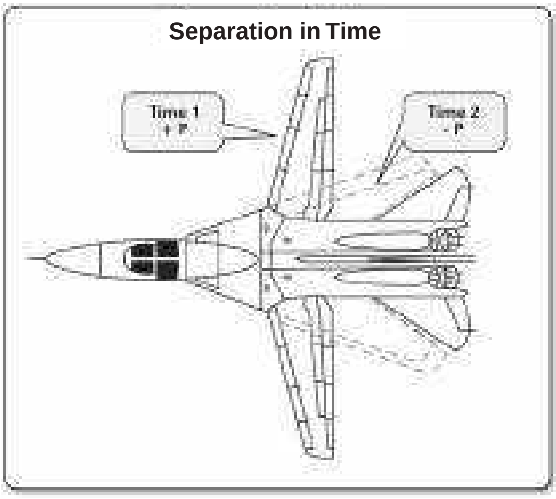

EXHIBIT 24.1

- *Separation in space:* The strategy for this principle is that at Place 1, the variable has property (+P), and at Place 2 it has property (−P). Classic examples of this principle include coffee pots, teapots and thermos bottles. Taken further, this principle is at the heart of a new technology called holographic conferencing. Using this technology, for example, a holographic image of an executive in Bangalore, India, can be seen by an audience talking with another executive in San Jose, California. Both people have human properties in one space and holographic properties in the other space.

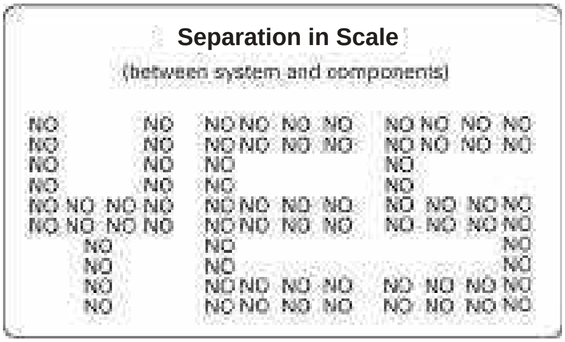

EXHIBIT 24.2

- *Separation in scale:* This separation strategy is applied to the system and its components, whereby the entire system has property (+P), and the component has property (−P), as illustrated in Exhibit 24.2. Another example is a chain, which is flexible at the system level but each link in the chain is rigid.

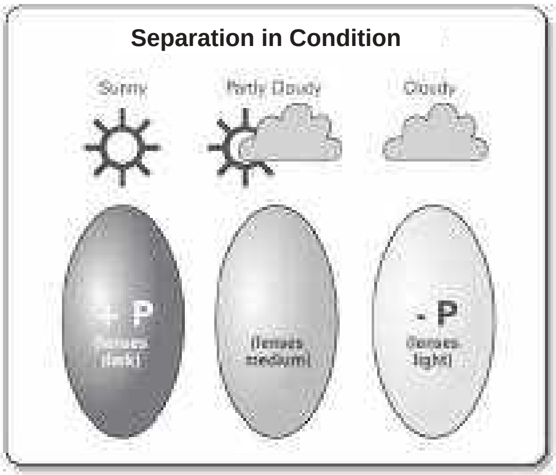

EXHIBIT 24.3

- *Separation upon conditions:* This separation strategy entails that the system under Condition 1 exhibits property (+P), and under Condition 2 it exhibits property (−P). An excellent example is Transitions lenses with a light-sensitive photochromic coating. The lenses are light or dark depending on the amount of UV radiation present (Exhibit 24.3).

3. Resolve Physical Contradiction

First carry forward the contradictory element or characteristic of your physical contradiction from step 2. This is the characteristic X that must meet the self-opposing requirements.

Next, define the time period of the physical contradiction as:

- T1: before the event.
- T2: during the event.
- T3: after the event.

After this, complete logic statements A and B:

A: To (improve, retain) the useful action of (state the useful action) X must be (present, large, hot, etc.) during T (1, 2, or 3).

B: To eliminate the harmful action of (state the harmful action) X must be (absent, small, cold, etc.) during T (1, 2, or 3).

In statement **A,** X could be (absent, small, cold, etc.), which means that in statement **B,** X would be (present, large, hot, etc.).

Now write the Physical Contradiction:

X must be____________during time T______and
X must be____________during time T______.

Then choose a Separation Principle (time, space, scale, or condition) to apply and solve the contradiction.

Example

Scenario: In electroplating, the rate of deposition of metal is increased when the plating solution is warm. The shelf life of the solution, however, is reduced dramatically with the increased temperature. It is necessary to increase the rate of deposition with minimal degradation to the solution. How can this be done?

The Problem

- The electroplating solution bath needs to be hot and cold.
- The characteristic is *temperature* of the solution bath.
- Time period is T1, T2, T3.
  A. To increase the rate of deposition, the solution bath must be hot during T2 (actual electroplating).
  B. To preserve the shelf life, the solution bath should be cold during T1 (before electroplating), T2 and T3 (after electroplating).

The Physical Contradiction

- Solution bath temperature should be hot during time T2 (electroplating).
- Solution bath temperature should be cold during time T1, T2, T3.

The Separation

- Separation of opposite requirements in *space.*

The Resources

- *Heat,* space, equipment.

The Solution

- Heat the parts—temperature is hot at the interface, cold everywhere else.

Additional Example—Manager Working in an Office

- Manager Beth wants information so she can have control, but she doesn't want information because she has too much already. Solution: Use periodic management reviews to separate the information in *time.*
- Beth also needs to work on a critical project, but doesn't want to work on a critical project because she has people tugging at her in the office. Solution: She works offsite for two days, thereby separating in *space.*

- Beth is still overwhelmed with work so she co-opts several of her colleagues into taking on certain tasks. She has separated in *scale* to solve her problem. Some call this delegation.
- To reduce the volume and complexity of issues due her attention, Beth requests that any item not affecting more than 20 people not be brought before her for consideration—she has separated in *condition*.

Resources

The *TRIZ Journal* is packed with resources, papers, and commentary. A quick search on the site for "Separation Principles" will yield some good information.

TRIZ Journal (www.triz-journal.com).

76 Standard Solutions

Learn how substances interact with fields to form solutions.

The 76 Standard Solutions are a collection of system models designed to provide conceptual hints that can lead to higher-order solutions or innovations. For example, one of the 76 Standard Solutions could prompt an engineer to add a luminophore substance to the refrigerant substance in a cooling system, thereby making leaks visible that would otherwise go undetected.

This technique comes in handy when the innovation opportunity is (a) well-defined and (b) contains at least one *technical contradiction* (see Structured Abstraction, Technique 23) or *physical contradiction* (see Separation Principles, Technique 24). Unless you're well-versed in the Theory of Inventive Problem Solving (TRIZ), you will need special assistance from an expert to properly apply this technique. Several U.S. and U.K. organizations can help (see resource list at the end of this technique).

Background

The 76 Standard Solutions are contained in the field of TRIZ, specifically *substance field modeling* (Su-Field). As with other TRIZ techniques like Functional Analysis, the 76 Standard Solutions are vested in the notion that all systems can and will be progressively modified to improve their value quotient (see Technique 3).

Su-Field modeling is the ability to represent a product- or service-related system as a set of objects, both called substances (S_1, S_2), that interact through the medium of a field, or a source of energy (F). While S_1 is always *passive* in nature and is called an *article,* S_2 is always *active* in nature and is called a *tool.* At a minimum, the modeled system must contain all three elements (S_1, S_2, and F) if it is capable of innovation or improvement.

In Su-Field modeling, a substance can refer to any part, material, component, person, or the environment. The source of energy in the system can be such physical fields as mechanical, thermal, chemical, electrical, magnetic, and gravitational, or any number of fields such as light, acoustic, olfactory, and so on.

The three Su-Field elements (S_1, S_2, and F) constitute the minimum requirements for a complete system, and the energy transfer between them is depicted by various symbols (Exhibit 25.1).

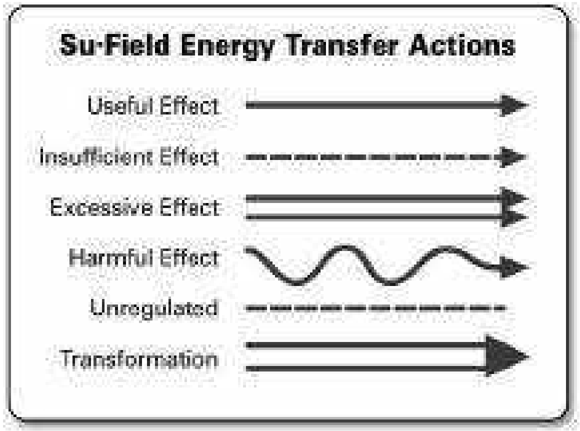

EXHIBIT 25.1

For example, the action of driving a nail illustrates the minimum Su-Field model (Exhibit 25.2). Your hand transmits a mechanical field (F) to the hammer (S_2), which in turn transmits the field to the nail (S_1). Note that the transfer of mechanical energy is considered a useful effect.

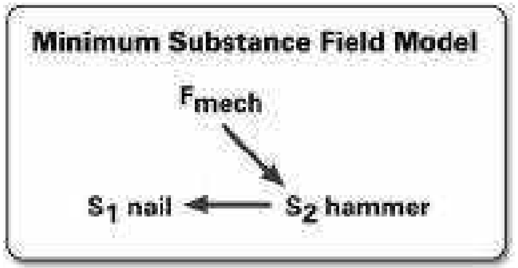

EXHIBIT 25.2

While the minimum Su-Field model has two substances (S_1 and S_2), and a field (F), there can be as many substances and fields as needed.

Imagine the types of jobs you could do with this one simple Su-Field model, never mind all 76 Standard Solutions (Su-Field models). How many possibilities are there for applying a force to a tool to affect an article?

The fundamental logic of the 76 Standard Solutions is that problems can be abstracted and modeled. The models in turn have specific rules, culled from a database of similar problem resolutions, revealing the direction the inventive process should follow if it is to discover an ample solution. In other words, the 76 Standard Solutions form an empirical algorithm for solving certain classes of innovation problems.

> Each problem that I solved became a rule, which served afterwards to solve other problems.
>
> —René Descartes

Steps

Su-Field modeling is performed in the operating zone where the actual contradiction occurs and an *initial Su-Field model* is created. Then, moving through a set of rules, the model is progressively developed until it reaches its *transformed state.* Strictly following the Su-Field logic process enables you to remove your psychological inertia and clear the way for an innovative solution.

We don't recommend using Su-Field modeling and the 76 Standard Solutions if you don't have experience. Seek an expert who can guide you through the process as follows:

- Develop a visual model of the problem for consensus using the five Su-Field categories.
- Converge on the category of Su-Field models that is most likely to fulfill your need for an innovation.
- Create an agreed-upon end state through the application of logical rules.
- Create specific solution concepts that either eliminate contradictions and/or improve the system's value quotient.

Exhibit 25.3 shows the general process for locating Su-Field models that may apply to any innovation problem or contradiction. Note that all

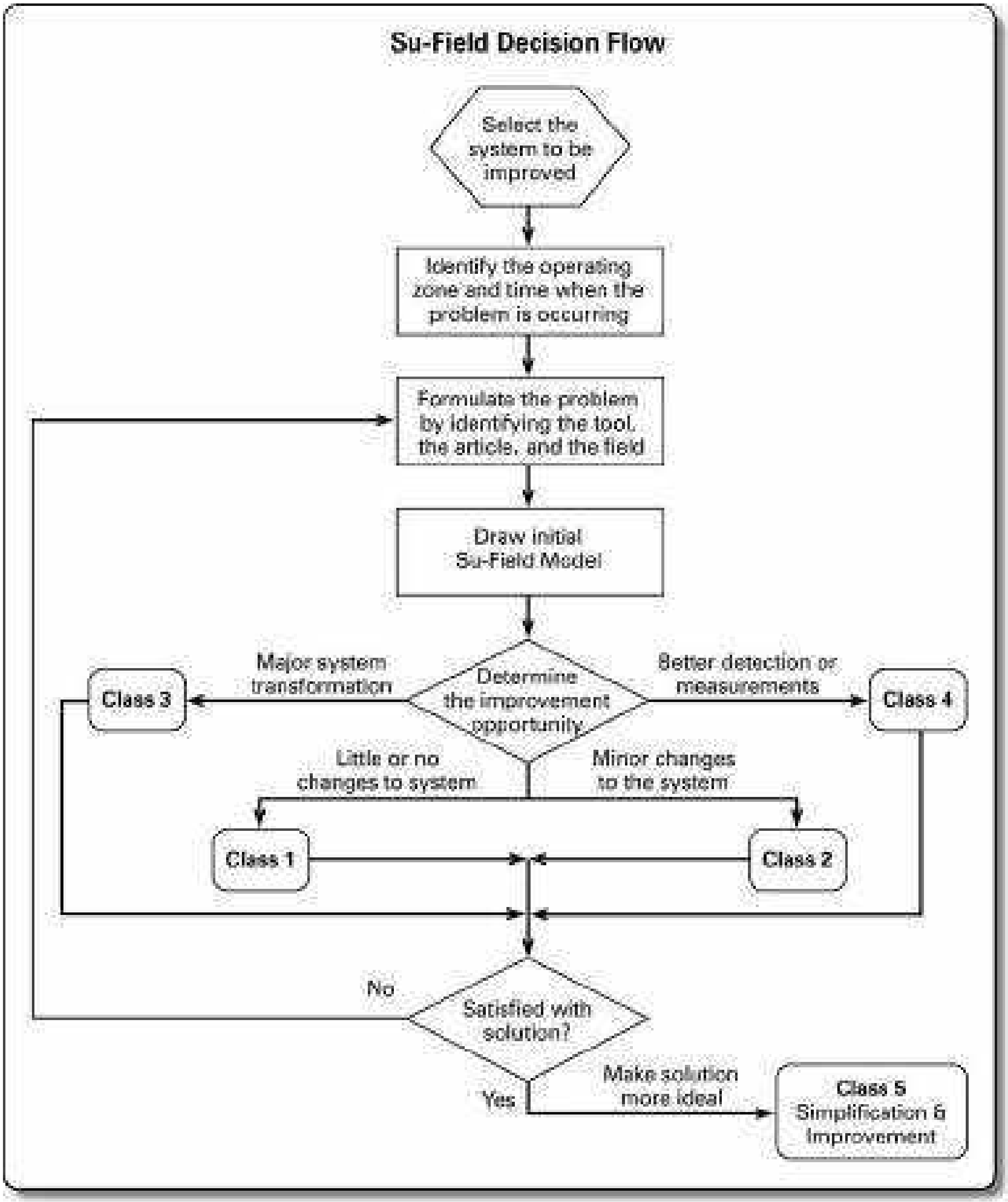
Su-Field Decision Flow
Select the system to be improved
Identify the operating zone and time when the problem is occurring
Formulate the problem by identifying the tool, the article, and the field
Draw initial Su-Field Model
Determine the improvement opportunity
Major system transformation
Class 3
Better detection or measurements
Class 4
Little or no changes to system
Minor changes to the system
Class 1
Class 2
No
Satisfied with solution?
Yes
Make solution more ideal
Class 5 Simplification & Improvement

EXHIBIT 25.3

roads lead to Class 5 for additional Su-Field models that can refine any work you accomplish using predecessor models.

Here is a little more about each of the five Su-Field model categories, which are loosely organized in order of increasing progression toward the ideal innovation:

Class 1: Solutions for improving the system with little or no change (13 solutions). Use when your innovation job statement requires an increase or decrease in some expected outcome. This generally requires only minimal changes to the system.

Class 2: Solutions for improving the system by changing the system (23 solutions). Use when you think your system is insufficient to meet the demands of the job to be done, and only moderate modifications need to be made.

Class 3: Solutions for making system transitions (6 solutions). Use when developing solutions at higher (super-system) or lower (subsystem) levels.

Class 4: Solutions for detection and measurement (17 solutions). Use when you need to innovate your ability to measure and detect something, or when doing so will lead you to a related innovation.

Class 5: Solutions for simplification and improvement (17 solutions). Use when you want to make the system simpler, more value-packed and, hence, closer to the ideal state.

Examples

We don't have space to show examples of every one of the 76 Standards Solutions, so we'll show just one example from each of the five Su-Field categories.

Class 1: Solutions for Improving the System with Little or No Change

Standard 1.2.2—If there is both a useful and harmful interaction between two substances and there is no need to maintain direct contact between the substances, the problem can be solved by the introduction of a third substance that is a modification of either the first or second substance (Exhibit 25.4).

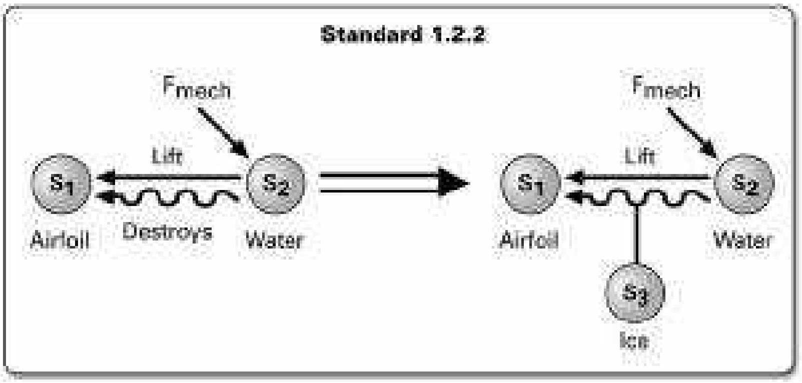

EXHIBIT 25.4

Scenario: Hydrofoils traveling at high rates of speed are damaged by the cavitational action of water on the hydrofoil. To prevent the destructive cavitational forces acting on the surface of the foil, a thin layer of ice is introduced by refrigerating the surface of the foil, thus forming a renewable source of protection.

Class 2: Solutions for Improving the System by Changing the System

Standard 2.1.2—If there is a Su-Field that is difficult to control and it is necessary to improve its efficiency, but replacing any of its elements is prohibited, the problem may be solved by building a double Su-Field through the introduction of a second field that it's easy to control (Exhibit 25.5).

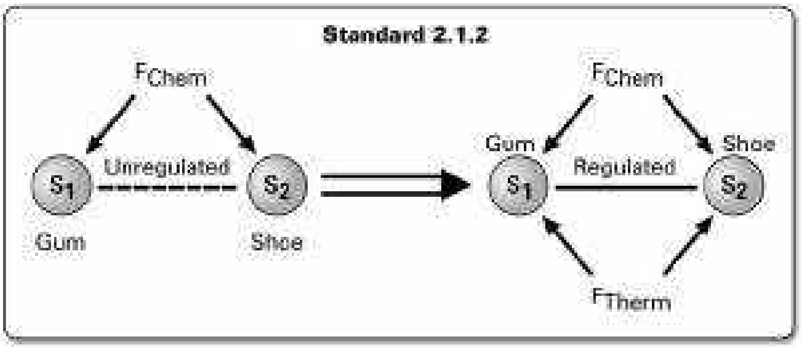

EXHIBIT 25.5

Scenario: Imagine if you had chewing gum stuck to your shoes or an article of clothing. Neither mechanical means nor washing will completely remove the sticky problem. That is because there is an unregulated interaction between the gum and the article of clothing. This problem can be solved by introducing a new (double) Su-Field to control the action of the field between the tool and article.

Class 3: Solutions for Making System Transitions

Standard 3.2.1—The efficiency of a system can be increased by transitioning from the macro-level to the micro-level. The system or its parts should be replaced with a substance capable of performing the required action when it interacts with a field (Exhibit 25.6).

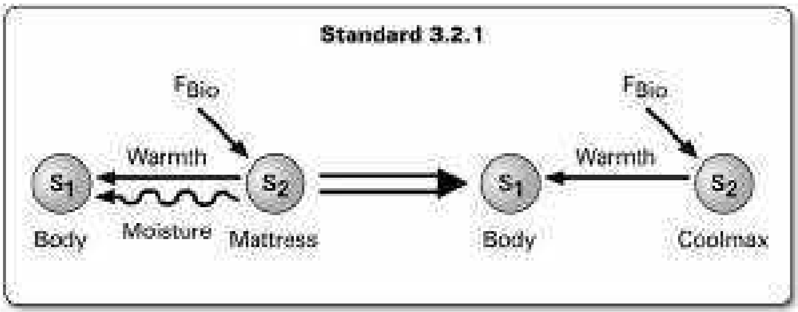

EXHIBIT 25.6

Scenario: Simmons Bedding Company unveiled its latest innovation, the HealthSmart bed, featuring a zip-off mattress top that may be laundered or dry cleaned. Its coolmax-channeled fibers wick away sweat and moisture as you sleep, and allow the fabric to dry quickly in the laundry. In the second layer, Nano-Tex (nano technology) creates a semi impervious layer that traps fluids and particles so they can be washed away. The third layer is terry cloth treated with Teflon fabric protector that provides an extra level of protection.

Application of this standard leads to a transformed Su-Field model with a new substance S_2, which was modified on the micro-level using nano technology polymers. The zip-off top provides several new actions—among them, liquid/particle containment and retardation of perspiration odor and fungi when it interacts with the biological field.

Class 4: Solutions for Detection and Measurement

Standard 4.2.1—If an incomplete Su-Field is difficult to measure or to detect, the problem is solved by synthesizing a regular or double Su-Field with the field at the output. Instead of direct measurement or detection of a parameter, another parameter identified with the field is measured or detected (Exhibit 25.7).

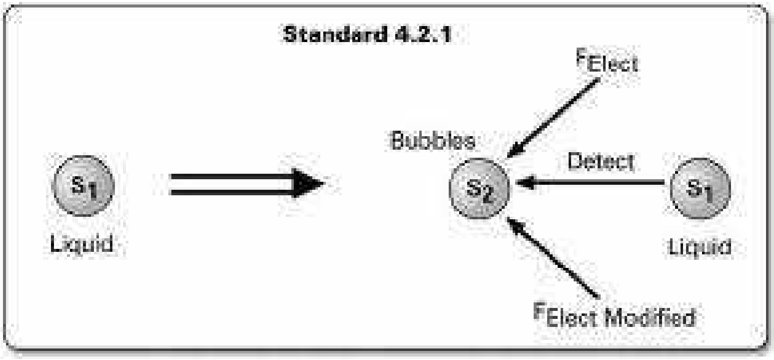

EXHIBIT 25.7

Scenario: To detect the moment when a liquid begins to boil, an electrical current is passed through the liquid. When the liquid starts to boil, air bubbles start to appear and electrical resistance is increased dramatically.

Class 5: Solutions for Simplification and Improvement

Standard 5.1.1—If it is necessary to introduce a substance in the system and conditions do not permit it, a void can be used instead of the substance.

Scenario: To dramatically increase strength and reduce weight of trusses, or any structural member, a clever combination of geometry and open spaces can be utilized to achieve the desired results.

For example, IsoTruss achieves its incredibly high strength-to-weight ratio with a special geometry that uses longitudinal and helically wound members (Exhibit 25.8). The "Iso" and "Truss" in "IsoTruss" come from its efficient geometry; isosceles triangles that form a truss of pyramids give the IsoTruss its unique strength and stiffness. The IsoTruss incorporates stable geometric forms with members that spiral in a piecewise linear fashion in opposing directions *around a central cavity.* The helical and longitudinal members are repeatedly interwoven, yielding a highly redundant and stable configuration.

EXHIBIT 25.8 Arantix Mountain Bike. Handcrafted by Delta 7 Sports, this bike features a patented IsoTruss carbon fiber and Kevlar spiderweb-like open lattice tube design. Its unparalleled strength-to-weight ratio provides an ultrastiff and responsive ride.

Photo by Lester Muranaka.

Resources

For a much more complete treatment of the 76 Standard Solutions, see:

Salamatov, Y. *TRIZ: The Right Solution at the Right Time*. The Netherlands: Insytec B. V., 1999.

For a good journal article on the 76 Standard Solutions applied to the problem of world hunger, see:

"Using the 76 Standard Solutions: A Case Study for Improving the World Food Supply." *TRIZ Journal*. www.triz-journal.com/archives/2001/04/e/index.htm.

Some organizations that may be able to help are:

Altshuller Institute (www.aitriz.org).

Breakthrough Management Group International (www.bmgi.com).

European TRIZ Association (www.etria.net).

TRIZ Journal (www.triz-journal.com).

TECHNIQUE 26

Biomimicry

Seek nature's eons of experience to find answers.

Biomimicry (or biomimetics) is the process of learning from and then emulating nature's ingenious solutions to complex problems. Imagine making high-end audio speakers based on a cricket that uses its burrow to amplify sound. Or drawing inspiration from a boxfish to develop a concept car with 60 percent less drag. Or creating self-assembling fibers, like those produced by spiders, that are five times as strong as steel.

These real-life applications of biomimicry only scratch the surface of this fascinating approach. Nature has spent billions of years designing and perfecting systems and processes, excelling at finding optimal solutions under conflicting constraints and demanding requirements. Science and engineering have similar goals: optimal results with minimal input and minimal use of resources. If you have to solve a problem, chances are nature already did it.

Although biomimicry is often applied by those trained to observe nature at its most fundamental level, it doesn't necessarily require doing expensive, time-consuming research. Many examples of nature's problem-solving abilities are available for the casual researcher. The scope of this book prevents us from offering a comprehensive education in biomimicry, but we can offer some general guidelines for learning from nature and leveraging its vast bank of knowledge.

Steps

1. Change Your Perspective

Using other techniques in this book, you have already scoped the JTBD (see Jobs To Be Done, Technique 1) and identified associated outcome expectations (see Technique 2). Now, ask, "What would nature do to solve this problem?" In doing so, you realize that nature isn't the environment in which your design will live; instead it's a model on which to base your design. This subtle shift is important if you want to draw inspiration from nature and follow its guiding principles:

- Nature runs on sunlight.
- Nature uses only the energy it needs.
- Nature fits form to function.
- Nature recycles everything.
- Nature rewards cooperation.
- Nature banks on diversity.
- Nature demands local expertise.
- Nature curbs excesses from within.
- Nature taps the power of limits.

  Source: (*Biomimcry: Innovation Inspired by Nature*, by J. Benyus, New York: William Morrow, 1997).

Nature's designs are organic. They make optimal use of the resources and energy available, only produce recyclable waste, and integrate with existing natural life cycles.

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2. Explore Existing Knowledge

Biomimicry has a rich body of literature, written by experts on every topic imaginable. Much of this information can be found online. Don't hesitate to make contact with experts; collaboration with professionals from different fields can yield inspiring solutions.

One body of exploratory computer science, now collectively known as Computational Swarm Intelligence, solves complex optimization problems by mimicking the flocking behavior of birds and the foraging behavior of ants (see *Fundamentals of Computational Swarm Intelligence,* by A. Engelbrecht, Hoboken, NJ: John Wiley & Sons, 2006).

3. Plan a Field Trip

If you can't find a solution to your problem in an existing knowledge base, you'll need to take a field trip (or several). Here's where someone experienced in biomimicry can point you in the right direction. At the very least, you'll need to identify an organism, ecosystem, or process that has solved a problem similar to yours, and then go where you can study the solution in its natural environment. Remember that solution ideas might be found in non-obvious environments. For example, if you need a way to dry out humid air, you can look in the tropics, or you can go to the desert where cockroaches drink water from the air.

If you put the history of the planet on a calendar year, bacteria arrived in March. Other species followed. The human species came at 11:45 PM on the *last day of the year.* Clearly we have a lot to learn from the way natural species have evolved, adapted, and innovated themselves to survive their own unique challenges and problems.

4. Observe and Learn

Once you're in the field, there are many ways to gather inspiration for your own design. Just remember that nature's solutions are often non-obvious and intricate, while at the same time functionally simple. Take time to immerse yourself. Patient study will uncover functionality you may never have considered. As you observe, keep these tips in mind:

- *Look for Metaphors:* Nature offers many metaphors that can be applied to a variety of artificially constructed systems. For instance, some termites regulate air flow through their mounds to keep the internal temperature and humidity near constant (Exhibit 26.1). A similar principal has been used in the design of high-rise buildings in Harare (Zimbabwe) and London, leading to significant reductions in environmental control costs.

EXHIBIT 26.1 Termite Mound. A termite mound can seem eerily like a skyscraper, especially when you consider the mound's efficient regulation of air flow, temperature, and humidity.

- *Identify Anti-Solutions:* When you think about how nature might solve a problem, also consider how nature might *not* solve it. For instance, manufacturing protective shielding for military applications requires metal to be molded at high temperatures, which consumes massive amounts of energy. On the other hand, nacre (mother of pearl) is just as strong, yet it grows organically and requires no excessive consumption of resources.
- *Consider Extremes:* Explore how nature has solved your problem by going to one extreme or another. Desert beetles, for example, use a hydrophilic (water attracting) shell to channel water to where it is wanted. On the contrary, lotus leaves keep water from building up where it isn't wanted using a hydrophobic (water repelling) design (Exhibit 26.2).
- *Examine Interactions:* Everything in nature interacts with its environment. When you have identified a source of inspiration, consider its impact on other elements in nature. For instance, animals share resources, such as watering holes, but use the resource at different times to avoid conflicts. Man-made creations can also take advantage of interaction and re-use. One example is the design of many hybrid vehicles that are powered by batteries that are recharged during braking.

EXHIBIT 26.2 Lotus Leaf. The leaf repels water, a feature that is often sought after in man-made solutions.

Are you drawing inspiration from an organism, a process, or an ecosystem? In either case, you'll need to understand the system in detail to be able to mimic it successfully and without negative consequences.

5. Document Solution Ideas

As a result, of exploring nature's genius, you should have one or more ideas you can investigate further.

Resources

Here are a few of the best web sites for biomimicry examples, case studies, resources, and expert help:

Bioinspiration & Biomimetics Journal (http://stacks.iop.org/bioinsp).

Biomimetics Network for Industrial Sustainability (BIONIS; www.extra.rdg.ac.uk/eng/BIONIS).

Biomimicry Database (http://database.biomimicry.org).

Biomimicry Institute (www.biomimicryinstitute.org).

For a fascinating presentation on biomimicry, see:

"Janine Benyus: 12 Sustainable Design Ideas from Nature." www.ted.com/index.php/talks/view/id/18.

KJ Method

Group and organize ideas by their natural affinities.

KJ Method provides a way to organize and refine your innovation ideas, sparking further dialogue and achieving consensus about which ideas are worth developing. Also known as an *affinity diagram,* KJ Method works best when you have more ideas than you can readily handle or process in your mind.

Usually KJ Method directs participants to *generate* ideas via classic brainstorming. However, given the many other powerful ideation tools in this book, we recommend you use KJ Method to help you organize and prioritize the highly creative and innovative ideas you've already generated.

KJ Method was named after Jiro Kawakita, a man of many talents who was a professor of cultural anthropology in Japan. After extensive field research in Nepal during the 1960s, Kawakita developed the KJ Method to improve the integration and categorization of qualitative data around such factors as the environment, population, relationships, hierarchy, and religion.

Steps

Scenario: Let's see how KJ Method helped the Patient Crusaders team organize and prioritize their ideas for making dental patients more comfortable and less afraid during treatment (also see Heuristic Redefinition, Technique 5).

A team of 6 to 8 people is optimum for KJ Method. Fewer than this can make prioritization too subjective; more than this can make it difficult to gain consensus.

1. Prepare Ideas

Write each idea you've come up with on a sticky note, and place the ideas randomly on a white board or large wall space. Also post the JTBD (see Jobs To Be Done, Technique 1) and associated outcome expectations (see Technique 2) so the team can keep these in mind.

2. Categorize Ideas

As a group, sort the ideas into related categories based on functionality, features, implementation, outcome, or whatever grouping makes sense (there are no right or wrong categories). Ideas that don't fit into a particular category can be saved off to the side. Place similar ideas on top of each other so you can see how many unique ideas there are.

Participants should be discouraged from discussing ideas, except for clarification, until voting occurs in step 4. Otherwise, you risk wasting time on ideas that won't be pursued in the end.

3. Label Categories

Review the idea groupings, and agree on a label for each one that represents the theme or concept behind the ideas in that group. Labels should be short, like *Dental Technology* or *Patient Communication.* No two categories should have the same or similar labels—if they do, combine the categories. As labels emerge, you may need to split some groups into multiple categories, or move ideas around to fit better with the category logic (Exhibit 27.1).

Labeling categories helps the team evaluate the suggestions from a thematic or system perspective. Plus, if the categories translate to *concepts,* the team can generate additional ideas using Idea Harvesting and Treatment (Technique 28).

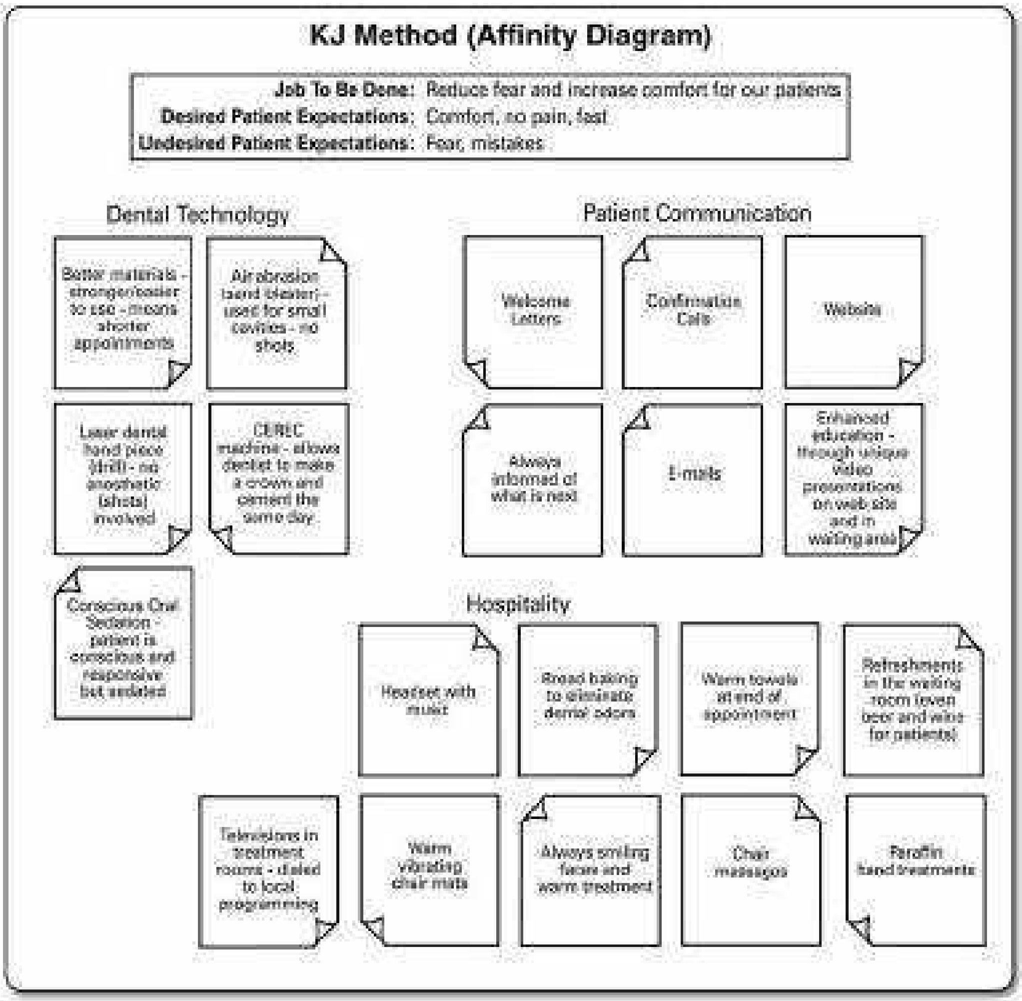

EXHIBIT 27.1 The Patient Crusader team organized their existing ideas into three categories.

4. Vote on Ideas

KJ Method is a technique for both categorizing and prioritizing ideas. The latter is usually accomplished by having team members vote on the ideas they find most promising. There are several ways to approach voting including:

- Give each team member 3 to 5 votes to place on the same idea or on multiple ideas. The ideas with the most votes merit further discussion and/or development.

- Have team members assign a percent (totaling 100 percent per person) to one or more ideas. For each idea that receives a vote, add up the percentages and divide the answer by the number of people who voted to determine a weighted score.
- Discuss each idea and try to build consensus around the strongest ones. Although this does take longer than voting, it tends to generate stronger buy-in for ideas in the long run.
- If you have many different *categories,* vote on these first to see if there are any that can be eliminated. Then vote on specific ideas within the remaining categories.

The Patient Crusaders team voted to implement a few of the simple and inexpensive ideas right away, including *welcome letters, confirmation calls,* and *warm towels at the end of the appointment*. They ranked several other ideas as potentially feasible solutions and will revisit these at a later date.

If you still have too many ideas after using KJ Method, use a Pugh Matrix (Technique 36) to help you prioritize them.

Idea Harvesting and Treatment

Organize and shape ideas to improve their yield.

Idea Harvesting and Treatment is a simple and effective way to make your ideas more practical and viable, as well as more appealing to those who are funding the innovation project (your stakeholders). After you've generated dozens of ideas for a better battery, do you just throw out the notion of making the battery biodegradable, or can you find some value in the idea?

What about your other ideas? Are they immediately applicable or do you need to overcome some constraints, such as cost, time, resources, or perception? Idea Harvesting and Treatment can help you answer these questions and subsequently choose the best ideas from your list for further development.

> You would not think much of a farmer who took a lot of trouble to sow a crop but only bothered to harvest a quarter of the crop. Yet that is exactly what most people do with the output of a creative thinking session.
>
> —Edward de Bono

Steps—Harvesting

Scenario: Let's say that your organization has a new innovation deployment. Your team has generated a list of ideas for publicizing the program's success both internally and externally. You can use Idea Harvesting and Treatment to organize and further refine these ideas.

1. Categorize Existing Ideas

Take the list of ideas you've already come up with and sort them into the following categories on an Idea Harvesting matrix (Exhibit 28.1):

- *Broad Concept:* Theory or notion that links one or more concepts.
- *Concepts:* General approaches or methods.
- *Specific Ideas:* Valuable, practical, and usable ideas.
- *Beginning Ideas:* Interesting starter ideas but not yet actionable.

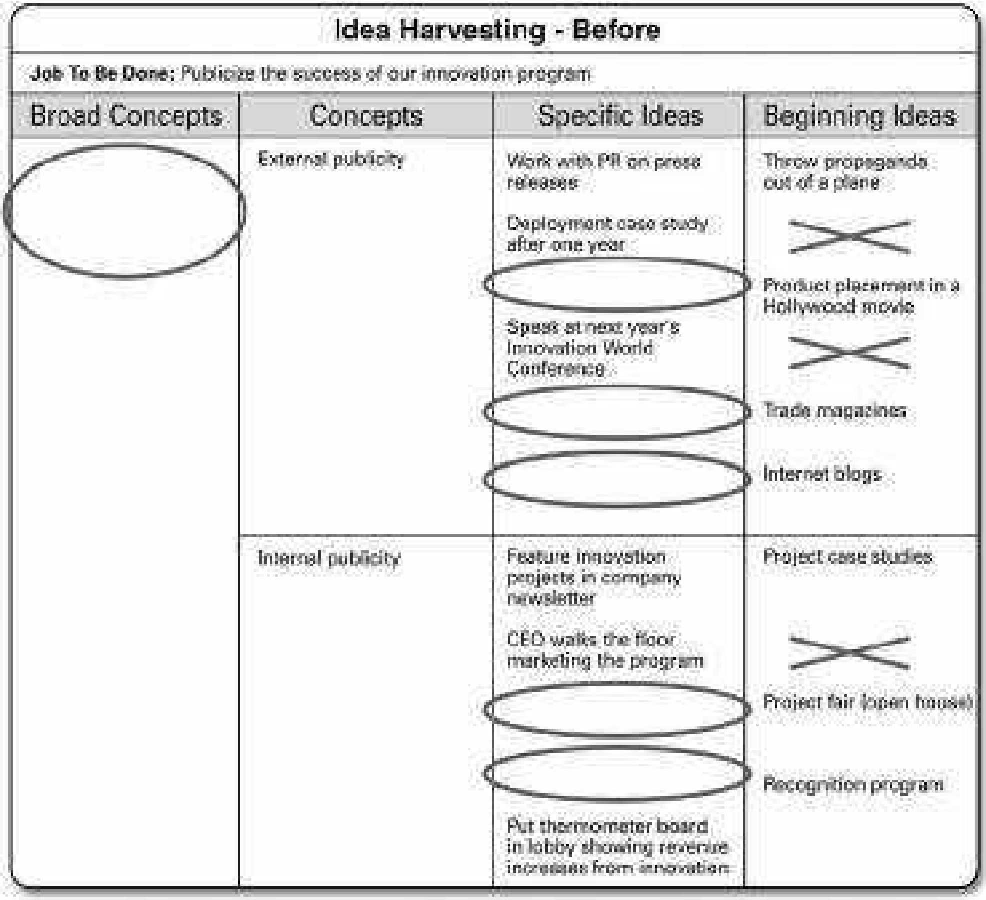

EXHIBIT 28.1 (Downloadable)

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For instance, ideas for publicizing your innovation deployment might include writing case studies, generating press releases, holding project fairs, and the rather fanciful suggestion of featuring one of your innovative products in a Hollywood movie. Some of these ideas are specific and actionable, while others need work.

A *concept* links a group of ideas together, whereas a *broad concept* brings all the concepts under one umbrella. Both concepts and broad concepts are subjective—there is no right or wrong answer as long as the answer serves the job to be done.

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2. Increase Idea Yield

Increase the yield of ideas and concepts by filling in any blanks on the Idea Harvesting matrix. Can you turn a beginning idea into a specific idea? Try to do this for all beginning ideas. If you get stuck, flag the idea for later treatment (see steps below). Also consider if you have articulated all the concepts and broad concepts behind the idea. Filling in these blanks may help you view the innovation opportunity from a different perspective, leading to more ideas (Exhibit 28.2).

You don't need to fill in any blanks in the *Beginning Ideas* column, unless you think of more to add.

Steps—Treatment

Scenario: Idea Treatment takes an unpromising idea, then shapes and strengthens it into a practical and valuable idea. For example, one fanciful idea for publicizing your company's innovation program is placing one of your new products in a Hollywood movie. Although this may seem unattainable at first, shaping and strengthening the idea might make it possible, or bring to mind associated ideas that are more realistic.

1. List the Idea Constraints

Choose an idea that has inherent constraints (cost, legality, timelines, technical feasibility, etc.). List all the constraints relative to the idea.

Idea Harvesting - After

Job To Be Done: Publicize the success of our innovation program

Broad Concepts	Concepts	Specific Ideas	Beginning Ideas
Demonstrate that innovation can be scaleable, reliable, and repeatable	External publicity	Work with PR on press releases	Throw propaganda out of a plane
		Deployment case study after one year	
		???	Product placement in a Hollywood movie
		Speak at next year's Innovation World Conference	
		Submit article to *Industry Week*	Trade magazines
		Deployment leader posts to 2-3 innovation blogs per week	Internet blogs
	Internal publicity	Feature innovation projects in company newsletter	Project case studies
		CEO walks the floor marketing the program	
		Annual fair features most successful projects	Project fair
		Project leaders invited to group lunch with CEO	Recognition program
		Put thermometer board in lobby showing revenue increases from innovation	

EXHIBIT 28.2 (Downloadable). For the innovation deployment example, we added four specific ideas spawned from associated beginning ideas, and also filled in the broad concept.

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One benefit of Idea Treatment is that it allows the innovation team to tailor the proposed ideas to fit specific organizational strategies. For example, if company policy is not to make any products that are lethal if accidentally ingested, you may need to *shape* your ideas to make sure they fit this requirement.

2. Shape the Idea

Brainstorm ways you could overcome each constraint (Exhibit 28.3). Don't pass judgment on any suggestions; some will be viable, while others may spark different ideas down the road. Let your creativity shape the original idea into a more viable option.

Shaping an idea helps you overcome constraints that make the idea implausible. *Strengthening* an idea leads you to make the idea more appealing to stakeholder groups.

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3. Strengthen the Idea

Now take the same idea and strengthen it by making it more appealing to stakeholders. Instead of listing individual stakeholders, identify a few groups segmented by organizational level, customer type, or whatever makes sense.

Idea Treatment - Shaping

Job To Be Done: Publicize the success of our innovation program

Idea: Product placement in a Hollywood movie

Idea Constraints	Shape the Idea
We don't know anyone in Hollywood	Call the producers directly Work with independent producers Ask our employees if they know someone in Hollywood
Product placement costs a lot of money	Enter contests sponsored by movie companies Create a YouTube video
Mismatch between product market and movie audience	Get product placement in company training videos Bring the movie to consumer homes (DVD, pay-per-view) Sponsor screening of the movie for clients or potential clients Create an animated cartoon featuring the product
Need publicity sooner rather than later	Create a YouTube video Advertise in movie theaters

EXHIBIT 28.3 (Downloadable)

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Idea Treatment - Strengthening

Job To Be Done: Publicize the success of our innovation program

Idea: Product placement in a Hollywood movie

Stakeholder	Point of View	Strengthen the Idea
Executives	Understand WIIFM (What's in it for me?)	Show the potential for high profile publicity
	Understand ROI (return on investment)	Gather the data that shows ROI
	How much control do I have over this?	Personal screening before the movie is complete
	Who else is doing this already?	Arrange benchmarks with competitors
	Why isn't anyone else doing this?	Pilot the idea and replicate if it works
	How does this link to the company strategy?	Do a strategic planning review with an expert
Managers	What are the resources needed from me?	Offer a part as a walk-on or extra in the movie
	How much will it cost?	Gather costs from the ROI developed for the executives
	How much control do I have over the finished placement?	Personalized preview
	Why do/don't you want to feature my product?	Design a time line or schedule for all major projects
Employees	How much extra work is this going to be for me?	Offer a part as a walk-on or extra in the movie
	How are we going to be compensated?	Offer overtime and free tickets to movie
	Why do/don't you want to feature my product?	Design a time line or schedule for all major projects
	How is this going to help with my personal development?	Participants in the project can add this to their resume

EXHIBIT 28.4 (Downloadable)

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For each group, make a list of the stakeholders' point of view relative to the idea. In other words, what are the wants and needs of the stakeholders in that group? What do you think their concerns and objections will be? Then, generate ways to improve the idea so that it meets the needs (or addresses the objections) of each stakeholder group (Exhibit 28.4).

When you've finished Idea Harvesting and Treatment, you should have increased the yield of viable ideas that can become solutions for your innovation opportunity. You can further evaluate these ideas using techniques like Six Thinking Hats (Technique 29) or Pugh Matrix (Technique 36).

Six Thinking Hats

Evaluate your solution ideas in six different ways.

Six Thinking Hats leverages different points of view to help your team evaluate its best ideas. The approach works especially well with controversial ideas, such as innovative new business models, because it makes time for objectivity and subjectivity, as well as for evaluating the pros and cons of the proposed solution.

Although you can use Six Thinking Hats to generate ideas, it works equally well after you've narrowed down the list of ideas to a couple of viable options. It can be tricky to keep the group on track, so you may consider additional training in this technique, or bringing in an experienced facilitator.

Background

Six Thinking Hats is a lateral thinking exercise created by Edward deBono in the 1980s. During the exercise, team members wear (role-play) a metaphorical hat that represents a mode of thinking (Exhibit 29.1):

1. *Black* is judgmental, warning of difficulties, dangers, and pitfalls.
2. *Yellow* remains optimistic, probing for the positive value and benefits of the idea.
3. *White* calls for information known or needed, is emotionally neutral, and seeks the facts.

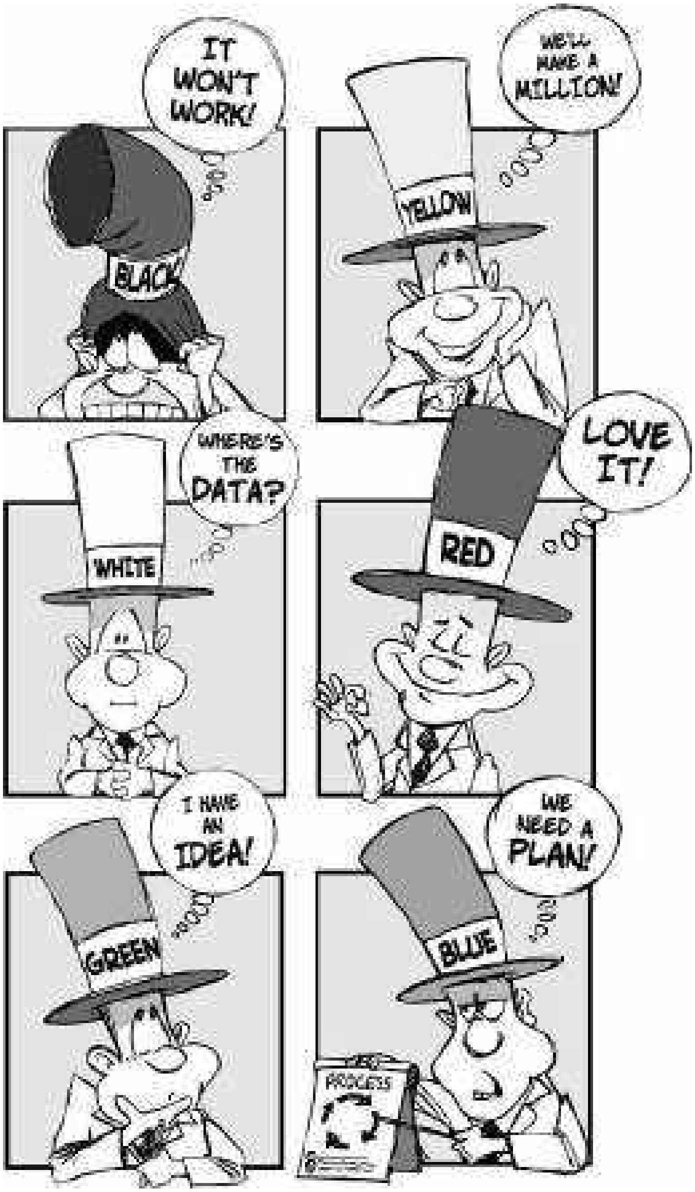

EXHIBIT 29.1 Thinking Hat. Each hat represents a different orientation to solving problems.

4. *Red* articulates emotion, feelings, and hunches, without explanation or judgment.
5. *Green* encourages creative thinking, focusing on new ideas, possibilities, and alternatives.
6. *Blue* represents process-based thinking, and is worn by the facilitator at all times.

Thus, if everyone on the team is wearing the white hat, all comments and suggestions must be factual or based on data. During this time, no emotional (red hat), judgmental (black hat), optimistic (yellow hat), or outlandish (green hat) thoughts are allowed.

Although Six Thinking Hats can be a lot of fun, it's also empowering because it makes use of every team member's intelligence and experience, and encourages constructive criticism. As a result, the team's performance and results are strengthened.

Steps

Scenario: GreenJeans Software sells computer programs to track household income and expenses. The company is looking to grow its market share, and wants to explore the feasibility of offering its service via the Internet. While most team members are in favor of this idea, they need to convince upper management that the service can be offered securely, and that it can be reliably supported with minimal restructuring.

1. Assign Facilitator and Establish Ground Rules

During Six Thinking Hats, the blue hat is worn by the facilitator. This person's role is to remain neutral and guide participants through the exercise. Before beginning, the facilitator should explain any ground rules, including the following:

- Reason for the meeting, which includes a recap of the JTBD (see Jobs To Be Done, Technique 1), and the key idea(s) the team will evaluate using Six Thinking Hats.

- Perspective of each thinking hat.
- Order in which the hats will be worn. Note that the order depends on the topic you're discussing, as well as participant familiarity with the topic and each other. For our example, the GreenJeans Software team will wear the hats in order of: White, Yellow, Black, Green, Red, and Blue.
- Time allotted to wear each hat. Typically 1 to 5 minutes per hat works well—except for the red hat, which should be limited to one minute or less.

Regardless of the sequence of hats, the facilitator must keep the team moving. Remember, the point is to view the idea from all six perspectives and not to remain fixated on any one point of view.

2. Assign a Scribe

Ask someone who will not participate in the exercise to take notes. Since the exercise is entirely verbal, this role is important for documenting the group's discussion and the outcome. Alternatively, you could provide a pad of sticky notes to each participant, and ask them to post their comments on a flip chart or white board as the exercise proceeds.

3. Assume the White Hat

Everyone puts on the first hat, depending on the order you've chosen. In our example, the team assumes the white hat, which represents objectivity. Participants must stick to factual information, including making notes of any additional information needed to evaluate the proposed idea. Key questions for the group to consider include:

- Why do we think this idea will fulfill the JTBD?
- What data do we have in support of the idea?
- What information do we need before we can move forward?

During the White Hat discussion, the GreenJeans team reviews the proposed specifications for the new online service, and the recommended modifications to the company's existing infrastructure.

When wearing the white hat, don't get sidetracked with fact-checking or arguments about whether something is true—validity can be confirmed later.

4. Assume the Yellow Hat

Moving on to the yellow hat, the team explores the positive aspects of the idea. In addition to articulating the value of the proposed solution, yellow hat thinking can result in a refined vision that takes the idea in a new direction. Key questions include:

- What are the benefits of this idea?
- Why do we like this idea?
- What's the best possible scenario that could result from implementing this idea?

For example, an online service for tracking household expenses could lead GreenJeans Software to abandon its packaged programs, drastically reducing manufacturing and distribution costs. It could also be a differentiator from the competition if the service remains on the cutting edge of web-based technology.

The Six Thinking Hats are about modes of behavior, not categories of people.

5. Assume the Black Hat

Next, participants wear the black hat to uncover risks and adverse outcomes that could result from implementing the idea. Caution, logic, and critical thinking are the keys to making the black hat session effective. A few critical questions include:

- What's the downside to this idea?
- What are the idea's weaknesses?
- What could go wrong if we implement this idea?

In our example, the GreenJeans team discusses security and cost concerns while wearing the black hat. Since these concerns are also held by management, the discussion serves a dual purpose by preparing everyone for the objections they will face when presenting the solution to management.

Beware of overusing the black hat. The goal is to flag potential failure points, not to generate alternative ideas or abandon the proposed solution altogether.

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6. Assume the Green Hat

The team puts on the green hat, which represents creativity and forward thinking. Since the green hat follows the yellow and black hats, questions to ask the team include:

- How can we improve on the idea?
- How can we make the idea more practical or appealing?
- How do we package the idea?

During the green hat discussion, the GreenJeans team suggests ways to overcome security concerns about the online service and how to differentiate the service from the competition.

If you're using Six Thinking Hats to *generate* new ideas, instead of evaluating a few key ideas, start with the green hat.

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7. Assume the Red Hat

The red hat gives everyone the opportunity to express opinions in a nonjudgmental forum. While wearing the red hat, participants don't have to justify or prove their statements; it's the time to be subjective. "How do you feel?" is the key question. Alternatively, you can use the red hat discussion to vote on any idea variations that came up during the green hat session.

If the topic of discussion is controversial, start with the red hat to get everyone's emotions out in the open. In fact, until this happens, you may not get the focus you desire on other points of view.

8. Assume the Blue Hat

At the end of the exercise, everyone dons the blue hat to outline next steps, assignments, and the like.

Resource

de Bono, E. *Six Thinking Hats*. Boston, MA: Little, Brown, 1999.

PART III

DEVELOP THE SOLUTION

Most organizations go about refining their products and services—making them better—without first questioning their legitimacy. But if you've gotten this far in the innovation process, then you've already legitimized your new solutions by (a) making sure they're well defined and (b) making sure they've passed through a rigorous yet expansive ideation process.

This third phase of innovation transforms your great ideas from the white board into workable models. The questions become:

- What functions will it perform and how do I design it?
- How will I assess how good it is?
- What alternatives do I have?
- Can I make my solution invincible, and manage the risk of trying?

First you *formulate the design* by specifying performance targets for all aspects of your new solution, including the processes that will make it. Use the Performance and Perception Expectations technique to gather customer expectations about your product or service. Then use these techniques to generate and further refine your initial design concepts: Axiomatic Design, Function Structure, Morphological Matrix, and TILMAG.

The next task is to *prioritize and select a design* by filtering through a number of design concepts to the point where just one is pursued for further development. Two techniques are very helpful in this regard: Paired Comparison Analysis and Pugh Matrix. You can also use both of these techniques to test how well the output of an idea session stands up to customer outcome expectations upstream in the innovation process.

Once you know which solution you'll carry through to commercialization, it's time to *optimize the design*. For this see these design-optimization techniques: Process Capability, Design Scorecard, Design FMEA, Discrete Event Simulation, and Rapid Prototyping. Also see Robust Design, which can help make sure your new solution functions as intended regardless of uncontrollable events and circumstances.

Performance and Perception Expectations

Identify what customers want in your solution.

Performance and perception expectations, and the degree to which they are satisfied, form the basis of customer satisfaction with your products and services. For example, people who drink diet soda expect it to have a certain caloric content (performance expectation), but also want it to taste good (perception expectation). If the soda fails in either regard, customers may move to a competing solution that better meets their expectations.

Just as outcome expectations provide actionable substance for a job to be done, performance and perception expectations provide actionable substance for innovating a specific solution (product, service, process or business model). At this point in your innovation project, you should have a solution in mind. Designing the solution begins with understanding and articulating performance and perception expectations from the customer's point of view. To be successful, you'll need at least a modest understanding of how to gather voice-of-the-customer data via surveys, focus groups, and interviews.

Background

Customers have three types of expectations—outcome, performance, and perception. Outcome expectations (see Technique 2), are specific to the *job* the customer wants to get done. Performance and perception expectations, on the other hand, are specific to the *solution* that will get the job done. All three types of expectations are closely aligned; however, performance and perception expectations provide more clarification than outcome expectations.

Performance expectations are objective, unambiguous, and measurable expectations customers have about a product or service. They must have an operational definition, a unit of measurement, and a desired target range. Examples include the weight of a product, service delivery lead times, the product or service cost, and such product quality characteristics as durability, reliability, maintainability, and so on.

Perception expectations are subjective, ambiguous, and difficult-to-measure characteristics desired by customers. Examples include ease of use, look and feel, ease of doing business, and timeliness. Many of these expectations can become performance expectations after establishing operational definitions and associated measurements.

Defining customer expectations as either performance or perception allows us to avoid confusion around the *voice of the customer* and the many labels often applied to it—customer needs, wants, requirements, standards, critical-to-quality (CTQ), critical-to-satisfaction (CTS), delighters, and so on.

Similarly, customers are traditionally classified into confusing or misleading categories—internal customers, external customers, partners, patients, clients, patrons, guests, fans, and so on. In reality, all customers can be simply defined based on their role as an *end user,* a *broker,* or a *fixer.*

It's important to understand all three types of customers so you can consider each group when designing your innovation. Once you've done this, you can determine how best to meet each group's expectations through the use of such techniques as Axiomatic Design (Technique 31), Function Structure (Technique 32), and TILMAG (Technique 34).

Steps

1. Define the Focus

With many products and services, design occurs at the subsystem level where many *target* components and processes interact to create the *final* solution. Thus, when you're defining performance and perception expectations, you need to agree on which part of the solution—target or final—is the focus.

Additionally, make sure your team has the same definition in mind. For example, what do you think of when you hear the word *prescription*? Do you picture a bottle of medication or a piece of paper? Both have very different features and functionality, and different end users. If you were part of a team charged with designing a better prescription process, you would certainly want everyone to have the same definition.

2. Identify Customers

It's important to identify the customers for your solution by type—each will have different performance and perception expectations. As we mentioned earlier, customers fall into three general categories:

1. *End Users*: The ones for whom a solution is created; they use products and services to get a certain job done.
2. *Brokers*: These are intermediaries, such as retail stores, car dealers, pharmacists, and travel agents. Brokers make products and services accessible to end users, and also transmit customer expectations to the solution provider to improve the value of the solution.
3. *Fixers*: These are individuals or organizations that improve the product or service during its life cycle through repair, modifications, corrections, additions, or deletions to better meet end-user expectations.

Keep in mind that customer roles are dynamic—they are determined by the customer's relationship with the solution at a given moment. For instance, the end user in a restaurant is the person(s) having a meal. A waiter is a broker, unless that waiter comes in on his night off to enjoy dinner, in which case he becomes an end user. A restaurant critic having a meal is an end user but also a fixer because her comments may influence the restaurant to provide a better product or service.

Think carefully about who the end users of your solution really are. For example, the end users for an airplane engine (target solution) are aviation manufacturing workers. The end users for an airplane (final solution) are airline employees. Passengers are actually end users of the transportation solution offered by the airline.

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3. Gather Expectations

For each customer segment, identify performance (objective and measurable) and perception (subjective) expectations. You can gather this information using customer surveys, focus groups, or interviews. The specific approach will depend, in part, on the level of innovation in your solution—it would be difficult for people to complete a survey, for instance, on a completely new offering they have never seen, although a survey would be in order if you're simply adding new features to a well-known product.

For the most part, focus groups work well because you can ask open-ended questions and the group dynamic usually generates more discussion than individual interviews. Ask participants to fill in the blank for this question: "A satisfying solution is one that is ____________." Note that if you change the wording slightly to "A satisfying solution is one that *has* ________________," you'll end up with a list of functional attributes instead of expectations. Similarly, if you ask, "A satisfying solution is one that *does* ______________," you'll uncover the job to be done.

Typically, performance and perception expectations fall into five categories: ease of use, timeliness, cost, options, and certainty, which refers to a series of quality measures such as reliability, maintainability, and so on.

It can appear sometimes that perception expectations are synonymous with outcome expectations, but they are not. While they can seem similar to the untrained eye, perception expectations relate specifically to the solution at hand (as do performance expectations), while outcome expectations are solution-neutral and relate to the job to be done.

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4. Classify Expectations by Type

Once you've gathered customer expectations, categorize each one as either a performance or perception expectation, and determine how you will measure it. For performance expectations, establish the operational definition, unit of measure, and targets for each of the measurements. For perception expectations, use a surrogate measure that is strongly correlated to the expectation.

Performance and Perception Expectations for VOIP Service				
End User Expectations	Type	Measure	Units	Target
Service always available	Performance	Availability	Percent uptime	>99.9%
Easy to use service	Perception	Effort	Numbers to dial	<12
Clear calls	Perception	Standardized clarity test	Number of words identified	>98%
No background noise	Performance	Static, clicks or hissing during test calls	Percent of call time with defect	<1%
Friendly service	Perception	Customer satisfaction	Rating	>90%
Fast technical problem resolution	Performance	Hold time Time to resolve issue	Minutes	90% <2 Min. 90% <15 Min.
Low cost	Performance	Cost per month	Dollars	50% of standard charges from local land line phone co.
Convenient to use	Perception	Access from computer, handheld device, phone	Service accessible from device	100%

EXHIBIT 30.1 (Downloadable)

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For example, Exhibit 30.1 shows end user performance and perception expectations for a Voice Over Internet Protocol (VOIP) service that allows people to make phone calls via the Internet.

For any solution, a performance expectation such as "reliability" would likely be tracked with a metric called "mean time between failures." This metric, in turn, is included in your Design Scorecards (Technique 39) for that solution.

5. Align Expectations between Customer Segments

After you have a thorough understanding of the expectations for each customer type, look for potential conflicts of interest and determine a way to minimize or resolve these issues. For instance, end users may desire a level of customization that makes it more difficult for fixers to service a product. In this case, the provider may choose to offer fewer customization options to end users in order to meet the fixer expectation of *easy to repair*.

Although it's critical to meet the expectations of end users, be careful not to alienate brokers or fixers along the way. The most successful organizations are able to align expectations between different customer segments so that conflicts are minimized.

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6. Translate Expectations into Design Requirements

Use other techniques, such as Axiomatic Design (Technique 31), to convert your customer's expectations into a viable design starting with functional requirements.

Performance expectations are the *Key Performance Indicators* (KPIs) on which you'll focus your design and optimization efforts, and which you will track over time with your Design Scorecards (Technique 39) and/or Process Behavior Charts (Technique 52).

Resource

For more on how to identify customer expectations, see:

Lawton, R. *Creating a Customer-Centered Culture: Leadership in Quality, Innovation, and Speed*. Milwaukee, WI: ASQ Quality Press, 1993.

Axiomatic Design

Transform what customers want into the best products and services.

Axiomatic design is the process by which you translate your customers' performance and perception expectations, or *customer attributes* (CAs), into *functional requirements* (FRs), then *design parameters* (DPs), then *process variables* (PVs). It's especially helpful when working with complex systems that contain extremely large numbers of FRs and, consequently, large numbers of DPs and PVs—sometimes numbering beyond the thousands. A jumbo jet or a powerful software application are examples of this.

The progressive axiomatic design activity ensures that the final solution is the best design, delivers what the customer needs, and can be reliably manufactured or delivered. While axiomatic design can be readily understood at a high level, applying it to complex systems (its purpose) requires an expert who has extensive education and experience with the technique.

Customer attributes are synonymous with performance and perception expectations, so see Technique 30 to help with forming the front end of your axiomatic design activity.

Background

Two axioms underlie axiomatic design—the independence axiom and the information axiom.

The *independence axiom* asserts that all FRs and their associated DPs remain independently attached; therefore, if you adjust a DP to satisfy an FR, you do this without affecting other FRs. Designs that don't satisfy the independence axiom are called *coupled*. Designs that do satisfy the independence axiom are called *uncoupled* or *decoupled*.

You always want to produce either uncoupled or decoupled designs because this keeps a design as modular and independent as possible. Therefore, if any one part of a system malfunctions, the unwanted consequences do not propagate throughout the entire system. Also, independent designs enable the segmentation of engineering work when dealing with very complex and extensive systems.

The *information axiom* is based on information theory, which essentially says that the best design is the one with the least information content—while also satisfying the independence axiom. Information content is defined in terms of probability: the more likely the design is to reduce the influence of variation from process parameter changes, different customer-usage conditions and repeated use, the better it meets the information axiom.

A design that meets the information axiom is called a *robust design* (see Technique 38) because it maximizes the probability that it will meet its specifications (process variables, or PVs) on an ongoing basis. For example, a process variable like *tensile strength* or *data-entry errors* can function as intended along a spectrum from zero to absolute perfection; but in reality it always functions somewhere in between the two extremes.

Axiomatic design is credited to Dr. Nam Pyo Suh, a professor of mechanical engineering at MIT.

In establishing designs that meet the independence and information axioms, the axiomatic design practitioner engages in a demanding and disciplined process of *zigzagging* between FRs, DPs, and PVs, as shown in Exhibit 31.1. In essence, this zigzagging is the process by which FRs are translated into their corresponding DPs and PVs—all the while maintaining as much independence as possible, and fulfilling the information axiom such that the design performs to its specifications as often as possible.

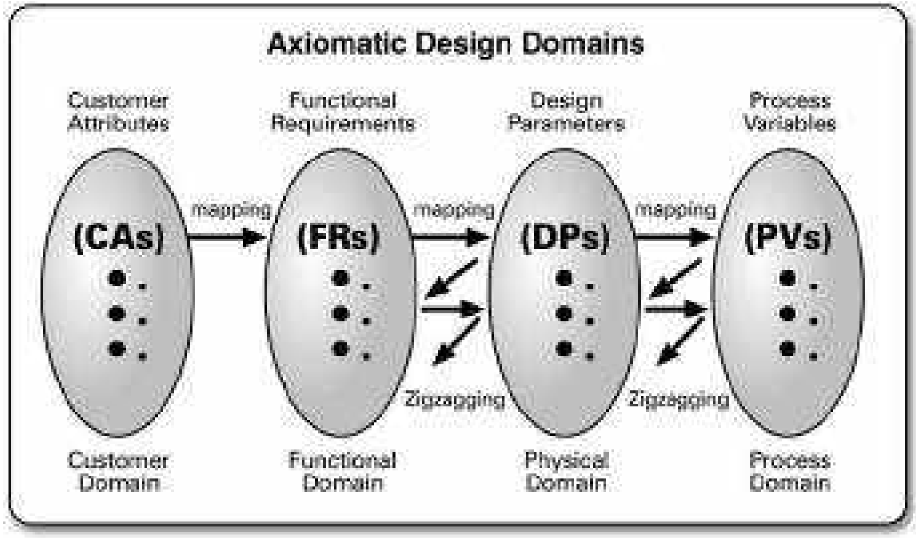

EXHIBIT 31.1

Independence Axiom

We can illustrate the independence axiom by showing the relationship of two DPs and two FRs—knowing that for such a simple 2×2 design, one would not need axiomatic design. But since axiomatic design is so complex in practice, this is the best way to illustrate how it works at a high level. The examples that follow are highly stylized for illustration purposes; in reality, they would be more extensive and detailed.

Coupled Design

Looking at Exhibit 31.2, we see that both water flow (FR1) and temperature (FR2) are influenced by both the angle of the cold valve (DP1) and the angle of the hot valve (DP2). The design is therefore coupled. Taking a service example, both the quality of a new hire (FR1) and the speed of the hiring process (FR2) are influenced by the number of interviewers involved (DP1) and the method of scheduling interviews (DP2).

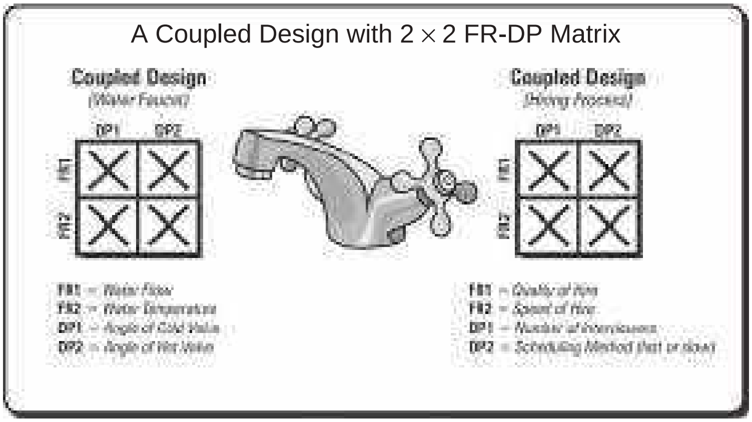

EXHIBIT 31.2 A coupled design is one in which all functional requirements cannot be achieved independently by adjusting design parameters without affecting other functional requirements.

Decoupled Design

A decoupled design is preferred over a coupled design. Looking at Exhibit 31.3, we see two simple FRs and DPs in a pulley-and-belt design for using the power generated from a car's crankshaft to run its air conditioner. The belt cannot slip sideways (FR1) and cannot slip forward or backward (FR2) as the system operates. In a decoupled design, both FR1 and FR2 are influenced by

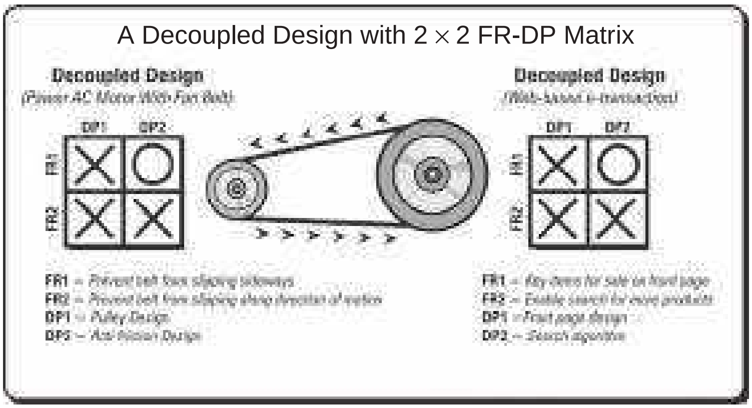

EXHIBIT 31.3 A decoupled design is one in which all functional requirements can be achieved independently by adjusting design parameters. However, at least one design parameter affects two or more functional requirements.

the pulley design (DP1), but only FR2 is influenced by the antifriction design (DP2).

Also shown in Exhibit 31.3 is a web-based e-transaction where both FR1 and FR2 are influenced by DP1, but only FR2 is influenced by DP2. In other words, the home page design (DP1) determines what shows on the home page (FR1) and enables further searching (FR2); but the search algorithm (DP2) does not determine what is showing on the home page (FR1), and only enables the identification of additional products for sale (FR2).

Uncoupled Design

An uncoupled design is preferred over a decoupled or coupled design. Looking at Exhibit 31.4, we see two FRs and two DPs involved in a faucet design, where the flow rate valve (DP1) influences water flow (FR1), and the hot/cold mixing valve (D2) influences water temperature (FR2). The DP1/FR1 combination is totally uncoupled from the DP2/FR2 combination, thereby ensuring that each FR/DP combination can stand alone.

We can further illustrate an uncoupled design in the service world by looking at two DPs and two FRs related to purchasing a product online. In Exhibit 31.4, the shopping cart design (DP1) influences friendly checkout

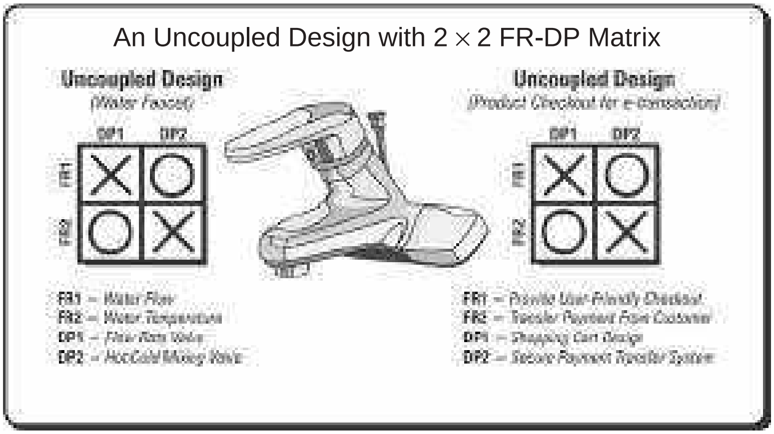

EXHIBIT 31.4 An uncoupled design is one in which each functional requirement is independently achieved by a corresponding unique design parameter.

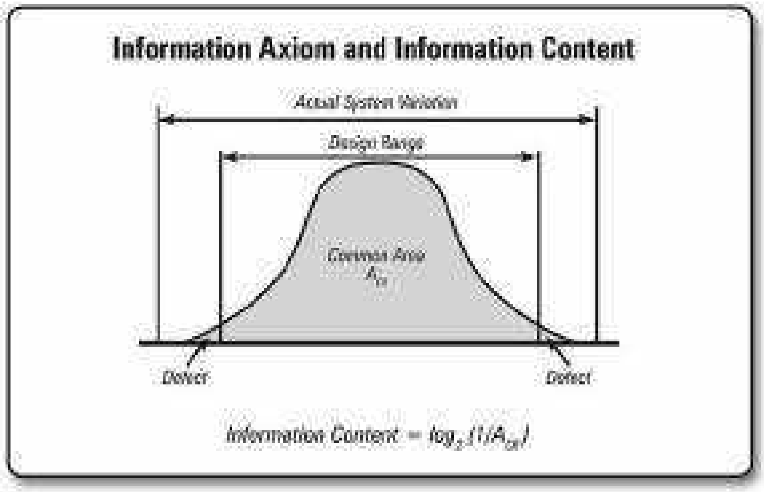

EXHIBIT 31.5

(FR1), and the secure payment transfer system (DP2) influences payment from the customer (FR2).

Example—Information Axiom

The information axiom can be best explained with the help of Exhibit 31.5, which shows that the success probability of any design can be calculated by using the design range (usually tolerance) and the system range (described by process variation). The information content of the design is calculated by the area under common range (A_{CR}) and is given by the following equation: Information content = I = $\log_2$ (1/A_{CR}).

It's clear from the equation that if the A_{CR} = 1, or the design range is equal to the system range, then information content equals zero—indicating that the design is as good as it could be. If the information content is greater than zero, then risk of defect or malfunction is present and, therefore, the design may not be optimal or the best it could be.

This also means that any design is good as long as the system variation range is within the design range, irrespective of process variation. But if the system range is beyond the design range, then defects, errors, or malfunctions will occur. The extent to which the system range exceeds the design range is the extent to which you are exposed to potential failures.

Your first objective with axiomatic design is to make your design as independent as possible with reference to functional requirements. After this you would make it as robust as possible, as per the information axiom, using such techniques as Robust Design (Technique 38), Design FMEA (Technique 40), and Mistake Proofing (Technique 49).

Steps

1. Determine Customer Attributes

Customer attributes (CAs) can be collected in any number of ways. The key to know is that in axiomatic design, performance and perception expectations are equivalent to CAs, and they are what customers expect from a specific product or service. In other words, CAs come into play when you have a specific solution in mind, and you need to design it in the best way.

2. Translate Customer Attributes into Functional Requirements

This step entails moving from the language of customers into the language of the designer, or what the solution will do. While the customer might say, "I want it to look good," the designer might translate this into "I need it to be a transparent blue color." The customer wants to arrive safely on time on a cross-Atlantic flight, so the designer needs 200,000 pounds of available thrust to get him and the other passengers there as they wish.

This step is also when the designer identifies any *design constraints* that need to be addressed. Such constraints (cost for instance) represent boundaries for acceptable design solutions—or realities you have to work around as you flow your functional requirements (FRs) into their corresponding design parameters (DPs) in the next step.

There are two kinds of constraints: *input* and *system*. Input constraints are imposed as part of the design specifications. System constraints are imposed by the system in which the design solution must function.

---

3. Translate Functional Requirements into Design Parameters

Next the designer translates each FR into a corresponding set of DPs in the physical domain. These DPs are your critical material/service targets and specifications. For instance, if the FR is to make a part blue in color, then the DP for that FR might be to target 0/0/255 (blue) on the RGB color scale, with a tolerance of plus or minus five points on the RGB scale.

4. Map Design Parameters to Process Variables

The final step of axiomatic design ensures that you map your design specifications to your process, so it can produce and deliver your new solution, time after time, without mistake. Using the same approach used in translating FRs into DPs, the designer translates each DP into a set of corresponding process variables (PVs). Therefore, if the DP is 0/0/255 on the RGB scale, plus or minus five, then what are the variables in the process that make the part meet this specification? These are the related PVs.

Note that the process entailed in translating FRs into DPs and DPs into PVs is done hierarchically and iteratively—starting at a high level of detail, then decomposing into finer levels of detail (see Exhibit 31.1). This is the zigzagging aspect of axiomatic design, as FRs are decomposed into DPs, and as DPs are decomposed into PVs. At each level, design decisions are made for each domain, which is zigging. Then the design team backtracks to the functional domain and determines the next level down, reflecting all the design decisions across the domains at the level above. This is the zagging part.

While zigging and zagging, the designer ensures that each set of lower-order FRs, DPs, and PVs retains as much independence as possible and also fulfills the information axiom.

Resources

For more reading and knowledge, see:

El-Haik, B. *Axiomatic Quality: Integrating Axiomatic Design with Six Sigma, Reliability, and Quality Engineering*. Hoboken, NJ: Wiley Interscience, 2005.

Pyo Suh, N. *Axiomatic Design: Advances and Applications*. New York: Oxford University Press, 2001.

Function Structure

Identify how the solution functions in its whole and its parts.

Function Structure breaks the intended overall design function into cohesive and naturally workable subfunctions that lend themselves well to error-free development. For example, you would use Function Structure when designing a refrigerator to move from the functional requirement (control freezer temperature at −18 C) to the design parameter (turn compressor on or off when air temperature is higher or lower than the set temperature).

The Function Structure technique is employed when you need to create design concepts and are translating functional requirements into design parameters. But since Function Structure doesn't necessarily address the independence of requirements and parameters, it's most effective when applied in conjunction with axiomatic design (see Technique 31). Function Structure is best applied with the help of a qualified engineer.

Steps

Scenario: To demonstrate Function Structure, we'll look at the design for an automatic hair washing machine—a device that would take the place of the person who preps you for a haircut when you visit a salon.

1. Clarify the Design Problem

What is the overall intent of the design, or the function the design must perform? Write the function in the middle box of a *Function Structure*

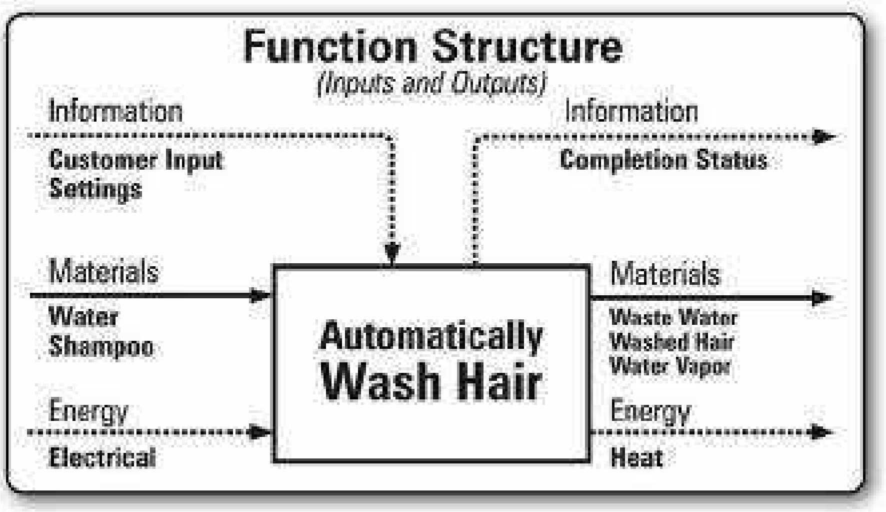

EXHIBIT 32.1

diagram (Exhibit 32.1). The intent of our example system is to *automatically wash hair.*

2. List the Inputs and Outputs for the Function

To the left of the function, list the inputs—what does the system need to perform its overall function? To the right, list the outputs—what will the system deliver (both intended and unintended)? List all inputs and outputs under the categories of *material, energy,* or *information.*

Exhibit 32.1 shows the inputs and outputs designated for the automatic hair-washing system.

3. Divide the Overall Function into Identifiable Subfunctions

Now ask, "What are the corresponding subfunctions needed to fulfill the main function?" List these subfunctions below the main function, connecting them in sequential order once you have listed them all (Exhibit 32.2). Keep in mind the following:

- Subfunctions are performed through some physical process or activity that is executed by a system or mechanism.

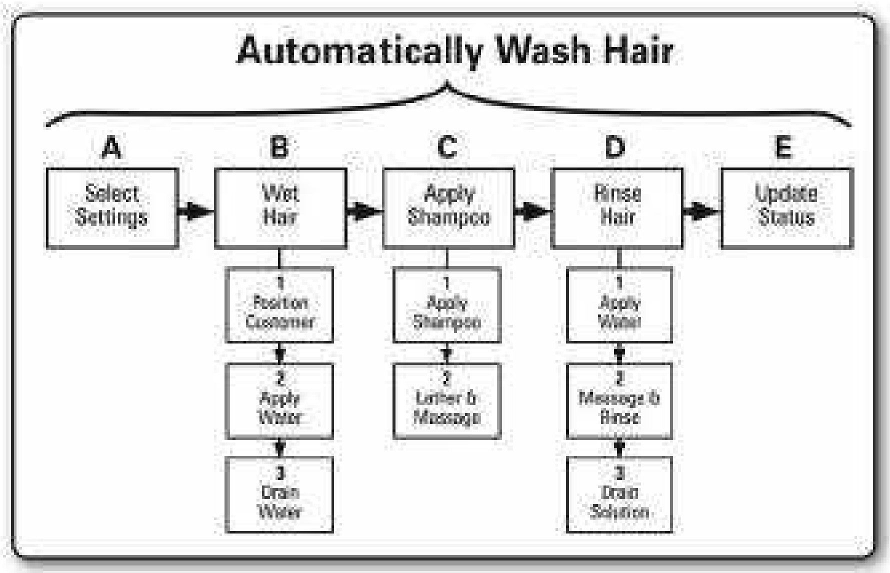

EXHIBIT 32.2

- Subfunction statements should consist of a noun and a verb (e.g., decrease pressure, register customer, rinse hair).
- You can keep dividing subfunctions until they cannot be subdivided further, but this isn't very practical. Only identify subfunctions to an appropriate level based on the type of design.
- Each subfunction should fulfill a customer need—either an outcome expectation (see Technique 2) or a performance or perception expectation (see Technique 30).).

4. Develop Possible Solutions for Each Subfunction

Once you've developed your Function Structure diagram to the appropriate level, the final step is to ideate possible solutions (design options) for each subfunction. You can combine or further subdivide the subfunctions as needed. Exhibit 32.3 shows the automatic hair-washing function broken down into subfunctions with the exchanges of material, energy, and information indicated. This can guide the ideation of solutions for each subfunction.

EXHIBIT 32.3

When seeking subfunction solutions, use any of the more advanced ideation techniques in this book, as simple brainstorming can leave you void of innovative ideas. During this process, stay focused on solutions at the subfunction level. For example, ask:

- How can I select settings?
- How can I wet hair?
- How can I apply shampoo?
- How can I rinse hair?
- How can I update status?

For our automatic hair-washing subfunctions, a list of possible solutions or design options are shown in Exhibit 32.4.

If you're satisfied with the list of possible solutions, move on to Morphological Matrix (Technique 33) to see how the subfunction solutions can be combined to create an innovative design. If you're still struggling to surface

Possible Design Solutions

Subfunction	Design Options
A (select settings)	Device control panel
B1 (position customer)	Reclining chair; Massage table; Lean forward; Fitted hood
B2 (apply water)	Spray nozzle; Water reservoir; Fill hood with water
B3 (drain)	Sink drain; Suction pump
C1 (spray shampoo)	Spray nozzle; Soapy solution; Deliver via bristles (see D2)
C2 (massage & lather)	Rotating bristles; Jets; Inflate inner hood lining
C3 (drain)	Same as B3
D1 (spray water)	Same as B2
D2 (massage & rinse)	Same as C2
D3 (drain)	Same as B3
E (update status)	Green flashing light; beeping sound

EXHIBIT 32.4

innovative design options, try TILMAG (Technique 34) or HIT Matrix (Technique 16).

Resource

For a full treatment of Function Structure, see:

Pahl, G., and W. Beitz. *Engineering Design: A Systematic Approach*. New York: Springer-Verlag, 1999.

Morphological Matrix

Generate solution concepts by combining design alternatives.

Morphological Matrix combines design options at the subfunction level to help you come up with new solutions. For instance, if you are building a self-driving car, you have many ways to design the car's subfunctions (GPS navigation, voice recognition, external sensors, etc.). Morphological Matrix enables you to determine all possible design solutions, including approaches that combine design options in ways you might not have thought of before.

You can use Morphological Matrix after you have identified your system's subfunctions with the Function Structure technique. Or, if you're following axiomatic design, Morphological Matrix will help you translate functional requirements into design parameters. Although the technique itself is easy to use, the team must have significant expertise related to the system to understand its subfunctions and evaluate the design options.

The premise of the term *morphology* is that by understanding the underlying parts of a system (the system's subfunctions), you will better understand the entire system (the system's overall function, or job to be done). Thus, when you look at a system's morphology, you are essentially asking, "What parts make up the whole?"

Steps

Scenario: In Function Structure (Technique 32), we determined a list of design options for an automatic hair washing machine. We can use Morphological Matrix to combine these options into possible solutions at the subfunction level.

1. Determine the System's Subfunctions

For simple designs, you can brainstorm a list of subfunctions. More complex systems require the use of Function Structure (Technique 32) or axiomatic design (Technique 31). For process-based innovations, a Process or Value Stream Map (Technique 46) will help you identify subfunctions, which may correspond to steps in the process.

Subfunctions should comprise the system as a whole, but should not be so granular as to overlap each other.

2. List the Design Options for Each Subfunction

Try to list at least two but no more than six design options for each subfunction; fewer than two options leaves no alternative routes through the matrix, and more than six makes it difficult to evaluate without the aid of a computer. Don't assess the options at this point but merely document them.

Unlike TILMAG (Technique 34), you can compare more than two design options simultaneously using Morphological Matrix, which makes it a more practical technique for complex systems.

3. Assess Feasibility of Design Options

Evaluate the design options for initial feasibility and eliminate any options that conflict with design constraints or customer requirements (Exhibit 33.1). Note that removing one option may make other options moot (such

Morphological Matrix

Subfunctions	Option 1	Option 2	Option 3	Option 4
A (select settings)	Device control panel			
B1 (position customer)	Reclining chair	Massage table	~~Lean forward~~	Fitted hood
B2 (apply water)	Spray nozzle	~~Water reservoir~~	Fill hood with water	
C1 (spray shampoo)	Spray nozzle	Soapy solution	Deliver via bristles	
C2 (massage & lather)	Rotating bristles	Jets	Inflate inner hood lining	
D1 (spray water)	Spray nozzle	~~Water reservoir~~	Fill hood with water	
D2 (massage & rinse)	Rotating bristles	Jets	Inflate inner hood lining	
D3 (drain)	~~Suction pump~~	Sink drain		
E (update status)	Green flashing light	Beeping sound	~~Printout~~	

EXHIBIT 33.1 (Downloadable). After listing all design options in the matrix, take time to eliminate any that conflict with design constraints or customer requirements.

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as the *suction pump* option in our example, which wasn't needed after the team removed the *water reservoir* option).

4. Generate Design Concepts

Combine the remaining options to derive design concepts (solutions for each subfunction). Choose one option from each row until all possible combinations have been documented (Exhibit 33.2). Depending on the complexity of the matrix, you may need to do this on a computer since the total number of combinations is likely to number in the hundreds, or even thousands. In our example, there are 648 possible design concepts, calculated by multiplying the number of options in each row ($1 \times 3 \times 2 \times 3 \times 3 \times 2 \times 3 \times 1 \times 2$).

Morphological Matrix Design Concepts

	A (select settings)	B1 (position customer)	B2 (apply water)	C1 (spray shampoo)	C2 massage & lather)	D1 (spray water)	D2 (massage & rinse)	D3 (drain)	E (update status)
1	Device control panel	Reclining chair	Spray nozzle	Spray nozzle	Rotating bristles	Spray nozzle	Rotating bristles	Sink drain	Green flashing light
2	Device control panel	Massage table	Spray nozzle	Spray nozzle	Rotating bristles	Spray nozzle	Rotating bristles	Sink drain	Green flashing light
3	Device control panel	Fitted hood	Spray nozzle	Spray nozzle	Rotating bristles	Spray nozzle	Rotating bristles	Sink drain	Green flashing light
~~4~~	~~Device control panel~~	~~Reclining chair~~	~~Fill hood with water~~	~~Spray nozzle~~	~~Rotating bristles~~	~~Spray nozzle~~	~~Rotating bristles~~	~~Sink drain~~	~~Green flashing light~~
~~5~~	~~Device control panel~~	~~Massage table~~	~~Fill hood with water~~	~~Spray nozzle~~	~~Rotating bristles~~	~~Spray nozzle~~	~~Rotating bristles~~	~~Sink drain~~	~~Green flashing light~~
6	Device control panel	Fitted hood	Fill hood with water	Spray nozzle	Rotating bristles	Spray nozzle	Rotating bristles	Sink drain	Green flashing light
7	Device control panel	Reclining chair	Spray nozzle	Soapy solution	Rotating bristles	Spray nozzle	Rotating bristles	Sink drain	Green flashing light
8	Device control panel	Massage table	Spray nozzle	Soapy solution	Rotating bristles	Spray nozzle	Rotating bristles	Sink drain	Green flashing light
	[illegible]	Fitted	[illegible]	Soapy	Rotating	Spray	Rotating	Sink	[illegible]

EXHIBIT 33.2 (Downloadable). Here we see just a handful of the 648 possible design concepts for an automatic hair washing machine that resulted from using a Morphological Matrix.

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5. Assess Feasibility of Design Concepts

The final step is to complete a preliminary evaluation of the design concepts that, as before, can be based on physical or cost constraints. Be careful not to eliminate ideas prematurely; if in doubt, leave them in. You can conduct further assessment using a structured evaluation technique such as the Pugh Matrix (Technique 36). In our example, we eliminated design concept numbers 4 and 5 because the fitted hood option will not work with a reclining chair or massage table.

Additional Example

In addition to complex designs, you can use Morphological Matrix to help you list and evaluate options for any type of process or service. In Exhibit 33.3, we see how one group used the technique to generate options for a fund-raising program sponsored by a local restaurant. The number of options in the matrix is nowhere near exhaustive, yet together they produce 500 different combinations (5 × 4 × 5 × 5). However, instead of combining all the design concepts in a list, the team chose one option from each row until they had enough viable solutions.

Another Morphological Matrix Example

Subfunctions	Option 1	Option 2	Option 3	Option 4	Option 5
Determine sources of funding	Manny's Diner	Employees	Grants	Community	Other businesses
Identify participants	Employees	Employees and families	Local school athletes	Community groups	
Identify beneficiaries	Local schools	Homeless shelters	Programs for the physically challenged	Hospitals	Food banks
Determine types of activities	Bowling	Softball	Pledge walks/runs	Discount coupons for dinner at Manny's	Bake sale

EXHIBIT 33.3 (Downloadable)

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Resources

For many helpful references including information about morphological analysis from the technique's originator, Fritz Zwicky, see:

Swedish Morphological Society (www.swemorph.com).

For an interesting look at combining Morphological Matrix with axiomatic design concepts, see:

Weber, R., and S. Condoor. *Conceptual Design Using a Synergistically Compatible Morphological Matrix*. http://fie.engrng.pitt.edu/fie98/papers/1245.pdf.

TILMAG

Pair ideal solution elements to create new design concepts.

TILMAG uses pair-based analogical thinking to transform your innovation's main features into unique design concepts. For instance, if you paired the feature *renewable power* with *fast start-up,* you might think of a battery-free flashlight that you shake to turn on. The underlying principle used to make the flashlight work could also provide a solution for your innovation.

The principle behind TILMAG is that the human mind works best when comparing only two pieces of information at a time. Thus, TILMAG helps you create unique solutions without becoming overwhelmed by all the possibilities. However, the tool increases in complexity as the total number of features goes up. For this reason, it's best used at the subsystem level, or when you're comparing fewer than seven features.

If you use Function Structure (Technique 32) to identify your innovation's subfunctions, you can follow up with TILMAG to help you design a solution for each subfunction.

Background

The TILMAG method was developed by Dr. Helmut Schlicksupp, a German author and consultant known for researching and developing creativity techniques. TILMAG is a German acronym for what translates into English as "the transformation of ideal solution elements in an association matrix." It sounds like a mouthful, but it's actually quite simple:

- *Ideal Solution Elements* (ISEs) are the features or functions that your innovation must have to meet customer expectations (for more information, see Performance and Perception Expectations, Technique 30).
- The *association matrix* helps you transform ISEs into new and innovative design concepts that meet the performance and perception expectations for your solution. It does this by pairing each ISE with every other ISE, which may bring to mind associations that were not evident before.

Steps

Scenario: Let's assume that your innovation is a laptop computer that police officers use in their cars. Using TILMAG, you can discover which features of the laptop will allow you to meet expectations and whether you can meet them in innovative enough ways to distinguish your laptop from the competition.

1. Develop Ideal Solution Elements

Translate your innovation's performance and perception expectations into ISEs: brief, concise phrases that describe a particular feature or function customers will expect your product or service to have. Note that ISEs should not be descriptions of the solution (e.g., long battery life), but instead should be conceptual (e.g., renewable power) so you have room for creativity.

In our example, the team determined that the laptop ISEs were *renewable power*, *fast start-up*, *large screen*, and *small size*. Of course, you may have other ISEs for a laptop used in a police car, including wireless connectivity and durable components. But since the complexity of the tool goes up as the number of ISEs increases, we'll limit our example to only four ISEs.

The TILMAG matrix needs at least three ISEs, and works best with four to six ISEs. With three ISEs, that's a relatively quick three cells to work. With six ISEs, the matrix grows to 15 working cells.

TILMAG Matrix			
TILMAG	1 Renewable Power	2 Fast Startup	3 Large Screen
Small size 4	Self-winding watch Hybrid car battery Battery-free flashlight Electrochemical reaction	Portable radio	Fold-out map Roll-up mat Projector
Large screen 3	Solar panel Microscope	Big screen TV Scenery backdrop	**X**
Fast startup 2	MP3 player	**X**	**X**

EXHIBIT 34.1 (Downloadable)

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2. Add Ideal Solution Elements to TILMAG Matrix

Across the top of the TILMAG association matrix, list all the ISEs except for the last one. Down the left side, list the ISEs in *reverse* order leaving off the first one (Exhibit 34.1).

3. Eliminate Duplicate Pairings

Cross out the cells where the ISEs correspond to each other (you don't need to pair *large screen* with *large screen,* for example). Also cross out the bottom right cell because this pairing already exists elsewhere in the matrix (Exhibit 34.1).

4. Pair ISEs

For each of the remaining cells, brainstorm and record associations that come to mind when you pair the ISEs (Exhibit 34.1). Ask what existing products, services, business models, or systems can you think of that have *both ISEs* as a feature or function. Try to identify at least one association for each pair. In some cells, you'll think of several associations. If nothing comes to mind, skip the pair and come back to it later.

5. Generate Design Concepts

Finally, translate the associations you brainstormed in step 4 into design concepts relative to your innovation. Discuss each association one at a time and determine if the association could be applied as a solution to your problem. For our example, we came up with several subsystem solutions for a police car laptop (Exhibit 34.2).

TILMAG Design Concepts

Association	ISEs	Defining Feature	Solution Idea
Self-winding watch	Small size, renewable power	Movement releases potential energy from internal spring	Same
Hybrid car battery	Small size, renewable power	Car battery recharged during braking	Laptop charged when car at rest
Battery-free flashlight	Small size, renewable power	Shake flashlight to turn it on	Laptop charged when car in motion
Electrochemical reaction	Small size, renewable power	Reaction produces energy	Laptop runs on electrochemically-charged gel pack
Solar panel	Large screen, renewable power	Large panels produce energy	Install solar panels in car that charge laptop
Microscope	Large screen, renewable power	Runs on batteries, makes small items large	Use retinal projection technology
MP3 player	Fast startup, renewable power	Operating system loads quickly	Use fastest loading operating system
Portable radio	Small size, fast startup	Limited functionality (audio only)	Limit software on laptop to required programs
Big screen TV	Large screen, fast startup	Image comes up quickly	Limit software that loads on startup
Scenery backdrop	Large screen, fast startup	Fake background drops quickly	Emulate GUI operating system, and programs that load quickly
Fold-out map	Small size, large screen	Compact storage, yet large view	Screen that unfolds to larger view
Roll-up mat	Small size, large screen	Compact storage, yet large view	Keyboard that rolls up when not in use
Projector	Small size, large screen	Projector is small, yet projects onto a large screen	Project laptop display onto car windshield

EXHIBIT 34.2 (Downloadable)

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Paired Comparison Analysis

Rank design concepts against each other in pairs.

Paired Comparison Analysis relies on a simple matrix format to compare different and often divergent innovation ideas or design concepts, enabling you to choose the one that gives you the greatest chance of success. For instance, a carmaker might have five different design configurations for a new gas/electric hybrid; which design is the best one for the market?

Use Paired Comparison Analysis when you need to compare either more upstream innovation ideas or more downstream design concepts. This technique is especially helpful when you don't have objective data regarding how different ideas could meet your customers' outcome expectations (see Technique 2), or when you're uncertain about how different design concepts could meet customer performance and perception expectations (see Technique 30).

Part of this technique's advantage is that it's easier to use than such other comparative techniques as the Pugh Matrix (Technique 36). Therefore, Paired Comparison Analysis enables you to quickly but comprehensively assess the relative worth of all your options before committing to any specific one.

Steps

Scenario: Let's imagine an advertising agency that has the opportunity to land a multimillion dollar client who wants to launch a new product (over-the-counter common-cold medication). The client wants to know what the advertising theme will be and what other themes were considered. The ad agency uses Paired Comparison Analysis to answer these questions.

1. Create a Clear Operational Definition

An operational definition is an unambiguous and understandable description of what your solution alternatives (ideas or design concepts) are trying to accomplish. In our example, the advertising agency's objective is to ensure the client *gains an extra 8 percent of market share* from the new cold-medication ad campaign. With this description documented, there is no ambiguity about why the agency is performing a Paired Comparison Analysis—and different people can be involved, using and interpreting the analysis in a consistent manner without any confusion.

2. Generate or Discover Alternative Ideas

Classically, completing a Paired Comparison Analysis calls for the use of brainstorming techniques to come up with great alternatives. We recommend using any or all of the ideation techniques in this book to move significantly beyond classic brainstorming. If simple brainstorming were sufficient, more teams would come up with more innovations more often than not. But this is not the case.

Write a clear description of each alternative idea, and assign a letter to each. You can also attach a descriptive title to the ideas. For example, possible advertising themes could include:

- *Dancing Ducks*: Take-off on AFLAC's talking duck, but uses a Nutcracker Suite or Swan Lake theme with ducks singing and dancing to lyrics describing the virtues of the product.
- *Breaking News*: News anchor delivering breaking news about how this new product alleviates the symptoms of the common cold so much better than competing products.
- *Expert Doctor*: Straight medical theme with actor posing as a doctor extolling the virtues of the product for treating colds for all members of the family. Provide comparative medical research findings.
- *Gospel Choir*: A gospel choir in a Sunday setting with uplifting and joyful music and lyrics describing how you will be saved from further suffering by using this product at the first sign of a cold.

You should not eliminate any alternatives at this point. Paired Comparison Analysis is a powerful tool for determining differences between alternatives, even if they seem very similar.

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3. Create a Comparison Matrix

A comparison matrix (Exhibit 35.1) is used to rank the ability of competing ideas to provide a real solution. The matrix lists each idea under consideration as both a row and a column. For all ideas that are not comparing themselves, or are not redundant (gray shaded boxes in matrix), you must decide which of the two competing ideas is better based on your operational definition.

Comparisons should be made quickly—try not to take longer than 10 seconds on each decision. Write down the letter of the idea you chose as better in each white cell, then indicate how much better you think the idea is on a scale from 1 (minor difference) to 3 (major difference). If there is no difference between the ideas, choose any of the two compared letters and add a zero after it.

For example, let's compare the *Dancing Ducks* theme with the *Breaking News* theme. Given that the intrinsic worth of a new medicine can be more comically conveyed in the format of a news broadcast than by dancing ducks, we rank the *Breaking News* theme much higher.

Competing Advertising Themes

		A	B	C	D
	Ideas	Ducks	News	Doctor	Choir
A	Ducks		B, 3	C, 1	D, 3
B	News			C, 1	D, 2
C	Doctor				D, 2
D	Choir				

EXHIBIT 35.1

4. Consolidate the Results

Add up the total of all the assessed values for each of the ideas. Convert these values into a percentage of the total score. For our advertising themes, the total score is 12 (derived by adding all the difference values). The results are:

Dancing Ducks (A) = 0 (0 percent)

Breaking News (B) = 3 (25 percent)

Family Doctor (C) = 2 (16.7 percent)

Gospel Choir (D) = 7 (58.3 percent)

Based on these figures, the choir theme is the advertising idea seen as most likely to deliver on the market-share goal for the client's new product. Be careful though—the Paired Comparison Analysis technique is used for determining which alternative is best based on only one criterion: the operational definition.

> If you want a more rigorous method of comparing multiple design concepts against performance and perception expectations, use a Pugh Matrix (Technique 36).

Our advertising example compared a small number of ideas. In reality, many more ideas can be compared, provided that they are gauged on the same operational definition. Because comparisons are made quickly using this technique, many combinations can be assessed in a relatively short period.

Resource

If you are interested in the original, classic works on Paired Comparison Analysis, see:

Thurstone, L. L. "A Law of Comparative Judgment." *Psychological Review* 34 (1927): 273–286.

Pugh Matrix

Evaluate all your design concepts to create the invincible solution.

A Pugh Matrix assists in evaluating multiple ideas or design concepts against each other in relation to a baseline, or *datum*. For example, an innovation team might have many ideas about how to whiten teeth using new technologies. Then, based on this idea, the team might generate several specific design concepts for possible commercialization. The Pugh Matrix can help refine these ideas and/or concepts, and even facilitate the creation of more invincible hybridized ideas or concepts.

Use the Pugh Matrix when you need to evaluate ideas against a set of criteria related to solution-neutral outcome expectations (see Technique 2), or when you need to evaluate design concepts against solution-specific performance and perception expectations (see Technique 30). The Pugh Matrix is a form of risk management: rather than prioritizing based on gut feel, rule out alternatives and formulate superior ideas or design concepts in a more structured, objective, and revealing way.

The Pugh Matrix and the concept of "controlled convergence" were invented by Dr. Stuart Pugh at the University of Strathclyde in Glasgow, Scotland. The basic idea behind the matrix is to discourage opinions and promote objectivity through the systematic elimination of inferior concepts and the elevation of superior concepts.

Steps

Scenario: Ray Ray's House of Hair has developed several competing design concepts for an automatic hair-washing function, possibly even with more features and benefits than provided by the traditional approach of having a human wash the customer's hair prior to cutting and styling.

1. Determine a Baseline (Datum)

The definition of your baseline depends very much on your innovation needs. When redesigning an existing product or process, if no specific alternatives have been defined, the status quo makes an ideal candidate. If you are investigating multiple different ideas or solutions, consider a middle-of-the-road example as a baseline. This will allow you to objectively compare all the options under consideration. In our hair salon example, we will consider the human hair-washing method as our baseline concept.

2. Select the Concepts to Be Evaluated

Consider all the alternative concepts for comparing to your baseline. These could be known alternatives, or new solution/design concepts you want to consider but have not investigated in detail. Remember that this is a group activity. Including a few way-out ideas often enhances group dynamics.

For automatic hair washing, Ray Ray's has five related but different automatic-hair-washing design concepts for evaluation, as shown in Exhibit 36.1 Each is a variation on either a reclining chair, a straight chair, or a massage table system with such features as spray nozzles, bristles, massage jets, massage hood, and other options (music, foot massage).

3. Define Evaluation Criteria

Each alternative concept is compared to the baseline datum relative to several evaluation criteria, in this case, solution-level performance and perception expectations. Each evaluation criterion becomes a row in the Pugh Matrix. When using the Pugh Matrix to evaluate initial innovation ideas relative to some job to be done, the list of evaluation criteria are synonymous with higher-level outcome expectations. (See the Introduction for more on how performance expectations differ from outcome expectations in the hierarchy and process of innovation.)

4. Use the Criteria to Compare Concepts

Rank each design concept for each of the criteria against the baseline (Exhibit 36.1). If the concept is better than the baseline, assign it a plus; if it is worse, assign it a minus; if there is no discernable difference based on the criteria in question, assign it an S.

Pugh Matrix Example

(Automatic Hair-Washing Solutions/Designs)

Expectations	0	1	2	3	4	5
Ease of Use	DATUM	-	-	-	-	-
Clean (No water or shampoo spill)		S	+	+	+	+
Comfortable		S	+	+	S	S
Speed		+	-	-	S	S
Efficacy		+	+	+	+	+
Reliable		+	+	+	+	-
Optional Features		S	+	+	+	+
Cost		+	+	+	+	+
Noise		S	S	S	+	S
Easy to Maintain		S	S	S	S	-
Total +'s (better than datum)		4	6	6	6	4
Total -'s (worse than datum)		1	2	2	1	3
Total S's (same as datum)		5	2	2	3	3
Comparison		3	4	4	5	1

Concept Summary
0 - Human Washing Method
1 - Reclining Chair with Spray Nozzle & Bristles
2 - Massage Table with Spray Nozzle & Massage Jets
3 - Massage Table with Spray Nozzle & Fitted Massage Hood
4 - Straight Chair with Fitted Massage Hood & Music
5 - Straight Chair with Fitted Massage Hood & Foot Massage

EXHIBIT 36.1 (Downloadable)

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For each concept add up the number of pluses, minuses, and Ss, then record these at the bottom of the matrix. Compare the total number of plusses and minuses to help select the best concepts(s). The comparison row is the total number of plusses minus the total number of minuses for each design concept.

For our hypothetical example, the best design solution seems to be the straight chair with the fitted massage hood that also plays music. But the Pugh Matrix is not just a simple mathematical exercise; it's a qualitative technique that forces discussion and the development of new and alternative options to find the very best one.

Some people add an *importance* column to the Pugh Matrix for the purpose of weighting certain evaluation criteria over others. But if this strategy is taken, be careful to remember that you still use this technique to spark discussion about how to create invincible ideas or solutions—not just select the one that has the highest rating or comparison score.

---

5. Scrutinize and Refine Concepts

In repeating rounds, develop new design concepts by (a) synthesizing the best features of different alternatives and (b) enhancing the strongest concepts by adding features from the unselected concepts to overcome weak areas. Doing this will result in the emergence of more and better innovative concepts, or hybrids, that can again be evaluated with the Pugh Matrix.

For example, even though the straight chair with the fitted massage hood that plays music is the best option, is there a way to overcome any drawbacks of also adding other features and functions to the solution? Maybe the system with the foot massage (option 5) could be designed in a way that makes the multifunctional system just as reliable and easy to maintain as the simpler system (option 4). Design-for-reliability and design-for-maintainability principles could be applied in this regard.

Even though the massage table options seem inferior because they take more time, maybe some customers are willing to spend more of their time (and money) for this option. Maybe Ray Ray's could add still more features to this option to make it even more enjoyable and relaxing. Or maybe the simple straight chair with the fitted massage hood and music is the best choice to pursue.

Resource

For more details about the Pugh Matrix and how to use it, see:

Pugh, S. *Total Design: Integrated Methods for Successful Product Engineering*. Wokingham, United Kingdom: Addison-Wesley, 1991.

TECHNIQUE 37

Process Capability

Predict the performance of your new solution.

Process capability compares the actual performance of a product or service to its requirements or specifications under two major conditions. One is when you want to predict how well your newly designed product or service will perform prior to its release and full implementation. The other is after your product or service is in full operation and you want to measure how well it is meeting its performance specifications or expectations.

Because we're primarily concerned about innovation, we'll focus on its predictive use. For example, if you've designed a new insulin pump, it should be capable of administering a certain amount of the hormone at a certain rate into the patient's body. If you determine that the pump's ability to consistently perform is lacking, you can use the Process Capability technique to improve its design by optimizing the settings of the pump's input variables (radius of the piston, motor speed, etc.).

Because there are so many different ways to calculate process capability, it's common to use the wrong metric. This creates an erroneous impression of how well the process runs, and creates confusion when comparing the performance of different types of variables and processes (service, manufacturing, transactional). Therefore, this technique is best applied at first with the help of a statistical or Six Sigma expert.

Background

One way process capability can be measured is as a simple *yield,* or the percentage of times the process meets its requirements. The Six Sigma community created another metric, *sigma level,* to normalize capability readings for different types of processes. (How, for example, do you compare the capability of an invoicing process with the capability of a light bulb manufacturing process?)

The sigma metric was also created to fine-tune performance measurement in a competitive business environment that requires perfection or near perfection. While a yield of 99.0 percent is equivalent to a 3.8 sigma level, a yield of 99.9 percent (just 0.9 higher) equates to a 4.6 sigma level. The goal of Six Sigma performance is to reach a sigma level of 6.0 or higher—equating to a yield of 99.99966 percent—or only 3.4 defects per one million opportunities for a defect.

The key is to make sure you determine the process capability for any new solution and, if it is lacking, improve its design—making it more robust to input variations through the principles of *parameter design.* Or, if this route isn't feasible, then you can take the less preferred but still effective route of tightening the tolerances of critical inputs (*tolerance design*), then improving your process capability while keeping your design as is. Rely on robust design (see Technique 38) for executing both of these strategies.

Steps

Scenario: Let's suppose a bank is testing a new information kiosk that provides customers with rapid approvals on refinancing mortgages. The bank assembles a team, the Kiosk Configurators, to pilot the new system and determine its process capability—or how well it meets customer expectations.

1. Determine Specifications (Performance Criteria)

Process, product, and service specifications come from customer expectations, engineering calculations, or even from examining the process itself. Some specifications are very rigid (e.g., tolerances for parts in a turbine engine). Others are not as rigid (e.g., telephone hold time for customer service). In either case, specifications should be clear and unambiguous, employing a Measurement Systems Analysis (Technique 47) to verify that your measurements are valid and reliable over time—or unbiased with acceptable variation.

For our example, the Kiosk Configurators conducted a pilot during which the team measured customer reaction to the time elapsed between when a refinancing request is submitted and when the system displayed the refinancing terms. The team determined that 97 percent of customers are willing to wait up to two minutes before receiving information, 80 percent are willing to wait up to three minutes, and 50 percent will wait four minutes.

Based on this, the Kiosk Configurators determined that the kiosk should display the refinancing terms within two minutes (120 seconds) for all users. In essence, the team set an upper specification limit (USL) at 120 seconds. There is no lower specification limit (LSL) because an instantaneous response is still acceptable (although very unlikely).

2. Collect Appropriate Data

Process data is either quantitative or qualitative in nature. Quantitative data, or *variable* data, is measured along a continuous scale (i.e., 1 to 60 seconds). Qualitative data, or *attribute* data, is measured in categories, like pass/fail, yes/no, blue/green, and so on. Both types of data have value, but usually variable data is preferred over attribute data because it tells you more about the process.

The Kiosk Configurators were able to measure performance in seconds during their pilot using a timing device in the kiosk program. They captured 100 data points on a Saturday morning, relying on real customers. The data were considered *short-term* because they were collected under controlled circumstances in a short period of time when all equipment was working correctly. The results are displayed in the dot plot shown in Exhibit 37.1 The data is stable and typically below the USL of 120 seconds.

3. Calculate Capability Metrics

The simplest capability metric you can calculate is the percentage yield. For example, using a pass-fail analysis, we can see in Exhibit 37.1 that 99 of the 100 pilot tests were below the 120-second upper specification. We could therefore report a yield of 99 percent. One issue with using pass-fail data is that we don't know how close the 99 successful tests were to the USL. Are we borderline or do we have a lot of wiggle room to accommodate any shifts or drifts in the process?

However, using the actual time measurements (Exhibit 37.2), we can identify where the *central tendency* of the data lies (as measured by the mean or median), how much variation is present in the data (range or standard deviation), and the shape of the data distribution (bell-shaped with most data in the center?). With these parameters, we can better describe the data and predict the impact of long-term shifts.

A common capability metric for continuous data is the sigma level, or the number of standard deviation (σ) units that lie between the mean and the upper specification limit (USL). In our case, with a mean of 95, a USL of 120 and a standard deviation of 10, there are 2.5 standard deviations in between: (120 – 95)/10 = 2.5.

This would be described as a *2.5 sigma process,* depicted in Exhibit 37.3. Using the properties of the normal distribution, we would predict that 0.6 percent (derived from a standard table) of the total population of customers would experience response times in excess of 120 seconds.

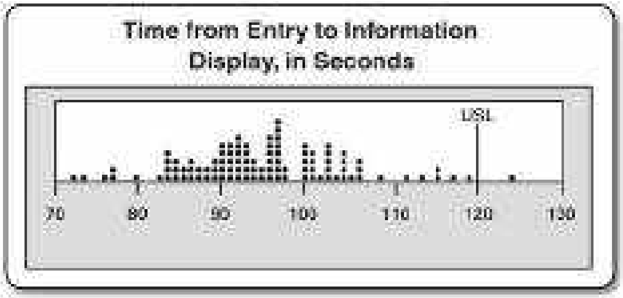

EXHIBIT 37.1

Descriptive Statistics-Kiosk Pilot Trials

Mean (Average)	95.0 seconds
Median (Middlemost)	94.5 seconds
Range (Highest – Lowest)	52.0 seconds (73–125)
Standard Deviation	10.0 seconds
Shape of Distribution	Normal (Bell)
Stability	Appears Stable (Short term)

EXHIBIT 37.2

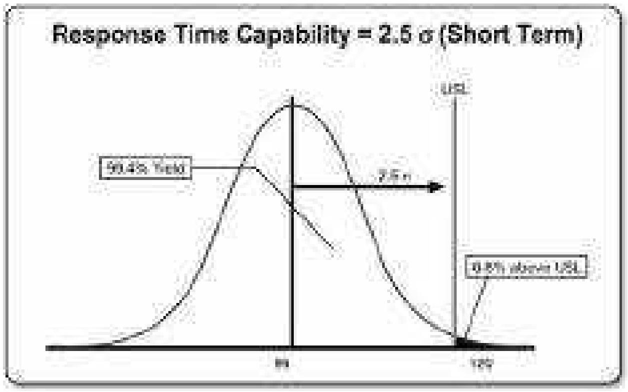

EXHIBIT 37.3

Process capability is expressed in either the short-term or the long-term. Recall that the Kiosk Configurators determined capability by collecting data from one short period of time. Therefore, they can expect 0.6 percent of customers to have wait times longer than 120 seconds *in the short term;* over the long term, however, they can expect the process to shift and drift, thereby deteriorating process capability.

Specification limits can be one-sided or two-sided. For two-sided specifications, you combine the capability of the lower specification limit (LSL) and the upper specification limit (USL) to derive an overall sigma level. Extensions to unstable processes, two-sided specifications, and distributions that are not normally distributed require additional analysis.

---

4. Improve the Design or the Process

After you implement your innovation, or during a test or pilot, you may find your process capability lacking. Or you may need to improve it over time as a response to competitive realities. Either way, you can improve process capability in one of two ways using robust design principles (see Technique 38). First, try improving the design (parameter design) so it can be more robust to input variation. Second, you can tighten the tolerances of critical parameters (tolerance design), followed by improving the associated process such that the design better meets performance expectations. Before either of these, however, make sure your process capability readings are correct and accurate using Measurement Systems Analysis (Technique 47).

For example, let's say the Kiosk Configurators want to significantly improve process capability due to new competitive pressures. They decide to redesign their solution, which is a transactional process comprised of various subprocesses, including but not limited to:

- Query for, obtain, and report the customer's credit score.
- Determine the dollar amount of the loan.
- Determine the interest rate of the loan.
- Query about and determine the loan down payment.

The Kiosk Configurators collect some data and discover that 80 percent of loan inquiries are delayed because of the time it takes to receive credit scores from bureaus. Therefore, for any loan below a certain loan amount, when the customer is also making at least a 25 percent down payment, the bank will provide a preliminary estimate of loan terms without utilizing the customer's credit score. This process parameter design enables customers to get a loan offer at the kiosk in 80 seconds on average, with an upper specification limit of 100 seconds. If such parameter changes do not improve the design to the extent wanted, we can employ a tighter tolerance on the cycle time for credit score reporting, and then improve the score-reporting process to make it faster.

Resources

Gygi, C., N. DeCarlo, and B. Williams. *Six Sigma for Dummies*. Hoboken, NJ: John Wiley & Sons, 2004.

Use the following software packages to quickly calculate a variety of capability metrics with additional analytic graphics:

JMP (SAS).

Minitab 15 (Minitab).

SigmaXL (SigmaXL).

SQC Pack (PQ Systems).

Robust Design

Make your design insensitive to uncontrollable influences.

Robust design helps you reduce the sensitivity of your innovation to uncontrollable *noise* variables. For instance, an automotive designer might use robust design to develop a more fuel-efficient car engine that is less susceptible to the vagaries of customer driving habits and environmental conditions. Or a physician's office might design a patient-scheduling routine that is minimally impacted by variations in staffing or patients arriving late.

Throughout the life cycle of a product or service, variation can and will occur. Because variation negatively impacts performance, the resulting customer experience will also be negative when the product or service fails to live up to expectations. Robust design seeks to predict variation before it occurs, and then prevent or minimize it through design.

To undertake robust design, you'll definitely need help from an experienced engineer or statistician familiar with this approach to testing and analysis. You'll also need to know how to apply several other techniques in this book including Performance and Perception Expectations (Technique 30), Axiomatic Design (Technique 31), Design FMEA (Technique 40), and Design of Experiments (Technique 50).

Noise variables are factors that negatively affect the performance of a product, service, or process, but which are difficult to control. Noise comes from three primary sources:

- Production variation (staffing, materials, supply, equipment, environment, skills, education, etc.).

- Customer use and abuse (improper use, varying expectations, high volume, high maintenance demands, etc.).
- Deterioration (drift in electronic parts, corrosion, employee fatigue, loss of effectiveness, etc.).

Steps

Scenario: As we proceed through the basic steps of robust design, we'll use the example of producing a skin patch that administers the correct dosage of medication to a patient over a specified time period. This can be a difficult job given that the drug's absorption rate depends on such uncontrollable factors as patient weight and skin thickness, correct application and usage of the patch, and variable environmental conditions that may affect the patch's efficacy.

1. Identify Customer Expectations

Robust design starts with conceptual *system design,* during which you define the ideal performance for your innovation, and make a list of measurable system features that are critical to the customer. You may have already done this using Performance and Perception Expectations (Technique 30). For our skin patch example, the ideal design will consistently dispense a dose of 1.0 mg/hr $\pm$ 0.2, regardless of patient fat content, skin condition, or other environmental factors.

A robust design is one in which the outputs are insensitive to input variation.

2. Develop Conceptual Design

Using the list of desirable and measurable features from step 1, create an initial design. For this high-level design, you can apply any number of techniques, including Axiomatic Design (Technique 31), Function Structure (Technique 32), Structured Abstraction (Technique 23), and Separation

Principles (Technique 24). Our skin patch design consists of multiple layers of fabric webs at varying angles with a breathable, waterproof cover material and a hypoallergenic adhesive.

3. Identify Control Factors and Noise Variables

As you move to a more detailed design, make a list of control factors and noise variables that may cause variation in performance (Exhibit 38.1). Control factors include anything that you, the provider, can reasonably manage—product specifications, equipment settings, storage, and so on. Noise variables are factors that are beyond your control—material variations (within tolerances), customer use and abuse, environmental conditions, and the like.

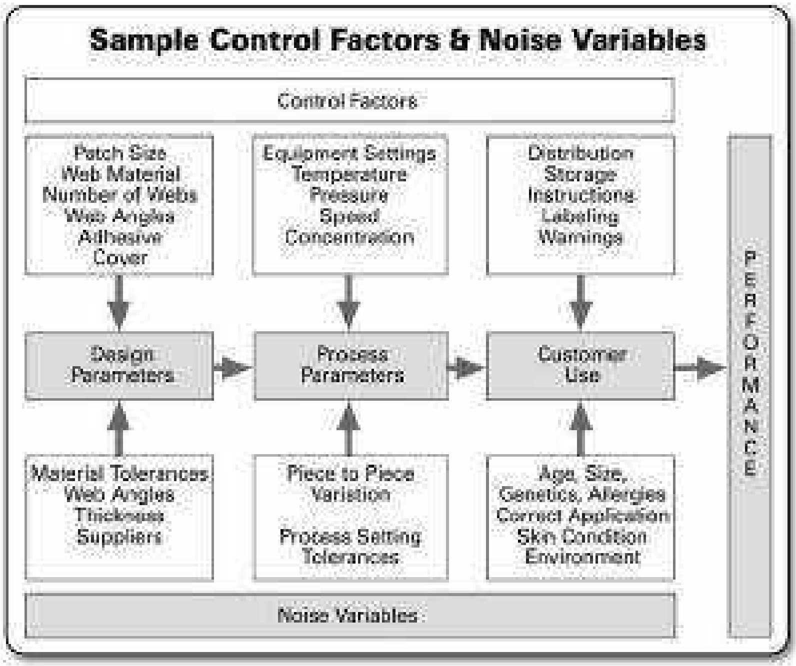

EXHIBIT 38.1 In this example, we see the factors that the skin patch manufacturer can control (top row), as well as noise variables (bottom row) that are beyond the manufacturer's control but have the potential to negatively affect product performance.

4. Identify Potential Deterioration

Throughout the product or service life cycle, deterioration is likely to occur. Components wear out, materials become damaged or lose their effectiveness. In the service realm, human error and inconsistencies contribute to process variation and deterioration. To reduce the impact of these factors on performance, use Design FMEA (Technique 40) to flag areas that are susceptible to wear or failure, and then design your product or service to avoid or withstand deterioration as much as possible.

With regard to our skin patch, we need to address several deterioration factors including how to best store the patch before use, and how to dispense consistent dosages over 12 to 36 hours as medication is depleted from the patch and absorbed into the skin.

5. Experiment and Determine Optimum Design

By this point, you've developed a conceptual design for your innovative product or service and have made a list of noise variables that could negatively impact performance. Now, entering the *parameter design* phase of robust design, you can use physical experiments and/or simulations to refine the design so that it is less affected by noise. For example:

- Use a Cause & Effect Matrix (Technique 53) to determine the relationship between the design's inputs and outputs. If you understand how each input affects the output, both individually and in combination, you can improve your design performance and reduce variability.
- Use Design of Experiments (DOE) (Technique 50) to test how varying control factors affect your design. You should also test control factors against noise variables to stress the design and ultimately reduce sensitivity to customer use and abuse, as well as deterioration.
- If physical experiments are not feasible or cost-effective, use a computer simulation such as discrete event simulation (see Technique 41) to determine which inputs result in the optimal output.

Through a DOE for our skin patch, we found an interaction between web thickness and web angles that will allow us to reduce the variation in hourly dosage (high thickness produces less web angle variation than lower thickness). We also found that the patch area has a curvilinear relationship with the dosage per hour. By working on the flatter part of the curve, we can widen the design tolerance to maintain the same performance over time.

Parameter design helps you determine optimal functional requirements for your innovation based on inputs, outputs, and the effect of noise variables.

---

6. Determine Detailed Design Tolerances

Now that you've minimized the impact of variation on your design, the last step in robust design is the *tolerance design* phase. Here you establish detailed tolerances or specifications that your design needs to operate within to meet expectations. For example, through our analysis of the skin patch design, we determined that expected variation, including noise, is approximately 0.033 mg/hr. This is more than acceptable if the required performance is 1.0 mg/hr ± 0.2.

Resource

For more information on the philosophy and method of robust design, see:

Fowlkes, W., and C. Creveling. *Engineering Methods for Robust Product Design: Using Taguchi Methods in Technology and Product Development*. Upper Saddle River, NJ: Prentice Hall, 1995.

Design Scorecards

Develop a dashboard to track your design and its underlying processes.

Functioning like the dashboard of a car, Design Scorecards provide critical feedback data on three levels: system performance, component performance, and process performance. For example, consider the design of a new washing machine that uses no detergent but works on the principle of ultrasonic waves and electrolysis. We can use Design Scorecards to record the progress of the design process, enabling necessary modifications to maximize the probability of implementation success.

For innovation, the key benefit of Design Scorecards is their ability to predict the final quality of a design and recognize gaps so it can be improved *before* it's implemented. Is there a risk that your design will go wrong? How will you know if and when it does? As well, you'll have to track your new innovation *after* it's implemented, making sure its performance record is visible to stakeholders so they can prevent malfunctions if possible, or at least react quickly to fix problems if they do occur.

Naturally, the more valid and robust your Design Scorecards, the more likely you are to notice and fix production problems or service issues before they lead to serious customer dissatisfaction. In this preventive regard, use Design Scorecards in conjunction with techniques such as Design FMEA (Technique 40), Measurement Systems Analysis (Technique 47), and Robust Design (Technique 38)—with the help of a qualified engineer if working with more complex systems.

Design Scorecards have many uses, but primarily they identify which parameters or *indicators* contribute most to an optimized design. This helps your innovation team decide where to focus efforts early in the design cycle.

Background

You should be concerned with three Design Scorecard levels, as follows:

- *Performance scorecard:* Predicts how the overall design will perform against its expectations and functional requirements. Once implemented, this is a summary comparison of actual-to-planned performance of the innovation.
- *Component scorecard:* Predicts the performance of key components that affect the overall performance scorecard elements. Once implemented, this summarizes the extent to which component quality levels fulfill design intent and expectations.
- *Process scorecard:* Predicts the overall quality level of key processes that produce the product or deliver the service. Once implemented, this summarizes the extent to which key processes and subprocesses meet overall performance targets.

While the purpose of Design Scorecards is to *prevent* problems, defects, and errors through superior design, they also enable better problem *detection* after a new solution (design) is implemented. If you are in detect-and-fix mode, any number of process-optimization techniques may help, such as Process Behavior Charts (Technique 52), Cause & Effect Matrix (Technique 54), Mistake Proofing (Technique 49), and Design of Experiments (Technique 50).

Steps

Scenario: An automaker is configuring a disc-brake subsystem for its 100-mile-per-gallon light vehicle. Before, during, and after the design process, we can predict and evaluate the quality of the design with the help of Design Scorecards.

1. Identify the Critical Parameters for the Performance Scorecard

Identify all the relevant customer expectations associated with your planned system or subsystem (see Performance and Perception Expectations, Technique 30). In addition, locate any functional requirements that are not specifically addressed by documented performance and perception expectations.

Performance expectations are measured in different ways, subject to the nature of the solution involved. For each expectation, clearly identify: (a) the type of variable (discrete, continuous), and (b) the measurement unit (percentage, currency, feet, hertz, decibel, pass/fail, etc.).

In our example braking system, we use a number of descriptive statistics at the performance, component, and process levels. For example, at the performance-scorecard level (Exhibit 39.1), to gauge the performance of our new braking system, we measure the following variables, or *performance indicators:*

Performance Indicator	Unit	Variable Type
Stopping Distance	Ft	Continuous
Low Vibration	Hz	Continuous
Noise Level	dB	Continuous
Appearance	Pass/Fail	Discrete

Continuous indicators are tracked by looking at their mean and standard deviation over a series of tests/observations. For example, the noise level associated with our braking system was measured at a mean value of 34 Db with a standard deviation of 1.5.

Discrete indicators are tracked by looking at their success rate. For the appearance indicator in our example, we are interested in the number of *passes*, considering the total number of observations or survey responses.

If you're implementing a business model innovation, then you might have such performance indicators as *profit, earnings, volume, customer loyalty, market share, revenue,* and so on.

Overall Performance Scorecard

				Continuous Data						Attribute Data			
	Requirement	Units	Continuous?	Target	μ	σ	USL	LSL	ST or LT	opp/unit	DPU	DPMO	Zst
1	Stopping Distance	Ft	Yes		60	2	66		LT			0.0	>6
2	Low Vibration	Hz	Yes		16	3.5	30		ST			0.0	>6
3	Noise Level	dB	Yes		34	1.5	35		LT			0.0	>6
4	Appearance	pass/fail	No							1	0.00001	10.0	5.76
										Total Opps		4	
Product Description		Light Vehicle Air Brakes								Product DPU		0.00001	
System Subsystem:		Front Brake System								Product DPMO		2.5	
Finished Prod./Final Ass'y		C6 Sedan								Product RTY		100.00%	
Date:		3/1/2008								Product Zst		>6	

EXHIBIT 39.1 (Downloadable)

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Some Performance Metrics and Terms

Requirement—Performance specification

Units—Items produced

GRR—Gage Repeatability & Reproducibility (Gage R&R)

Continuous—Type of data (scale)

Attribute—Type of data (categories)

Target—Desired performance level

μ—Average or mean

σ—Standard deviation

USL—Upper specification limit

LSL—Lower specification limit

ST or LT—Short term, long term

Opportunity—Chance for a defect or error to occur

DPU—Defects per unit

DPMO—Defects per million opportunities

Zst—Short-term capability

Product RTY—Rolled throughput yield

2. Determine Target and Specification Limits for Performance Parameters

These limits are obtained from customer input, regulatory requirements, or design functional requirements. Upper specification limit (USL) refers to the maximum allowable value for the parameter, whereas lower specification limit (LSL) indicates the minimum allowable value.

Typically three scenarios apply to specification limits: (1) more is better, (2) less is better, and (3) achieve a specific target. More-is-better type requirements will have only an LSL, less-is-better type will have only a USL, and achieve-a-target types will have an LSL and a USL.

In our example (Exhibit 39.1), let's consider *stopping distance*. Customer input and legislation require that the distance be "55 feet or less." In reality, a stopping distance less than the specification is preferred, so an upper specification limit of 55 feet is used. Because any shorter stopping distance would be acceptable, specifying a lower specification limit (LSL) is not necessary.

Discrete indicators, such as *appearance,* will typically have a target value of "none" or 0: we would always want our test to pass. For example, customers might be asked if the appearance of a product pleases them or not. They can answer yes (pass) or no (fail) on a questionnaire.

3. Predict the Performance Indicators

In this step, we predict the values of each of the performance indicators (parameters). This is achieved through the use of transfer functions in the form of $Y = f(x)$. The transfer function is obtained from scientific principles, Design of Experiments, or other known empirical relationships.

For example, we can predict the deflection performance of a spring by utilizing the transfer function, $F = K \times X$, where F is the spring force, K is the spring constant and X is the deflection. By measuring the mean and standard deviation of K and F, and using the transfer function, we can predict the mean and standard deviation of X. This in turn can be converted to a sigma level or defect level.

The predicted values are later compared against actual measured performance values collected during prototyping, piloting, and design implementation.

When assembling your scorecard for your new design, keep in mind how data will be collected and reported for your performance indicators. Actual, observed indicator values may be sourced from specific test runs, data collected from usage in the field, customer satisfaction records, call center logs, and so on.

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4. Build the Overall and Individual Component Scorecards

Identify the critical components that significantly influence the performance of the overall system. Major components of our disc brake system are *caliper, brake pad, rotor, piston,* and *hub,* as shown in Exhibits 39.2 and 39.3.

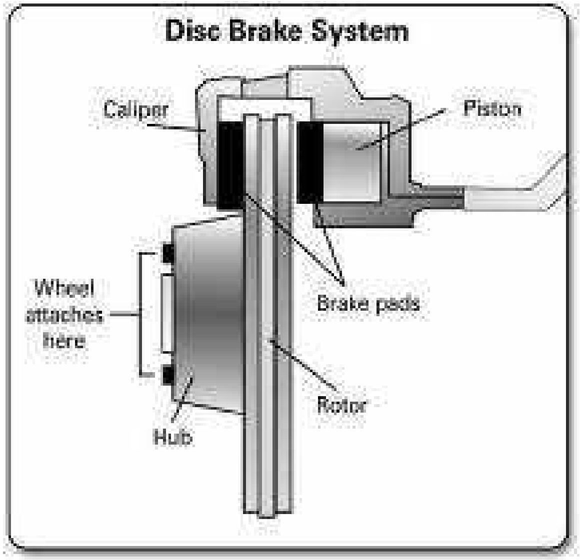

EXHIBIT 39.2

Once the components are identified, predict their performance by identifying their critical inputs. For example, the performance of the caliper component is affected by *surface area, parallelism, volume, clamp load, deflection,* and *appearance* of the caliper (Exhibit 39.4). By measuring the performance of these individual items, we can predict the performance of the caliper.

Build a scorecard for each critical component using historical process capability data (see Technique 37), Design of Experiments (Technique 50), and simulations. You can then use this data to predict the overall performance of each of the components.

> By evaluating alternative components to optimize or improve designs, the component scorecard facilitates dialog between designers and suppliers.

5. Build the Overall and Individual Process Scorecards

Identify the critical manufacturing and/or service delivery processes (and subprocesses) that significantly influence the performance of the overall system and its critical components. For the disc brake system, some of the manufacturing and assembly processes include *caliper welding, caliper mounting,* and *rotor mounting* (Exhibit 39.5). Recognize that we've itemized these few processes as an illustration; in reality, there are dozens and even hundreds of processes associated with complicated designs.

Once the critical processes are identified, you can predict their performance by identifying the parameters that affect them. Again, we identify only two parameters that affect the caliper-welding process: *strength* and

Overall Component Scorecard

	Part	# Requirements	Part Count	Total Opps	Part DPU	Part DPMO	Part RTY	Part Zst
1	Caliper	6	4	24	0.00080	33.33	99.92%	5.49
2	Brake Pad	4	4	20	1.41699	70849.54	24.24	2.97
3	Rotor	5	4	20	4.01690	200845.05	1.80%	2.34
4	Piston	4	4	20	0.04580	2280.05	95.54%	4.34
5	Hub	3	4	16	0.00007	4.38	99.99%	5.95
6								
7								
8								
9								
10								
	OVERALL	**22**	**20**	**100**	**5.4804**	**54803.629**	**0.42%**	**3.10**

Finished Prod./Final Assembly	C6 Sedan
System Subsystem:	Front Brake System
Prepared by:	A.B. Smith
Date:	3/1/2008

EXHIBIT 39.3 (Downloadable)

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surface appearance (Exhibit 39.6). By measuring the performance of these parameters, we can predict the performance of the caliper-welding process.

Build a scorecard for each critical process using data from capability studies (see Process Capability, Technique 37), past experience, manufacturing data, and estimates from similar processes. You can then use this data to predict the overall performance of each of the critical processes and subprocesses.

At a glance, the process scorecard uncovers weak processes and improvement opportunities.

Component Scorecard

					Continuous Data					Attribute Data				
	Requirement	Units	GRR	Continuous?	Target	μ	σ	USL	LSL	ST or LT	Opp/unit	DPU	DPMO	Zst
1	Surface Area			Yes		15	2	20	10	LT			0.0	>6
2	Parallelism			Yes		25	5	30	20	LT			0.0	>6
3	Volume			Yes		35	2	40	30	LT			0.0	>6
4	Clamp Load			Yes		45	2.22	50	40	LT			0.0	>6
5	Deflection			Yes		55	1.444	60	50	LT			0.0	>6
6	Appearance			No							1	0.0002	200.0	5.04

Total Opps	24
Product DPU	0.00080
Product DPMO	33.3
Product RTY	99.92
Product Zst	5.49

Part:	Caliper
Part Count:	4
Supplier:	AJB
System Subsystem:	Light Vehicle Air Brakes
Finished Prod./Final Assembly:	C8 Sedan
Prepared by:	A.B. Smith
Date:	3/1/2008

EXHIBIT 39.4 (Downloadable)

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Overall Process Scorecard

	Process Step	# Requirements	Total Opps	Process DPU	Process DPMO	Process RTY	Process Zst
1	Caliper Welding	2	57	0.0001	1.7544	99.99%	>6
2	Caliper Mounting	2	9	1.07091	118991	34.27%	2.68
3	Rotor Mounting	3	8	2.54288	317860	7.86%	1.97
4							
5							
6							
7							
8							
9							
10							
	OVERALL	7	74	3.6139	48836	2.69%	3.16

Finished Prod./Final Assembly	AMF Sedan
System Subsystem:	Front Brake
Prepared by:	A.B. Smith
Date:	3/1/2008

EXHIBIT 39.5 (Downloadable)

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6. Interpret the Scorecard

You interpret the completed Design Scorecards after you implement your new solution and you have enough data for a specified period of time. As you interpret your scorecards, consider the following:

- Do your chosen measurements enable you to accurately, precisely, and reliably evaluate the indicators? (See Measurement Systems Analysis, Technique 47.)
- Are there any design corrections that can be made to improve performance? (See Robust Design, Technique 38, and Process Capability, Technique 37.)

Process Scorecard

				Continuous Data							All Data	Attribute		
	Requirement	Units	GRR	Continuous?	Target	μ	σ	USL	LSL	ST or LT	# applications	DPU	DPMO	Zst
1	Strength	kPa		Yes		10000	1000		9000		13		0.0	>6
2	Surface Appearance	pass/fail		No							44	0.0001	2.3	>6

Total Opps	57
Process DPU	0.00010
Process DPMO	1.8
Process RTY	99.99%
Process Zst	>6

Process:	Welding of Slide Caliper
System Subsystem:	Automotive Air Brake
Finished Prod./Final Assembly:	C6 Sedan
Prepared By:	A.B. Smith
Date:	3/1/2008

EXHIBIT 39.6 (Downloadable)

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- Are performance, component, and process indicators linked in a direct and complete cause-and-effect way?
- Are there any unanticipated business considerations (such as cost and timing)?
- Are there any unanticipated marketplace considerations (such as new competitive threats or changing customer expectations)?
- Are any of your indicators too volatile? (See Control Plan, Technique 55.)

Design Failure Mode and Effects Analysis

Anticipate what can go wrong with your solution before it does.

Design Failure Mode and Effects Analysis (DFMEA) is used to anticipate possible failures or problems with your new solutions *before they occur,* and to have a plan for what to do in response. Carmakers, for instance, anticipate what could go wrong and prevent it when they install mechanisms that don't allow a driver to shift from *park* into *drive* unless the person's foot is depressing the brake.

Use DFMEA during your preliminary, initial, and detail design reviews to uncover any potential *failure modes.* Then your first priority is to prevent these modes by improving the design itself (see Mistake Proofing, Technique 49). If you can't mistake-proof your solution (as in the foot-on-brake example), your next priority is to detect a failure mode before it occurs and prompt the user to take action. The oil warning light in a vehicle is an example of this approach.

With DFMEA, you attempt to predict future risks and mitigate or head them off in advance. Predicting what could fail, and what you will do about it, could keep you out of firefighting mode and enable you to avoid unnecessary and costly delays in getting your new solution to market. For more complex solutions, you may need the help of an expert to apply this technique.

A *Design* FMEA focuses on the interface of a new product, service, or solution with customers. A *Process* FMEA focuses on the behind-the-scenes steps that produce the product or enable the service provided. However, both FMEAs share a common format, approach, and interpretation.

Steps

Scenario: Suppose a company that currently manufactures disposable razors and shaving lubricants is developing a new product that combines both shaving and lubricating functions in one. The new design is for a disposable razor that houses shaving gel in a hollow handle. The gel is automatically dispensed through a porous pad just below the blades. Since the product is disposable, the amount of gel in the handle should be matched to the life of the blades.

In constructing a Design FMEA, the language differs in a few key spots from a Process FMEA. For example, in a Process FMEA, the first column usually lists the process step under analysis. The first column of the Design FMEA, however, is a list of product or service components and the functions they're supposed to perform.

1. Complete Administrative Information

Using a DFMEA worksheet (Exhibit 40.1), complete the product/service name, the name of the team leader who prepared the DFMEA, and when it was initiated.

2. Identify Items and Functions

In the first column of the DFMEA worksheet, list all the components that could contribute to a failure mode and the intended function for each one. For example, one component of our shaving system is the blade, and its

Design FMEA

Product/Service Name:	Mach 3 Razor	Prepared by:	Page ___ of ___
Responsible:	Mary Jones, project leader	FMEA Date (Orig) ________	(Rev) ________

Item and Function	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes (or Failure Mechanism(s))	OCC	Current Design Controls	DET	RPN	Recommended Action(s)	Responsibility and Completion Date
Name of item being analyzed and its functions (required to meet design intent)	In what ways might the component/ subsystem/ system potentially fail to meet the design intent?	What is the effect of each failure mode on the function as perceived by the customer? (Internal or External)	How severe is the effect to the customer?	How can the failure occur? Describe in terms of what can be corrected or controlled. Try to identify the causes that directly impact the failure mode.	How often does the cause or failure mode occur?	What are the existing prevention, design verification or other activities that will (1) prevent the cause of the failure mode or reduce its rate of occurrence, (2) detect the cause and lead to corrective actions, or (3) detect the failure mode once failure has occurred.	How well can you prevent or detect the cause or failure mode?	SEV x OCC x DET	What are the actions for reducing the occurrence or improving detection, or for identifying the root cause if it is unknown? **Should have actions only on high RPN's or easy fixes.**	Who is responsible for the recommended action?
Blades – cut hair	Too dull	Hair not cut close enough, discomfort	7	Not sharpened properly in manufacturing	3	Statistical tolerancing of edge angle, capability verified	3	63	None	N/A
			7	Worn out prematurely	3	Specification of optimum steel grade (440C) for blade and supplier quality management plan	3	63	None	N/A
			7	Corroded	3	Specification of optimum steel grade (440C) for blade and supplier quality management plan	3	63	None	N/A
	Wrong angle	Hair not cut close enough, discomfort, injury	7	Deformed blade spacers	5	Statistical tolerancing of spacer dimensions, but difficult to hold tolerances with current material	7	245	Investigation of alternative spacer materials	Joe Morris, Materials department, Dec 1, 2009
Porous gel part - apply gel, control gel flow	Low or no flow of gel	Inadequate lubrication, discomfort, injury	10	Clogged	2	Gel formulation to ensure adequate solubility	8	160	Ensure gel specifications are adequate and achievable	Mary Jones, project leader, and Scott Perkins, Cream & Gel Products Mgmt. Mgr., Oct 15, 2009
			10	Pore size too small	7	Spec limits for pore size from part supplier, but impact of variation not well understood currently	7	490	DOE or other study to determine effect of pore size and other potentially interacting variables	Fred Fritz, Design Engineering, Nov 30, 2009
	Excessive gel flow	Gel runs out too soon	5	Pore size too large	7	Spec limits for pore size from part supplier, but impact of variation not well understood currently	7	245	DOE or other study to determine effect of pore size and other potentially interacting variables	Fred Fritz, Design Engineering, Nov 30, 2009

EXHIBIT 40.1 (Downloadable)

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desired function is to *cut hair*. The gel component is designed to *provide lubrication*. The porous pad *applies gel* and *controls flow of gel*. The hollow handle *provides grip* and *holds gel*. And so on. For this example, we'll limit ourselves to the blades and porous pad.

3. Identify Potential Failure Modes, Failure Effects, and Potential Causes

Now ask, "What can go wrong with this component?" The answer is your *failure mode*. Then ask, "If this does go wrong, how will it affect customers?" This is your *failure effect*. Finally, brainstorm the possible reasons for your failure mode. These are your *potential causes*. Keep in mind that one item or function can have multiple potential failure modes, and each failure mode can have multiple potential causes.

In the razor example, the blades item has two potential failure modes shown—*too dull* and *wrong angle,* both with the same effects of shaving discomfort and an un-close shave. Potential causes of these failure modes are poorly sharpened edges, wear, corrosion, and deformed plastic spaces that position the blades.

4. Determine Severity and Rate of Occurrence

The severity (SEV) of a failure effect and the rate of occurrence (OCC) of a potential cause are rated on a 1 to 10 scale, according to Exhibits 40.2 and 40.3.

	Severity of Effect	Rating
Extreme	Affects product safety. Catastrophic consequence on customer.	10
High	Product inoperable, with loss of primary function, customer highly dissatisfied.	8
Moderate	Product inoperable with moderate consequences on customer.	5
Low	All systems functional. Minor defects noticed by some customers.	3
None	No effect. No defects or defects too minor to be noticed by customer.	1

EXHIBIT 40.2 (Downloadable)

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	Likehood of Occurrence	Rating
Very High	Failure is almost inevitable	10
High	Repeated failures	7
Moderate	Occasional failures	5
Low	Relatively few failures	3
Remote	Failure is unlikely	1

EXHIBIT 40.3 (Downloadable)

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In our example, severity scores range from a moderate 5 to the highest severity of 10 because the customer could get injured by some failures. Occurrence ratings range from 3 to 7, predicting that some causes would occur very infrequently, while others could become a chronic issue.

If you need a more granular or finely tuned approach for your severity and occurrence ratings, see *Potential Failure Mode and Effects Analysis* (2001), available from the Automotive Industry Action Group at AIAG.org.

5. Establish Current Design Controls

Establishing design controls entails examining current design features, component specifications, and necessary information to ensure that the potential cause can be avoided, or at least detected if it occurs. These controls then become inputs into making a Control Plan (Technique 55). Controls in the razor example include specifications for incoming parts or materials, material selection, and an understanding of the impact of component variation on performance.

Another area where a Design FMEA differs from a Process FMEA is in the *controls* and *detection* sections. In a Process FMEA, controls are production controls; in a Design FMEA, controls are design controls.

	Likehood that control will detect or prevent failure	Rating
None	Design Control will not and/or cannot detect/prevent a potential cause/mechanism and subsequent failure mode.	10
Low	Design Control has a low chance of detecting/preventing a potential cause/mechanism and subsequent failure mode.	7
Moderate	Design Control may detect/prevent the existence of a potential cause/mechanism and subsequent failure mode.	5
High	Design Control has a high probability of detecting/preventing the existence of a potential cause/mechanism and subsequent failure mode.	3
Very High	Design Control will almost certainly detect/prevent the existence of a potential cause/mechanism and subsequent failure mode.	1

EXHIBIT 40.4 (Downloadable)

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6. Determine the Detection Rating for Each Design Control

How likely is it that the control in place will either detect the failure mode or its cause, or prevent the failure mode or its cause from happening? Rate this on a scale from 1 to 10 using the guidelines in Exhibit 40.4.

For our razor, some controls are deemed reasonably effective (3), while others suffer from known materials issues or lack of solid information (7).

7. Determine Risk Priority Number for Each Failure Mode

The Risk Priority Number (RPN) is the pivotal column and set of numbers on the DFMEA worksheet. To calculate the RPN for each failure mode, multiply the scores for *severity, occurrence,* and *detection*. The higher the number, the higher the priority should be for design revisions or corrective actions. You can see in our example which failure modes have a higher priority of occurring and, therefore, are candidates for immediate corrective action.

However, even if the RPN is low, but we have a severity rating of 10, that failure mode must be addressed because the effect would be catastrophic (like an air-travel accident or death related to surgery).

A key difference between a Process FMEA and a Design FMEA is in a corrective action's impact on failure effect severity. With a Process FMEA, it's usually not possible to change the severity of a given failure effect, as improvements are usually limited to reducing its occurrence or enhancing its detection. This is not the case with a Design FMEA, where design changes *can* reduce the severity of a particular failure mode.

8. Implement Corrective Actions for High Risk Priority Numbers

The next portion of the DFMEA consists of a section for tracking corrective actions, responsible parties, and the results of those actions. When

Design FMEA (Continued)

Recommended Action(s)	Responsibility and Completion Date	Action Results: Actions Taken	SEV	OCC	DET	RPN
What are the actions for reducing the occurrence, or improving detection, or for identifying the root cause if it is unknown? **Should have actions only on high RPN's or easy fixes.**	Who is responsible for the recommended action?	List the completed actions that are included in the recalculated RPN. Include the implementation date for any changes.	What is the new severity?	What is the new failure rate?	Are the detection limits improved?	Recompute RPN after actions are complete.
None	N/A	N/A	N/A	N/A	N/A	N/A
None	N/A	N/A	N/A	N/A	N/A	N/A
None	N/A	N/A	N/A	N/A	N/A	N/A
Investigation of alternative spacer materials	Joe Martin, Materials dept., Dec 1, 2008	Complete. Nylon selected to replace polystyrene on Nov 15. Manufacturing capability confirmed to required tolerance on Nov 25.	5	3	3	45
Ensure gel specifications are adequate and achievable	Mary Jones, project leader, and Scott Perkins; Cream & Gel Products Manufacturing Manager, Oct 15, 2009	Specification requirements confirmed. Gel production study still underway to confirm capability.	10	TBD	TBD	TBD
DOE or other study to determine effect of pore size and other potentially interacting variables	Fred Fritz, Design Engineering, Nov 30, 2009	Study completed, determined USL and LSL for pore size on Oct 20, met with pad suppliers Oct 30 and confirmed capability to produce.	10	3	3	90
DOE or other study to determine effect of pore size and other potentially interacting variables	Fred Fritz, Design Engineering, Nov 30, 2009	Study completed, determined USL and LSL for pore size on Oct 20, met with pad suppliers Oct 30 and confirmed capability to produce.	5	3	3	45

EXHIBIT 40.5 (Downloadable)

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corrections have been made, the severity, occurrence, and detection values are revisited to help judge success. Our example shows several corrective actions taken (and one underway), and their effects on their respective failure mode RPNs (Exhibit 40.5).

Note the actions taken to prevent the wrong angle of blades. Implementing a material change for the blade spacers ameliorates this problem, because the new material has much better dimensional stability, and variation in blade angle will be much smaller. This changes the severity of the potential problem from one of possible injury to only discomfort.

When driving design changes from a DFMEA, here are some common themes:

- *If high severity is the problem,* first attempt to eliminate the failure mode altogether. If this is impractical, aim for reducing the severity of the effect. Some potential activities include changing materials, increasing strength, reducing stresses, incorporating redundancies or backups, and other design changes aimed at making the performance less sensitive to unforeseen variation. See Robust Design (Technique 38) for help.
- *If high occurrence is the problem,* first attempt to eliminate the potential cause altogether. If this can't be done, work toward making the cause less likely to occur. Again, such actions as material changes, redundancies, and spreading out stresses or loads are often successful.
- *If high detection ratings are the problem,* the corrections should be aimed at making the design failures easier to perceive, or to fill in the gaps of required information. Actions like additional testing, changes in testing procedures, or other studies are the ticket.

Resource

An excellent reference for both Design and Process FMEAs is:

Automotive Industry Action Group. *Potential Failure Mode and Effects Analysis*. 2001. Available from AIAG.org.

Discrete Event Simulation

Visualize and test your innovation through computer modeling.

Discrete event simulation (DES) is a computer-based modeling approach that enables you to simulate processes with substantially less cost, time, and risk than full-blown models. If you have an innovation in mind—such as a way for travelers to get through airport security more quickly—you could use DES to try out your ideas without physically changing the security layout or shuffling travelers through an unfamiliar system.

You should use DES when your innovation is particularly process dependent, with many variables that could affect the flow of customers or products. It does require a significant amount of time to build a detailed and accurate model, especially for more complex processes. But don't shy away from making the effort to learn this powerful technique—you can always enlist the help of a DES expert.

Not all systems can be modeled with *discrete* event simulation. Some events are *continuous*, such as the rate of evaporation. These occurrences can be modeled, but they require a different approach. For more information see *Theory of Modeling and Simulation: Integrating Discrete Event and Continuous Complex Dynamic Systems,* second edition, by B. Zeigler, H. Praehofer, and T. G. Kim, New York: Academic Press, 2000.

Steps

Scenario: Imagine that you're building the tallest skyscraper in the world and you need to know how many elevators to include. The plans call for a building 850 meters high, with 170 floors housing a mix of residential and commercial areas. To meet these demands, your team estimates that 100 elevators will be required. Hopefully this number can be reduced by simulating traffic patterns using DES.

1. Choose Software

DES requires the use of a modeling software application. Depending on the one you choose, you may need some experience with software logic to program the model with all the details related to your process. Recommended simulation software packages include: AutoMod, SigmaFlow, ProcessModel, Arena, and iGrafx. While some have higher-end features and incorporate complex logic rules (like AutoMod), others allow you to get started with DES for a minimal investment (SigmaFlow, iGrafx); these more affordable applications provide most basic users with everything they need to conduct valuable simulations.

> Discrete event simulation is performed often in the banking and call center industries—or any industry that processes resources through a system at unpredictable flow rates with a large variation in volume.

2. Develop Process Flow

The success of the simulation depends on your ability to describe the process in sufficient enough detail to produce realistic results. You can derive this information from a Process Map or Value Stream Map (Technique 46). Be sure to include key subprocesses, decision points, and queues (waiting lines).

> Discrete event simulation is based on queuing theory, which is the mathematical study of waiting in lines or queues.

3. Assign Process Attributes

For each process step, enter the associated attributes—characteristics or factors that have the potential to affect the process flow or outcome. The specific attributes you use will depend on your process. To determine the number of elevators for our skyscraper example, we'll use the following process attributes:

- *Queue Capacity:* An estimated number of passengers for each floor, varied by time of day and day of the week.
- *Cycle Time:* The time it takes to complete a specific process step, such as loading the elevator with passengers.
- *Arrival Rate per Floor:* Varies by time of day and floor function (a food court at lunchtime will see more arrival traffic than one of the residential floors).
- *Resource Capacity:* The number of elevators and the specific floors serviced by each elevator.

Costs and value-add designations can be assigned for each process step. This enables you to summarize the overall cost and value-added time of the process during the simulation.

4. Determine Resources and Attributes

Enter the resources and associated attributes. Resources are people or equipment on which the process relies. If the resources are people, attributes might include work schedules, percentage availability, and specific roles or tasks. In our skyscraper example, the resources are the elevators, which have the following attributes:

- *Capacity:* The maximum number of people each elevator can accommodate and the weight limit for each elevator.
- *Transportation Time:* The elevator speed as a function of direction (up or down) and as a function of distance between stops.
- *Measurement Statistics:* Attributes that are not assigned a value up front, but are incremented throughout the simulation to keep track of events like elevator utilization, availability, downtime, and so on.

To simulate reality, all models must run through random scenarios many times. These random distributions are accomplished by a computer algorithm known as the *Monte Carlo method,* which tells the computer what random scenario to generate next.

5. Determine Process Entities and Attributes

Enter the process entities and associated attributes. Entities are the objects that move through the process—people, parts, raw materials, and so on. The entity attributes interact with the process and resource attributes and result in random outcomes during the simulation. For our skyscraper simulation, the entities are the elevator passengers. The attributes we've identified include:

- Elevator call time (the specific time an entity pushes the call button).
- Wait time for the elevator to arrive.
- Entity weight.
- Entity pairing/grouping (is the passenger alone, or with others?).
- Departure floor.
- Departure time.
- Arrival floor.
- Arrival time.

Each process has a finite amount of capacity. If this becomes full, new entities are blocked from entering or proceeding through the process. Understanding how to optimize the capacity for a particular process is one of the benefits of discrete event simulation.

6. Run Trial Simulations

The first few times you run the simulation, you'll be validating the model. Choose how long you want the simulation to run, and pause it any time to examine how well the model is working. Allow for a warm-up period to fill the pipeline and reach steady-state.

During these early runs, look for deficiencies in logic or process settings that are not realistic. For instance, you might have built an infinite waiting line for the elevator (this is not actually realistic, although sometimes it feels like forever before an elevator finally arrives). Or, the elevator may be processing calls in sequence instead of following a logic algorithm or rule-set that, for instance, tells the elevator to stop for a passenger on floor 55 on the way down to floor 50, even though the button for floor 55 was pressed after the one for floor 50.

It may take several iterations before you get the model just right, especially if you're new to this technique. *Don't give up!* Once you get the hang of it, you'll find that discrete event simulation can be an invaluable approach.

---

7. Run Actual Simulations

When you have a valid model in place, run as many simulations as needed, varying both the process and entity attributes to see how they affect the model. Some software allows you to watch the process in action during the simulation, although this will slow it down. Or you can let it run and track the resulting data both during and after the simulation. Either way, the longer you run the simulation, the larger the sample size will be and the closer to reality your results will come.

During the skyscraper simulation, we changed a few of the elevators to a double-deck style, with two elevators linked one on top of the other. We also sped up the single-deck elevators. These changes reduced the number of elevators to 56, a significant reduction over the initial estimate (Exhibit 41.1).

You can use Design of Experiments (Technique 50) to help you determine specific attribute combinations you should test during the simulation. Design of Experiments allows you to identify interactions caused by changing two or more variables simultaneously.

---

8. Verify Results

After the simulation, you should further validate your findings using piloting (see Technique 44) or prototyping (see Technique 43).

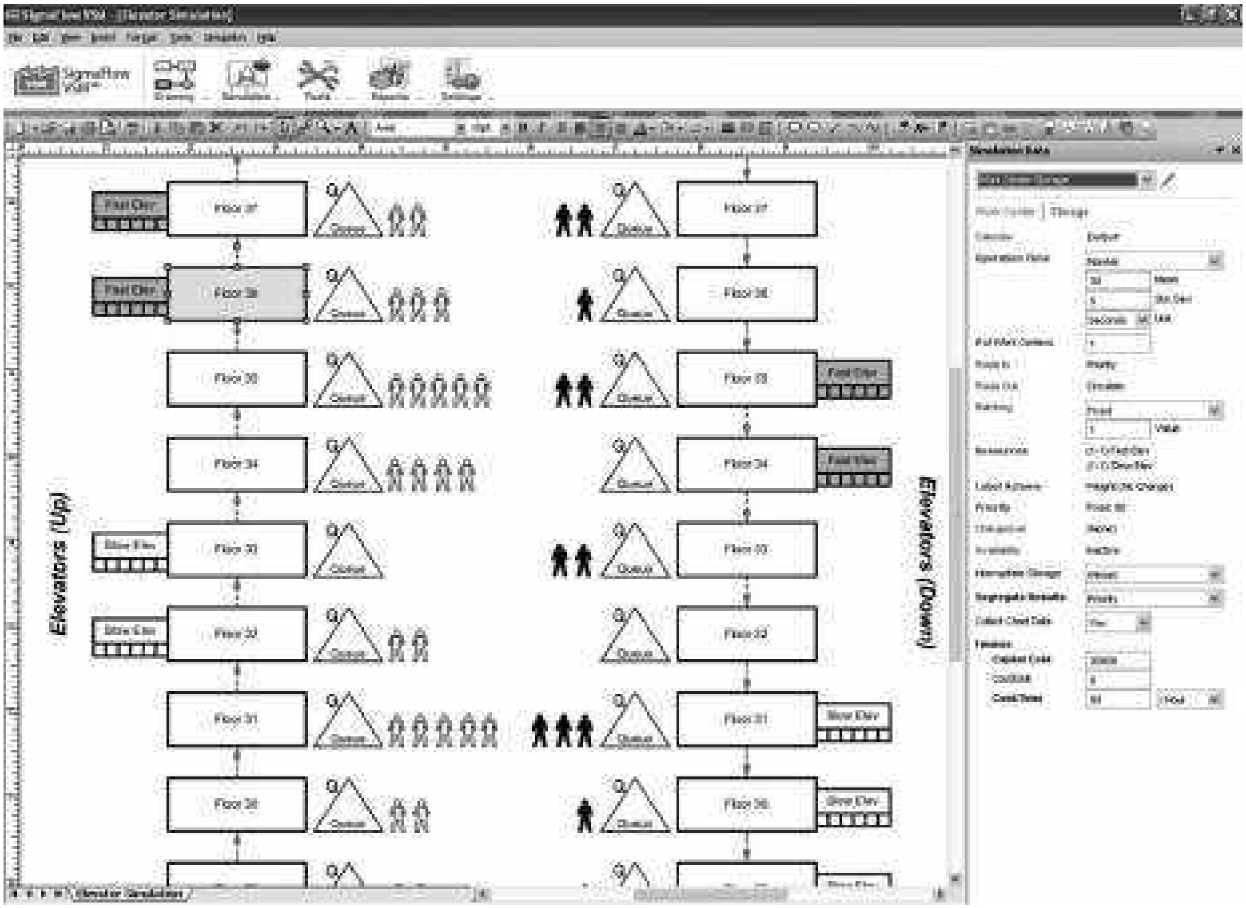

EXHIBIT 41.1 This is a sample, stylized output of the SigmaFlow Simulator Process Analyzer. In addition to performing discrete event simulations, this product also performs value stream mapping, improvement score-carding, and other analytics.

The advantages of discrete event simulation are speed, flexibility, and cost. However, poor modeling or failure to verify your findings in the real world can lead to processes that are unexpectedly impacted by small fluctuations in demand or resources.

Resources

For more information about DES, see:

Banks, J., J. Carson, B. Nelson, and D. Nicol. *Discrete Event System Simulation* 4th ed. Upper Saddle River, NJ: Prentice Hall, 2004.

SigmaFlow's Simulator Process Analyzer software (www.sigmaflow.com). This is an affordable way to conduct discrete event simulations. For a 14-day trial, go to the web site and select VSM/Simulator on the Contact Us page. To extend the typical 14-day trial to three months, use license ID *23392* and password *vsms3–65095*.

Rapid Prototyping

Make a fast 3D model of your solution to explore its viability.

Rapid prototyping is a design and communication technique that quickly (in less than a few days) creates a three-dimensional model of a new innovation or product design. When NASCAR race teams have to make fast design changes, they use rapid prototyping to identify potential production pitfalls. The University of Tennessee Anthropological Research facility uses rapid prototyping to recreate skeletal remains for forensic reconstruction.

The value of rapid prototyping comes in when you need to dramatically reduce the time and expense involved in making a model of your innovation so it can be assessed and optimized by designers and manufacturing engineers before it goes into production. As well, rapid prototypes are also used by marketing and sales professionals to test and anticipate customer reaction.

Gaining from this technique requires skill with *computer aided design* (CAD) software, as well as the availability of a rapid prototyping machine (Exhibit 42.1). Therefore, you may need the help of someone who is versed and knowledgeable in this arena and its associated technologies.

Rapid prototyping is about creating a better, faster, less expensive and more precise mousetrap—one that is built from the bottom (or concept) up to the finished product, ready for manufacture. The faster and more accurately you make your prototype, the faster you can get it to market and sell it.

EXHIBIT 42.1 3D Systems' Viper Pro SLA. System builds accurate and durable parts quickly through an additive manufacturing process.

Background

There are three main ways to create a rapid prototype. *Formative* techniques use machines to make raw materials into the desired shape. *Subtractive* processes start with a large solid, then remove material to make the shape desired. *Additive* processes rely on layering material over and over until the part or product reaches its final position and shape.

While there are many choices and options for engaging in rapid prototyping, we'll cover the basic steps involved in *stereolithography*—an additive technique by which plastic models are built thin layer upon thin layer, resulting in a three-dimensional prototype created by a machine with very little human involvement.

Some Advantages of Rapid Prototyping

- Don't have to machine, mold, or cast a prototype.
- Shortens prototype construction time and improves product design.
- Uncovers expensive mistakes *before* producing millions.
- Requires fewer steps than traditional part creation.
- Doesn't require human input, except some data entry.

In addition to stereolithography, other rapid prototyping techniques include: free-form fabrication, auto fabrication, digital fabrication, used deposition modeling, 3D printing, selective laser sintering, powder-binder printing, layer-based manufacturing, and solid imaging.

Steps

Scenario: Let's say a company is developing a new product that can play all handheld game brands and associated games on one simple device—stretching our minds to assume the owners of this new product have hurdled all the associated patent, legal, and technology barriers. The company assembles the Cool Case team to design a case for the new universal game platform—the outer shell that houses its components.

To begin, the Cool Case team has a few dimensions in mind: height, width, depth, lightweight, big screen, the needed control buttons, and so on. Note that any team ready for prototyping has already determined the expectations of the customer, as well as the functional requirements of the product and many or most of its design parameters (see Axiomatic Design, Technique 31, for more details).

At the outset of rapid prototyping, ask yourself how soon you need the prototype. Also ask how finished it needs to be. Is a fairly raw form sufficient, or does it have to be polished and smooth for a presentation? These questions guide the level of detail you need and the process involved in building your prototype.

1. Input Computer Aided Design Data

Using computer aided design (CAD) for rapid prototyping involves entering dimension-related data into the system, which then creates an electronic model based on that data. The key at this step is to ensure you have the correct data according to your design specifications, and that your data doesn't violate any rules of geometry that are embedded in CAD. If these rules aren't followed, files will be defective and possibly unusable—so, needless to say, CAD and geometry skills are very helpful at this stage.

The Cool Case team enters all its dimension data—the height, width, and length of the handheld case; all the inner and outer diameters of each hole where the playing buttons will protrude; the angle of the spherically shaped case; and several other design parameters. Having done this, assuming no geometry rules are violated, CAD will generate a three-dimensional image of the prototype on the screen. Of course with CAD, you can turn and rotate the screen image to perform a visual inspection of its integrity.

2. Export Data into Stereolithography Files

The stereolithography (STL) process requires that you export your CAD file into an *STL file*. In turn this file directs the stereolithography machine to build your prototype. If you aren't using stereolithography, you will have to convert your CAD data into another type of file format, depending on the process used.

3. Select Material and Specify Process

Different rapid prototyping machines use different materials within a limited range. Some examples of materials are: thermoplastic resins, polycarbonate, wax, powdered materials, plastics, and metals. Depending on the materials chosen and type of machine involved, you'll also have to perform other set-up steps that shouldn't require much time.

Generally speaking, the stereolithography process works by building the prototype, layer by layer, using a laser beam that solidifies each slice of the model until it is complete. As the model is created, multiple horizontal slices are stacked on top of each other until the model is complete. Most stereolithography machines take specifications for layer thickness within the range of 0.0005 to 0.02 inches.

The thicker your stereolithography layers are the less accurate your prototype will be, and the less time it will take to build. Thinner layers create a smoother, more accurate model, but it takes a longer time to complete the process.

Also at this stage, you want to determine how many prototypes you want to build at one time—or during one run cycle of the stereolithography machine. Basically you are limited by the size of your prototype and the area in which the stereolithography machine has to work. If the area is 36 in. × 36 in. × 36 in., that designates your working areas.

We should mention, too, that you can build different parts or prototypes during the same machine run. Such variety can be programmed into the machine, and the operator can set the machine up for such varied output. As long as your job doesn't exceed the working space limits and STL file-size limits, you can run as many parts with as many designs as you want.

4. Create Rapid Prototype

This is when all of your initial data, prep work, and STL files merge to create your rapid prototype. The human involvement is over, and the rapid prototyping machine builds the prototype in layers—a process that can take from 10 minutes to several hours or more. Exhibit 42.1 is a stereolithography machine made by 3D Systems Corporation.

The Cool Case team decides to build 14 plastic prototypes of the game case—enough for the upcoming core design team meeting (eight people)—plus four more that are needed at another location for a customer focus group session, plus two for the chief designer on the project.

5. Clean and Finish the Prototype

Depending on which method of rapid prototyping is chosen, all prototypes require some type of cleaning. Some parts might need to be taken off their frames, and others might require dusting. Some parts require curing in an oven. Parts must then be finished by rubbing off jagged or rough edges.

Resource

Grimm, T. *User's Guide to Rapid Prototyping*. Dearborn, MI: Society of Manufacturing Engineers, 2004.

PART IV

DEMONSTRATE THE INNOVATION

Even great designs or solutions can be thwarted by poor implementation. Most organizations know this, but they still struggle to get their solutions over the last hurdles before commercialization. Can your processes make your new product or service easily and cost-effectively? Can you deliver your new product or service to customers consistently with no errors? Will your new business model actually work in the real world?

This final phase of innovation is when you create, test, and implement your new solution. First you *build a working model* of your new solution using the Prototyping or Piloting techniques. Just because a design is sound on paper, or sound as a preliminary model, doesn't mean it will perform as expected under all working circumstances at all times. Information gathered from the working model is used to improve or optimize your solution.

When your working model proves ready, it's time to *map the processes* involved in making and delivering it—a formidable task for which you can use the SIPOC Map and Process Map/Value Stream Map techniques.

After processes are documented, they have to become as fast, efficient, and flawless as possible. This means you *optimize the processes* that generate all the value for your new solution. Several techniques will help you do this, but you should start with Measurement Systems Analysis, because it ensures the validity of any data you use in optimization studies (see the Design of Experiments, and Conjoint Analysis techniques). Then use Work Cell Design and Mistake Proofing to optimize the layout of people, machines, materials, and other factors in an office or factory.

With an optimized innovation ready for the market, it's time to *improve and transition* the project to its owners for ongoing operation. Use the Process Behavior Charts and Control Plan techniques during and after this transition. Also use the Cause & Effect Diagram and Cause & Effect Matrix to diagnose, solve, or at least mitigate any implementation problems encountered.

Prototyping

Build a fully functioning model of your new product to test and perfect it.

Prototyping is building an initial physical, functioning model of your innovation. As such, it helps you verify the design of the super-system—say, a bicycle—as well as the interoperability of the subsystems—the drive train, gears, brakes, tires, and so on. A prototype also tests the robustness of your design and its sensitivity to uncontrollable factors. Additionally, prototyping helps you verify that the required resources and processes are available to support full-scale production or delivery of your innovation.

Prototyping is typically leveraged by product or component manufacturers who need to prove a new design concept, or when the design is particularly complex or expensive to produce. By working out any issues before the design goes into full production, prototyping helps prevent rework and the costs associated with tweaking functions when the product doesn't work in the real world the way it was designed on paper.

If you've never done prototyping before, you can benefit by working with someone who has. For the most part, though, expertise on the product's specific design requirements is the main prerequisite.

Rapid prototyping (see Technique 42) is often used as a precursor to prototyping. A rapid prototype is usually made of plastic and is not meant to be structurally sound. A prototype, on the other hand, should resemble the finished product, in materials and functionality, as much as possible.

Steps

Scenario: Imagine an airplane that mimics the silent flight characteristics of owls to reduce aircraft noise. The design features a retractable, brush-like fringe on the plane's wings that breaks up air flow to lessen sound waves. The feasibility of this design could be verified by building a series of prototypes.

Geoffrey Lilley, a professor emeritus at the University of Southampton in England, has pioneered research related to the silent flight of owls and the potential applications in aeronautics. It seems the fringe on an owl's trailing feathers enables significant noise reduction during flight. In addition, a coating of down-like feathers on the owl's wings and legs absorbs sound. Similar features may someday be incorporated into airplanes to dampen sound.

---

1. Design Prototype Evaluation

Prototyping is an iterative process—you'll likely need to build more than one full-scale, working model in order to thoroughly evaluate your design. Thus, when designing a prototype, you'll need to determine the purpose of the prototype evaluation, as well as what changes to the product design will be needed to meet this objective. You'll also need to determine how you will measure the design's performance relative to the specific evaluation; often this is done by adding instruments to the prototype that measure the design's response to test variables.

For example, our first retractable fringe prototype could measure the device's functionality, as well as our ability to build the device itself. Our second prototype could be a modified wing assembly with the fringe device attached, which would determine if the fringe device works well with other subsystems in the wing (e.g., flaps, spoilers, ailerons). Our third prototype could be a set of modified wings on an airplane. At this level, we would measure the fringe's effect on noise and the amount of drag it adds during flight. We would also determine if the new design affects other systems, such as the landing gear or control system.

Along the way, we would test for *noise* sensitivity—how the design reacts to changing environmental conditions or customer use/abuse. We may use one of the prototypes as a proof of concept to secure funding. We may also demonstrate it to customers.

Some innovations are so new that customers don't "get it" until they see it. The microwave oven and the sliding door on minivans were such inventions; both used prototypes to bring the idea home.

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2. Build a Prototype

Once you've determined what you need to evaluate with a particular prototype, build the prototype using production equipment and staff as much as possible. This enables you to validate several key items:

- *Manufacturing and Assembly Processes:* Do you have the right materials, equipment, and tools to produce the new design? Is the design easy to assemble and repair? What is the defect rate?
- *Human Capital Readiness:* Are employees properly trained and staffed to meet the requirements of the new design? Does the design introduce any safety concerns?
- *Production Tooling Issues:* Do you need any special tools to assemble or manufacture the design? Does assembly require any *jigs* or *fixtures* (functional aids) that make assembly possible?

Prototypes often progress from a high-level design to more detailed iterations to allow the team to work out issues with production tooling, fixtures, and processes.

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3. Evaluate the Prototype Using a Function Audit

After the prototype is built, the next step is to evaluate your design using a *function audit*. A function audit (Exhibit 43.1) is similar to going to the doctor for a stress test, only in this case, the product is the patient and you're the physician measuring the design's response to both

Function Audit

Product: X947-400QSV231 Aircraft Wing Assembly				Date: 10/08/08
Subsystem: Trailing Edge Retractable Fringe 32-P2V1				
Supersystem Function	**Measure**	**Target**	**Tolerance**	**Measured Value**
Lift	Pounds of lift force during level flight	600,000	- 0.3%	- 0.1%
Noise Level	Decibels	80	+ 2.0%	75
Drag	Pounds of drag force during level flight	60,000	+ 1.0%	- 0.1%
Subsystem Interface Function	**Measure**	**Target**	**Tolerance**	**Measured Value**
Activate trailing edge fringe	Pound force	1.75	+ 0.2 - 0.2	1.76
Retract trailing edge fringe	Pound force	1.7	+ 0.2 - 0.2	1.7
Subsystem: Leading Edge Slat 24-Q1V4				
Supersystem Function	**Measure**	**Target**	**Tolerance**	**Measured Value**
Subsystem Interface Function	**Measure**	**Target**	**Tolerance**	**Measured Value**

EXHIBIT 43.1 (Downloadable). This is a partial Function Audit for the wing fringe prototype.

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controllable and uncontrollable factors. To do this, you'll need to determine the following:

- The subsystems you want to test (based on your particular objectives for the prototype).
- The functions each subsystem provides, both to the super-system and to other subsystems.
- The target and specification desired for each function, and how you will measure compliance. Typically, measurements are done by specially designed measurement devices that are integrated into the prototype design at critical interfaces.

4. Evaluate the Prototype for Robustness

In addition to evaluating functionality, both at the subsystem and super-system levels, a prototype should help you test the design for robustness. In other words, how well does the product perform under varying conditions, such as changing environmental conditions or customer use and abuse? If you leveraged robust design principles (see Technique 38) during the design process, and if you have been thorough in your prototype testing thus far, you should encounter few issues at this stage.

In our example, we would make sure to test the wing fringe concept at varying altitudes, in high and low humidity/temperatures, and in various weather conditions (snow, rain, wind, etc.).

5. Consider Additional Evaluations

In many cases, you'll need to evaluate the prototype for availability, maintainability, environmental impact, and reliability. For example, if we wanted to know how well our wing fringe design functions over a long period of time (reliability), we could use a Highly Accelerated Life Testing (HALT) device to activate and retract the wing fringe continuously until it fails. Another option would be Highly Accelerated Stress Screening (HASS) testing, which subjects the prototype to worse conditions than the product is likely to undergo—for example, exposing the fringe to extremely high temperatures, compression, or tensile stress (to simulate wind).

6. Repeat the Prototype Process

It's unlikely that you'll test everything with a single prototype. Therefore, be sure that your schedule and budget allow for repeating steps 1 through 5 based on varying objectives. Also, remember that your innovation may still need to undergo a pilot or finished product testing, both of which are more focused on real-world system performance.

Piloting

Build a fully functioning model of your new service to test and perfect it.

Piloting is the practice of guiding your innovative offering through real, yet controlled conditions to test performance, safety, quality, durability, and marketability. Restaurant chains, for example, sometimes make a new food or beverage available in a test market before expanding the item to all locations. Banks run pilots before offering new services or opening new branches.

Prior to full scale production or delivery, a pilot demonstrates to stakeholders and customers how your innovation addresses both provider and customer expectations. In addition, feedback at this stage helps you hone your offering, increasing its value quotient (see Technique 3) and bringing you closer to achieving the ideal innovation.

Prototyping is typically the precursor to a *product pilot,* while discrete event simulation (Technique 41) can be conducted before or instead of a *service pilot.*

Steps

Scenario: A highly renowned culinary school wants to appeal to future chefs who might not be able to afford going to school full time for two years. It develops a hybrid course that features online instruction for the first and third semesters, with hands-on semesters at the school in between. Prior to launch, the school runs a pilot to work out the kinks in their *V-Chef* course, and to gather initial customer feedback.

1. Plan the Pilot

Using a *pilot charter,* like the one shown in Exhibit 44.1, develop and document the objectives, metrics, scheduling, and cost estimates for the pilot. Time spent here will help you achieve your objectives rather than having to compensate for poor planning during the pilot run. Your planning session should answer the following questions:

- What are the objectives of the pilot? What features or functions of the innovation need to be validated?
- How will you measure product or service performance? What metrics will you monitor?
- Who are the customers for this product/service, and how will you involve them in the pilot?
- How much will the pilot cost, and how does that compare to the cost of launching an innovation that flops?
- Is there data available from a previous pilot that would be helpful for this pilot?
- Are there any piloting mistakes your organization made in the past? If so, how can you avoid the same pitfalls during this pilot?

Referring to our V-Chef example, the objective is to *assess the online course* and its ability to successfully convey culinary concepts to the students. The team will track two key metrics: *course completion rate* and *level of skill at graduation.* As an incentive to participate, pilot students will be offered a substantial discount on the course.

Before designing the pilot, make sure your team agrees on what constitutes a successful (and an unsuccessful) pilot.

---

2. Design the Pilot

Determine and document all the logistical and technical details that are needed to make the pilot a reality. For example:

- What should the pilot environment look like? What is the set-up?
- Where will the pilot be held?

Pilot Charter

Team Name:	VCP	Charter Date:	20-Apr-08
Pilot Name:	Virtual Chef (V-Chef) Course	Pilot Leader:	J. Moynette
Pilot Start Date:	01-Jan-08	Executive Sponsor:	A. Fields

Product / Service Description:
Hybrid Culinary Course (1st, 3rd semesters online; 2nd, 4th semesters on site)

Previous Pilot?	Y (N)	Where:	
Is there data available	Y (N)	Data Source:	

Pilot Study Objectives:
Assess the online course and its ability to successfully convey culinary concepts to students.

Metrics:	Baseline	Target
Course completion rate	92%	95%
Percent of passing grades on first semester exam	84%	90%

Financial Impact:
Cost of Pilot Study: See attachment   Cost of Field Failure: See attachment

Logistics:
Location of Pilot: online (various); main campus
Duration of Pilot: 6 months

Resources:	Role / Responsibility:
J. Moynette	Pilot Team Leader / Instructor
V. Nanard	Instructor
R. Racun	Instructor
TBD	Online course hosting / tech support
TBD	Students

Roles - skills gap analysis complete?	Due Date: 1-May-08	Date Completed:
Training completed?	Due Date: 31-May-08	Date Completed:

Approvals:

Pilot Team Leader ____________   Executive Sponsor ____________

Date ____________   Date ____________

EXHIBIT 44.1 (Downloadable)

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- How long should the pilot run?
- Will you need multiple pilots? With the same or different participants?
- Where will you find participants? How will you request their assistance? How will they be compensated?
- How will you collect data? How will you quantify participant responses?
- In the event something goes wrong, what is the backup plan? If changes are needed during the pilot, how will they be implemented?

The V-Chef team must work out several issues, including how to locate qualified students and how technical support will be provided during the pilot. In addition, the team realizes that one of the metrics it chose (*level of skill at graduation*) will make the pilot extremely long (an entire two-year program). So, it opts to replace this metric with one that can be measured earlier (*percent of passing grades on first semester exams*).

Of course, you expect some things to go wrong during the pilot—otherwise you wouldn't need a pilot. But you should have a backup for critical resources who, were they unavailable, would keep you from running the pilot as planned.

---

3. Designate Resources

Identify and schedule resources—people who will run and monitor the pilot, plus customers or other participants. Resources also include physical equipment, rooms, and other enabling tools. When reviewing your resource list, consider the following:

- What is the role of each participant, both employees and customers?
- Are the selected personnel equipped to perform their respective roles? If not, what training is needed to close the gap?
- Which performance metric will be tracked by which resource?
- Have you established a clear communication strategy for participants and other stakeholders?
- Have you addressed all remaining questions, especially safety issues?

The resources involved in the V-Chef example include the pilot team, the technical support team, and the students, as well as the infrastructure for the online course.

> The U.S. government recently piloted the "Registered Traveler" program with 10,000 frequent travelers. In exchange for filling out detailed background checks, participants receive a card that allows them to go through expedited airport security checkpoints.

4. Run the Pilot

Running the pilot brings all your planning and preparation together. During the live pilot, people are actively involved, and data is collected and communicated as needed. Be sure to consider the following:

- Have enough people on hand to answer questions.
- Monitor your data collection points periodically to ensure everything is working as planned.
- Make sure that participants know their feedback is valued—even if it's not what you expected or you don't like what they have to say.
- If the pilot lasts more than one day, keep communication lines open with participants, resources, and stakeholders.

During the V-Chef pilot, all technical issues are reviewed by the team on a weekly basis, and adjustments are made as necessary. At the end of the first semester, the pilot students complete an online exam designed to test their knowledge. Only students with a passing grade are invited to attend the second semester. In addition, all students complete a questionnaire and an interview regarding their experience with the online portion of the course.

5. Analyze the Results

After the pilot, take time to correlate and analyze the data you collected. Depending on the complexity of the pilot data, you may need to conduct statistical analysis to determine what changes, if any, need to be made to the product or service. Discuss the results with the team and determine:

- What aspects of the product or service do you need to modify for it to better meet customer expectations?
- What additional opportunities for improving the offering did you uncover?
- Did the pilot achieve its objectives, or do you need to run another pilot?

The V-Chef pilot demonstrates that the hybrid course is a viable option for the school. However, the amount of technical support required for the online course far exceeds the team's expectations. Since many of the issues are platform-related, the school decides to delay commercial launch of the hybrid course until it can find a more reliable vendor.

After making changes to your offering, schedule another pilot to make sure the changes work as planned and don't introduce any unacceptable side effects.

SIPOC Map

Identify the key inputs and outputs of your processes.

SIPOC (Supplier, Input, Process, Output, Customer) is a high-level map of a process that helps springboard the transition of a developed solution into production or delivery. For example, one pharmaceutical design team made a SIPOC Map to demonstrate the process involved in developing a new drug for reducing the risk of diabetes. Another health care provider leveraged a SIPOC Map when introducing an integrated hardware/software system for allowing patients access to their medical records over the Internet.

Use a SIPOC Map when you need a shared understanding of how you plan to produce and deliver your innovation to customers. This is your first order of definition, to be followed by more detail using a Process Map or Value Stream Map (see Technique 46).

Steps

Scenario: With the nation on the verge of an obesity crisis at all age levels, market research concludes that there would be serious demand for a drug that integrates with diabetic diets and associated exercise programs. A pharmaceutical design team developed a promising chemical compound to meet this need, and used a SIPOC Map to design a *new drug development process* that would ensure a smooth path for bringing the drug to market.

1. Create a High-Level Map of the Process

The P in SIPOC designates the *process*—the set of activities or tasks that transform inputs into outputs. To begin, identify the first and last tasks in the process, where it starts and stops. Specifying these steps helps to scope the project and clarify boundaries between the organization and its suppliers and customers. Next, identify the sequential steps between the first and last steps. Specify an action and an object in each box.

Be sure to define the process in general terms, listing just the high-level steps. For our example, these steps are:

1. Conduct preclinical testing.
2. File an investigation for a new drug with the Food and Drug Administration (FDA).
3. Complete clinical trials (Phases I, II, III).
4. File a new drug application (NDA) with the FDA.
5. Secure FDA approval for NDA.

It's extremely important to keep the development of the SIPOC Map *high-level*. If team members want to talk in depth about a particular step, the facilitator should focus on the big picture instead.

Sometimes, it can be helpful to do a fun or simple SIPOC example first (such as ordering and delivering a pizza) to warm the team up and demonstrate the level of discussion required to complete the SIPOC Map.

---

2. Identify the Outputs of the Process

The O in SIPOC designates the final output, or the final product, service, or information provided to the customer. For our example, the pharmaceutical team identified the following outputs associated with its new drug development process:

- New drug.
- New drug information.

SIPOC Map Cheat Sheet		
SIPOC	**Questions**	**Quick Tips**
Supplier	Who is the supplier?	Consider person, department, or organization.
Input	What are the inputs into the process?	Consider materials, equipment, procedures, people, and policies.
Process	What are the actions necessary for each step in the process?	Include an action (verb) and object (noun) for each step.
Output	What is the final product, service, or solution provided to the customer?	Identify the specific item that is provided to a specific customer.
Customer	What is the person, group, or process that will be using or benefitting from this output?	Link a specific output to a specific customer.

EXHIBIT 45.1

- An approved new drug application (NDA).
- New drug specifications.

There may be more than one output to a process, and sometimes outputs have secondary value for internal customers or regulators. Having a common and consistent definition of outputs allows everyone to set their sights on what the process produces and for whom—again, at a macro level.

> As you build your SIPOC Map, you can use the "cheat sheet" shown in Exhibit 45.1 to guide your answers.

3. Identify the Customers of the Outputs

The C in SIPOC designates the customer, or the person, group, or process receiving the output(s). The pharmaceutical team documented these relationships as direct links:

- New drug → Patients
- New drug information → Physicians
- Approved NDA → FDA
- New drug specifications → Manufacturing group

While the pharmaceutical team identified one customer per output, there can be multiple customers and outputs in a SIPOC Map. For example, when a pizza is delivered the customer gets both the product and the bill—two different outputs for the same customer. But sometimes different outputs go to different customers. A car dealer repairs your car, which is under warranty. The repaired car goes back to you, the customer, and the invoice goes to the car manufacturer, which is also a customer.

4. Identify the Inputs Required by the Process

The I in SIPOC designates the key inputs—materials, information, or products that are essential to the process. The Inputs for our pharmaceutical process are:

- Chemical compounds.
- Diabetes knowledge.
- Drug research data.
- Trial patients.
- FDA regulations.

Inputs may take on different roles in the process. Some act as key ingredients and are consumed in the transformation; in the drug-development process, chemical compounds are such ingredients. Other inputs are used to enable the operation of the process; in our example, we might designate *physicians* and *policies* as such inputs, but we didn't list them on our example SIPOC Map (Exhibit 45.2).

5. Identify the Suppliers of the Inputs to the Process

The S in SIPOC designates the suppliers, or the individual, group, or department that provides the input(s). There is a direct link between a specific Supplier and the specific Input, such as in our example:

- Chemical lab → Chemical compounds
- Medical community → Diabetes knowledge
- R&D team → Drug research data

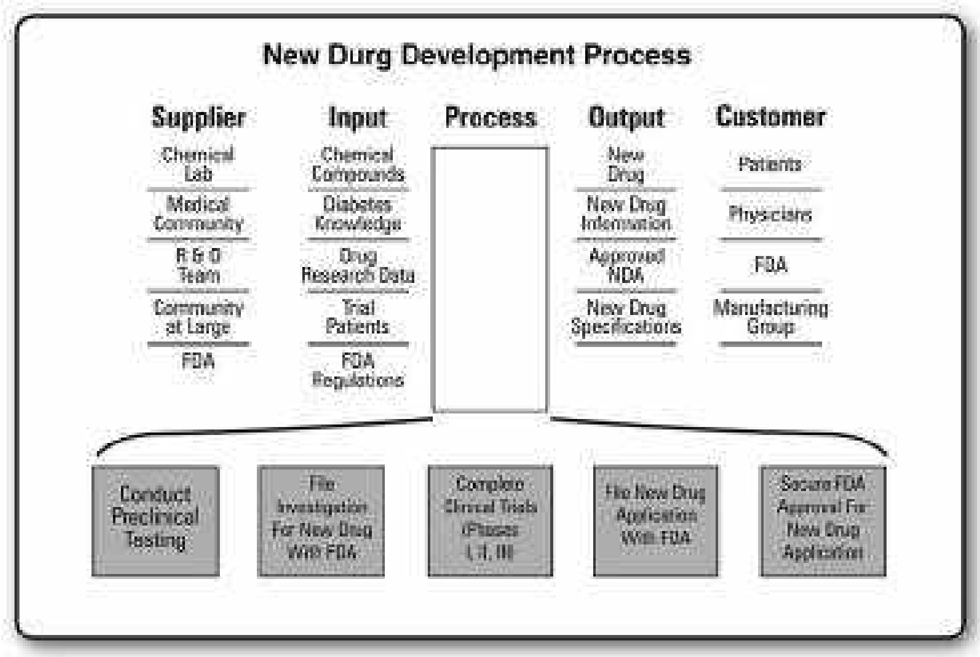

EXHIBIT 45.2 (Downloadable)

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- Community at large → Trial patients
- FDA → FDA regulations

Exhibit 45.2 shows a completed SIPOC Map for the new drug development process.

Process Map/Value Stream Map

Flesh out the details of your process.

Process Maps are basic flowcharts that depict the progression of steps, decisions, and handoffs involved in transitioning a new product or service from paper (its design) into production/delivery to customers. Value Stream Maps do this, too, but they add a level of sophistication related to time and the identification of value-added versus non-value-added activity (waste identification).

For instance, designing inflatable movie screens that can float in pools is one thing, but making them is another. It's the same with transactional processes like those in banking and insurance: there's no substitute for a robust, well-documented, and efficient process that all can see and follow.

Process and Value Stream Maps can be used in one of two ways: to document the as-is process the way it currently runs, or to document the future state of the process if it hasn't been developed, tested, and implemented. Obviously in the context of innovation, these maps are used to develop the future state. While you can apply them without the help of an expert or facilitator, it's best to enlist one, especially when building Value Stream Maps.

Using a Process or Value Stream Map to document how work will be accomplished—how process inputs are transformed into process outputs—creates needed consensus and positions the organization to implement an innovation as planned, with quality and reliability. No mishaps, defects, or costly mistakes.

Background

Everything an organization does for customers, with suppliers, and behind the scenes should be done according to an established, measurable process. When it comes to innovation, this process shows how you *will* produce your new product or deliver your new service. What work needs to be done? How will it be accomplished? Who will be responsible for each of the process steps, and in what sequence will all the detailed tasks be performed?

Typically, when building future-state maps, you have an existing process that's well documented—so the job is to improve or innovate what you already do. But you may not have any process at all to make or deliver your new innovation, so you have to start from scratch. Or you might have an existing process that you can adjust to accommodate your innovation.

There are numerous ways to draw Process and Value Stream Maps, and numerous symbols used for depicting various activities and actions. But it is best to develop your own approach that works for you and your organization, and not get too hung up on whether you are using the "correct" method and symbols.

To make value stream mapping as smooth as possible, have your team prep itself by reading up on the basic principles of Lean—an approach that increases the speed, efficiency, and value of operations while reducing waste in both product and service environments.

First articulated in *The Machine That Changed the World* (New York: Harper Perennial, 1999) authors James Womack and Daniel Jones distilled Lean into five principles in their follow-on work, *Lean Thinking:*

1. Specify the *value* desired by the customer.
2. Identify the *value stream* for each product, service, or solution—and eliminate, consolidate, or streamline all steps that are wasteful or include waste (non-value-added activity).
3. Make the product *flow* continuously through only value-added steps.
4. Introduce *pull* between all steps to enable continuous flow.
5. *Strive for perfection* so the number of steps, time, and information required to operate the process continually drops, while quality levels are maintained or improved.

Steps—Future-State Process Map

Scenario: Imagine a corporation has developed a new product called a *gutter slapper,* a device that moves from end to end inside a gutter sweeping away leaves and debris. To produce this device, you must control the flow of information and material through a process—as seamlessly, efficiently, and flawlessly as possible.

A good future-state mapping team is comprised of people who will actually perform the work later, a good facilitator or team leader, the person who is in charge of the process (process owner), and any others as needed, such as scientists, engineers, subject-matter experts, suppliers, regulators, or customers.

---

1. Define the Map Boundaries

The first step in building a Process Map is to identify the scope of the map—its starting and ending point. As you do this, keep in mind that you can't eat an elephant in one bite, so begin with a manageable portion. For the gutter slapper, we begin at *order entry* and end at *invoicing*.

If you've already developed a SIPOC Map (Technique 45), this will give you the starting and ending points for your process—and the main steps in between. You can always go back and add or subtract scope to your Process Map after you determine more about what will be involved in bringing your innovation to market.

Give yourself plenty of space to draw your Process Map, using a long stretch of wall. Many facilitators line the wall with a 36-inch roll of butcher block paper or brown paper.

---

2. Map the Future-State Process

To map a process, keep asking: *What will happen next? Who will perform this step or action?* Write this information on note cards or Post-it Notes and tape it to the working surface on the wall.

As you go along, create *swim lanes* as necessary. These depict all the steps performed by certain individuals, teams, or departments, and

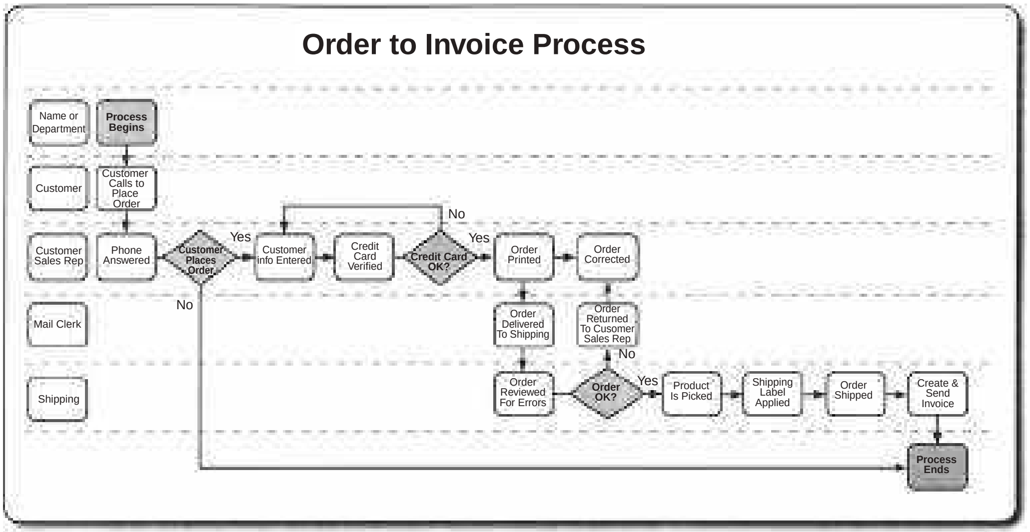

EXHIBIT 46.1

they show when handoffs are made from one person or group to another (Exhibit 46.1).

There are several standard symbols used when mapping a process, all of which are available in software applications such as Microsoft Visio and iGrafx. For our example, we only show you two of the most important symbols—a box that depicts a step in the process that always flows into the next step, and a diamond shape, which depicts a yes/no question.

After an eight-hour session, the gutter slapper team decides how its future order-entry process should look (Exhibit 46.1).

3. Finalize the Future-State Process Map

As a final step, add any information to your map that might further illuminate the process. Some people add the element of time across the top of the map to show how long steps take. You can also attach documents or forms to certain steps; doing so provides details that aide in the further development, testing, implementation, measurement, and monitoring of the process.

In addition, you may want to identify areas where you anticipate possible problems, such as bottlenecks, service errors, poor productivity, defects, shift imbalances, changeover snags, and excessive handoffs. Doing this gives you a basis for making anticipated process improvements and ensures that your innovation has the best chance of success as you bring it to market.

Steps—Future-State Value Stream Map

The steps involved in value stream mapping are much the same as they are for process mapping. But since value stream mapping is more complex, you may want to have a Lean consultant present, or at least read up on value stream mapping.

With any new innovation that doesn't simply plug into an existing process, the intent is to design a superior process from the outset. And a superior process is one in which value-added time is maximized while non-value-added time is minimized. The definition of value-added time is that for which customers are willing to pay because it directly relates to what they are buying.

For example, the step of *reviewing order for errors* is an internal activity that doesn't directly concern the customer. While the customer doesn't want any errors related to his order, he's not thrilled about paying for this activity because he'd rather the company not commit any errors in the first place. On the other hand, the customer is willing to pay for the *ship order* step. Therefore, checking for errors is non-value-added, while shipping a product to a customer is value-added.

We'll give you the steps for completing a future-state Value Stream Map, using part of the order-to-invoice process as an example (Exhibit 46.2). The steps and figure are reprinted with permission from *The Complete Idiot's Guide to Lean Six Sigma*, by Breakthrough Management Group, New York: Alpha (2007):

1. Place each of the planned process steps in order from first to last in the center of the document.
2. Place the substeps under the major steps in a vertical stack.
3. Label each process step with who will do it.
4. Indicate any rework loops by drawing lines back to any place in the process where work must return based on inspection or any other decision criteria.
5. Identify any supplier or recipient of information or material from the process, and draw a separate icon to represent each one.
6. Draw a line in the direction of the material or process flow from or to the outside entity with an arrow. Use icons to help clarify in what format the information is moving (e.g., use an envelope to indicate it is mailed, and an envelope with an *E* in the middle to indicate it's e-mail).

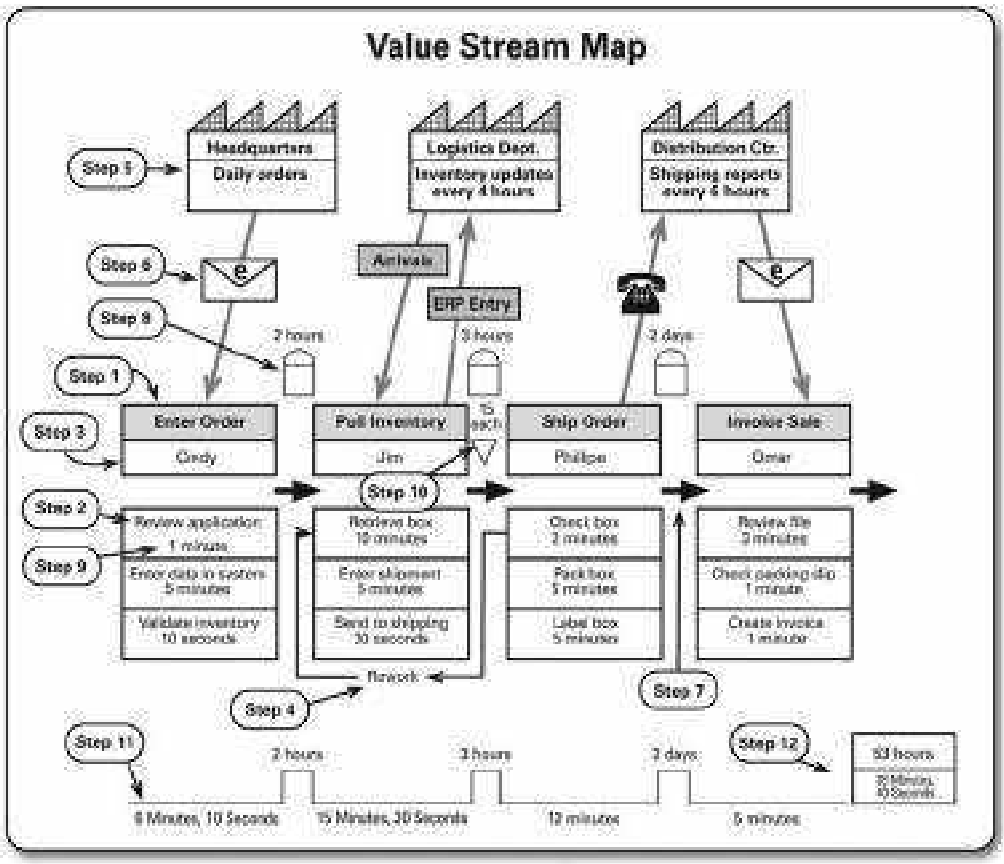

EXHIBIT 46.2

Source: Breakthrough Management Group, *The Complete Idiot's Guide to Lean Six Sigma*, New York: Alpha, 2007. Reprinted with permission.

7. Insert arrow in between each major step indicating process flow (left to right generally).
8. Insert any anticipated queues in between the steps and use the queue symbol.
9. Collect basic data around how long it will take to complete the major steps or substeps. Fill in any times or piece-count information in the relevant steps (e.g., 10 orders/hour). Write the estimated process cycle times on the bottom of the baseline chart. (Cycle time is how long a step spends on one unit, not including how long the unit is in a queue waiting for work to be performed.)

10. Measure any inventory wait expected at any step. Insert the inventory icon with the estimated average piece count above it. (Piece count is the number of separate items to be shipped.)
11. Forecast the wait times for any of the steps and insert on the baseline chart.
12. Calculate the total queue times and the total time for the process, and display this in a time line at the bottom of the chart. This distinctive time line is found on all Value Stream Maps, and at a glance it shows how much of the total elapsed time (lead time) is value-added.

Resources

Good reading for value stream mapping is:

Rother, M., J. Shook, J. Womack, and D. Jones. *Learning to See: Value Stream Mapping to Add Value and Eliminate MUDA*. Cambridge, MA: Lean Enterprise Institute, 1999.

For a general background in Lean, see:

Womack, J., and D. Jones. *Lean Thinking*. New York: Free Press, 2003.

Womack, J., and D. Jones. *The Machine That Changed the World*. New York: Harper Perennial, 1991.

For a summary and description of Value Stream Map symbols, visit:

Strategos (www.strategosinc.com/value-stream-mapping-3.htm).

Several software applications aid in the creation of Process Maps and Value Stream Maps. Three we recommend are:

iGrafx.

Microsoft Visio.

SigmaFlow.

Measurement Systems Analysis

Make sure you know your measurements are valid.

Measurement Systems Analysis (MSA) assesses your ability to accurately and precisely measure your innovative solution. For instance, if you're designing a device that detects the presence of airborne biohazards, you need to be sure that the device performs accurately and consistently over time. An MSA would help you identify and reduce variation both in the manufacturing process and in the device itself.

Even when it's not a life-or-death situation, variation leads to customer dissatisfaction and the inability to reliably meet performance and perception expectations (see Technique 30). As you near the completion of your innovative solution design, you can use MSA to identify and correct measurement system error, resulting in a higher quality, more reliable design. To be successful with MSA, you will need some experience with statistics.

Background

Measurement Systems Analysis starts with translating customer and process requirements into metrics (measurable outcomes). These metrics can be based on subjective qualitative data (taste, appearance, etc.), or objective quantitative data (e.g., seconds, number of defects). The type of data determines the type of MSA:

- An *Attribute MSA* evaluates qualitative data for accuracy (the percentage of agreement with a known standard), and precision (how often the people or systems taking measurements agree with themselves and each other).

- A *Variable MSA* evaluates quantitative data for accuracy, precision, and stability (the consistency of the measurement system over time).

Accuracy compares measurements to a known standard. Quantitative measurements frequently have an international standard that is considered the truth. Qualitative measurements, however, require a strong operational definition of the standard based on customer expectations.

Precision tracks the amount of variation when the same item is measured multiple times. It's typically measured relative to *repeatability* (same person, differing results) and *reproducibility* (multiple people, different results).

Steps—Attribute MSA

Scenario: Motivated Helpers International (MHI) is a start-up company that wants to break into the virtual personal assistant market. As such, MHI needs to hire many new employees, all with similar skills. Applicant resumes must be reviewed quickly by several different appraisers to determine if a face-to-face interview is in order. An Attribute MSA determines: (a) if MHI's appraisers are consistent when reviewing the same resume more than once, (b) how each appraiser's reviews compare to the others, and (c) if the appraisers agree with the standards that MHI's human resources department has established for new employees.

1. Review Current Measurement Systems

At the outset of every MSA, make sure you understand the current measurement system. Answering these key questions can help:

- How and where is measurement data initially collected?
- Who conducts the measurement or observation? Who are the appraisers?
- What is the root source of the data (e.g., customer complaints, inspectors, derived from other metrics)?
- Is the measurement altered through calculations, filters, or sampling?
- Can you verify the correctness of the measurement calculations?

An Attribute MSA is not limited to binary (pass/fail) decisions. The same method can be used to evaluate responses that have multiple categories (e.g., emergency room triage codes or help desk severity levels).

2. Establish Operational Definitions

Develop an *operational definition* that provides a clear and standard explanation of each metric and how it should be measured. Be sure to include:

- What is the standard for acceptance? Is it well-defined?
- Are there written and visual procedures for measuring/observing?
- How are appraisers trained?
- Do all appraisers have access to the same evaluation tools?
- Do appraisers take any shortcuts during the measurement process?

No two things are alike, but even if they were, we would still get different values when we measured them.

—Donald J. Wheeler, *Evaluating the Measurement Process,* Knoxville, TN: SPC Press, 1990.

3. Select Samples

Choose a number of samples that will serve as the *baseline* for appraisals. Samples should reflect a wide spectrum of expected results, with about half meeting the operational definitions established for the metric and half falling short. The degree to which the samples meet or fail the standard should also vary.

Sample size depends on the acceptable margin of error. For an Attribute MSA, a typical sample size is 30 with a margin of error near ±10 percent at 90 percent agreement.

4. Select Trained Appraisers

Select at least three appraisers (people who will measure or evaluate) who are trained in the proper evaluation of samples based on the operational definitions.

5. Conduct the Measurement Study

Provide the appraisers with the MSA samples and record their evaluation results. After some time has passed, conduct a second evaluation session in a different order than the first. Appraisers should not be aware that they are evaluating the same samples.

For the MHI study, three appraisers were given 20 sample resumes as part of a larger group. A week later the 20 samples, with only the applicant names changed, were mixed into another group. The appraisal results were recorded in a standard Attribute MSA worksheet (Exhibit 47.1).

6. Summarize MSA Results

After both evaluation sessions, compare the appraisals as follows:

- *Repeatability (within appraiser agreement):* Does each appraiser agree with himself between the evaluation sessions? If one person measuring the same item with the same device gets widely varying results, repeatability is poor and the fundamental measurement system is flawed.
- *Reproducibility (between appraiser agreement):* Do appraisers agree with each other? If repeatability is good but results vary between appraisers, then reproducibility is a problem with the measurement system.
- *Agreement with Standard:* Does each appraiser agree with the standard?

The evaluation results for MHI's study are shown in Exhibit 47.2.

When we summarize all appraisers versus the standard, we see that only seven times out of 20 (35 percent) did all appraisers agree with each other *and* the standard. This is far below the minimum recommended 90 percent

Attribute MSA Worksheet

Product/Unit Name:	Resume Review - Motivated Helpers International
Date of Study:	January 18, 2008
Performed By:	Lisa Hireu
Rejects	True standard based on job requirements; 8 samples are marginal

Good Resume (Interview): Accept   Bad Resume (Don't Interview): Reject

Resume	True Standard	Appraiser A		Appraiser B		Appraiser C	
		Trial #1	Trial #2	Trial #1	Trial #2	Trial #1	Trial #2
1	Accept	Reject	Reject	Accept	Accept	Accept	Accept
2	Reject	Reject	Reject	Reject	Reject	Reject	Reject
3	Reject	Reject	Reject	Accept	Accept	Reject	Reject
4	Accept	Reject	Accept	Accept	Accept	Accept	Accept
5	Accept	Accept	Accept	Accept	Accept	Accept	Accept
6	Accept	Reject	Accept	Accept	Accept	Accept	Accept
7	Reject	Accept	Reject	Accept	Accept	Reject	Reject
8	Reject	Reject	Reject	Reject	Reject	Reject	Reject
9	Accept	Accept	Reject	Accept	Accept	Accept	Accept
10	Accept	Reject	Reject	Reject	Reject	Reject	Reject
11	Reject	Reject	Reject	Reject	Reject	Reject	Reject
12	Reject	Reject	Reject	Reject	Reject	Reject	Reject
13	Accept	Reject	Reject	Accept	Accept	Accept	Accept
14	Reject	Reject	Reject	Accept	Accept	Reject	Reject
15	Accept	Reject	Reject	Accept	Accept	Accept	Accept
16	Reject	Reject	Reject	Reject	Accept	Reject	Reject
17	Accept	Accept	Accept	Accept	Accept	Accept	Accept
18	Accept	Accept	Accept	Accept	Accept	Accept	Accept
19	Accept	Reject	Reject	Accept	Accept	Accept	Accept
20	Reject	Reject	Reject	Accept	Accept	Reject	Reject

EXHIBIT 47.1 (Downloadable)

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agreement rate for an attribute measurement system (the bar would be set even higher for processes with more severe consequences).

> Some appraisers may have a bias relative to the standard (they tend to fail when the standard is pass, or pass when the standard is fail). A careful review of the MSA results will bring this bias to light.

Attribute MSA Results

Within Appraiser Agreement:	# Inspected	# Matched	Percent
A	20	16	80.00%
B	20	19	95.00%
C	20	20	100.00%

Between Appraiser Agreement:	# Inspected	# Matched	Percent
	20	8	40.00%

Each Appraiser vs Standard Agreement:	# Inspected	# Matched	Percent
A	20	11	55.00%
B	20	14	70.00%
C	20	19	95.00%

Summary

All Appraisers vs Standard Agreement:	# Inspected	# Matched	Percent
	20	7	35.00%

EXHIBIT 47.2 (Downloadable)

Copyright © 2009, Breakthrough Management Group. A blank version of this customized form is available for download at www.innovatorstoolkit.com/download.

7. Improve as Needed

If your measurement system is flawed, the MSA study will lead you to specific actions to improve consistency and operational definitions, and reduce appraiser bias.

The consequences of poor measurement systems include:

- Misunderstanding customer requirements.
- Rejecting products that a customer would deem acceptable.
- Shipping products that are unacceptable to the customer.
- Not identifying changes in performance in your processes.
- Mistakenly believing that an improvement has been made when, in reality, none has occurred.
- Making data-driven decisions based on inaccurate data.

Steps—Variable MSA

Scenario: The Getcher Fish Company wants to offer a small hand-held turbidimeter that measures the amount of suspended solids in water. This new product will help sports fishermen detect high fish activity (indicated by low turbidity). A Variable MSA measures the accuracy and stability of the turbidimeter.

1. Review Current Measurement System

As with an Attribute MSA, you need to have a good understanding of the process or product requirements, and how compliance is measured (see Attribute MSA step 1).

2. Establish Operational Definitions

The fundamental requirement for a Variable MSA is that the data can be measured on a continuous quantitative scale. As such, a standard operational definition for the performance metrics may already exist. If not, develop a clear definition suitable for your purposes.

For example, Getcher Fish's turbidimeter is aimed at the sport fishing market, so it does not have to be as accurate as similar instruments used for environmental measurements. At a level of 10 NTUs (nephelometric turbidity units), the measurement variation can be within ±2.5 NTUs and still be acceptable.

3. Select Samples

Many Variable MSA studies are run on test instruments in a lab setting to measure physical characteristics of a device. As a result, the sample size can be limited. For the turbidimeter, we'll test one known standard sample 20 times over a 20-day period.

4. Conduct the Measurement Study

If you're running a simple Variable MSA in a lab setting, the procedure is fairly straightforward. Most importantly, ensure that all tests are done by appraisers who have been trained to correctly and consistently measure and document the process or product output.

Software packages such as Minitab or Sigma XL make MSAs easier by reducing tedious calculations to a few keystrokes.

5. Summarize MSA Results

After completing the measurements, review the results for:

- *Accuracy:* The average difference (bias) between the results and the known or agreed upon standard.
- *Stability:* Any trend patterns or significant shifts in the output.
- *Repeatability:* Random variation in the measurement results.

With regard to our turbidimeter, the Variable MSA determined that the device exhibits a tolerable amount of variation (only 0.25 NTUs above the reference value of 10 NTUs). However, the study did not measure *reproducibility* (variation that may result when the device is used by different fishermen). For this, we would need to run an MSA study that measures both the repeatability and reproducibility of the device by testing 10 samples, three times each, with three appraisers.

Resources

For more on analyzing MSA results, see:

Automotive Industry Action Group. *Measurement Systems Analysis*. Southfield, MI: AIAG Publications, 2002. www.aiag.org.

Work Cell Design

Configure the workspace for flow and optimization.

Work cell design organizes people, equipment, and processes into the most efficient combination of resources to maximize value creation while minimizing waste. This concept is leveraged by home builders, for example, when they design a kitchen. As a center of activity, the kitchen needs to be laid out in a way that supports the flow of making dinner, doing dishes, putting away groceries, and other activities.

Needless to say, if you have a new innovation—product, service, or business model—it pays for you to configure a work cell design before launching into full production or delivery. In doing so, you'll optimize your processes and reduce the time it takes to meet customer demand.

The steps that follow are a good start, but to take full advantage of work cell design you need to understand more about the principles and practices of Lean—an approach that increases the speed, efficiency, and value of operations while reducing waste in both product and service environments (see Resources in Technique 46).

Background

Traditionally, manufacturers sought to keep their machines running as much as possible to maximize productivity and decrease piece costs. These days, many manufacturers (and service providers too) have realized the benefits of keeping parts, products, or service delivery flowing at a rate dictated by *customer demand.* This ensures that only the required amount of product or service is produced, as close as possible to the time it's actually needed. One component of achieving this objective is a properly designed work cell.

Steps

Scenario: RayRay's House of Hair is a new chain of beauty salons that aims to reduce customer wait and servicing time. Let's see how RayRay uses the Work Cell Design technique to optimize the flow of the hair-cutting process.

1. Gather Data

When designing a work cell, you need two key pieces of information—the customer demand rate and the time the process takes. With this data, you can determine *takt time*—the rate at which you must produce in order to keep up with demand.

- Customer demand can be represented in any increment that makes sense for your innovative offering. How many products do you sell in a day, a week, or a month? How many customers do you serve in a minute, an hour, or a day?
- Process time can be defined as either lead time (the total time the process takes from beginning to end, including wait time), or cycle time (the total time it takes to complete one process step).

In our example, RayRay gathers this data by visiting other beauty salons to see how many customers come in during a given period. He does this several times, on different days of the week, and during different times of the day to determine customer demand rate. To determine process cycle time, RayRay times several customers as they go through each step in the process (customer check-in, shampoo, hair cut, and payment).

If your product or service is new, you may not have previous customer demand or time data. In this case, you can derive the data from a pilot study or prototype. Or, you can gather data from similar processes, or even from your competitors (if they'll let you).

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2. Calculate Required Resources

Once you have the customer *demand rate* (DR) for your product or service, and the *cycle time* (CT), you can determine the *number of resources* (NR) needed to maintain takt time by using two simple formulas:

$$DR = 1/\text{takt} \qquad NR = (DR)(CT)$$

For example, RayRay's research shows that the *demand rate* for hair cuts is one customer every five minutes (DR = 1/5, so the takt time is 5 minutes). The *cycle time* for a hair cut (not including check-in, shampoo, or payment) is 15 minutes [NR = (1/5)(15) = 3]. So, RayRay's would need three resources, or stylists, to maintain takt time and keep up with customer demand.

If the process requires more than one person to maintain takt time, you can apply workload balancing to create an even distribution of work across the resources so that none are overburdened or underutilized. For more information about workload balancing, see *The Toyota Way Fieldbook,* by J. Liker and D. Meier, New York: McGraw-Hill, 2005.

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3. Optimize Process Flow

Refer to your Process or Value Stream Map and identify the value-added and non-value-added steps. A value-added step is one for which the customer would pay. All other steps are non-value-added, even if they are essential to the process. Then:

- *Eliminate non-value-added steps.* For example, RayRay determines that interrupting a hair cut in progress so the stylist can check in a new customer is a non-value-added step. He eliminates this step by installing an automated kiosk where customers check in themselves.
- *Minimize or eliminate excessive movement or transport of people or objects.* At RayRay's customers pay for their hair cut when they check in, eliminating a trip to the cashier afterward.
- *Strive for one-piece flow.* To reduce wait time, parts, products, and customers should move through the process one at a time instead of in batches.

Depending on how complex your process is, you may need different Process or/Value Stream Maps—one that provides a high-level view of the process, and any number of more detailed maps that document the subprocesses. In each case, you should attempt to eliminate or minimize non-value-added activities and wasted motion, and strive for one-piece flow.

4. Develop Standard Work

For each process step, develop *standard work*—a list of tasks required to complete that step, in order. This ensures an optimal work sequence and maintains consistency between employees who perform the same type of work. Train employees to follow the standard work documentation, and keep it in a place that can be conveniently referenced.

Note that optimizing the process flow and developing standard work may take several iterations. Repeat steps 3 and 4 as time allows, collecting data along the way, before moving on.

Don't confuse standard work with standard operating procedures (SOP). An SOP typically contains detailed and lengthy instructions for creating or assembling a product or delivering a service. Standard work identifies the best way for a person to complete a particular task and documents this information with pictures or very few words.

5. Arrange Workstations

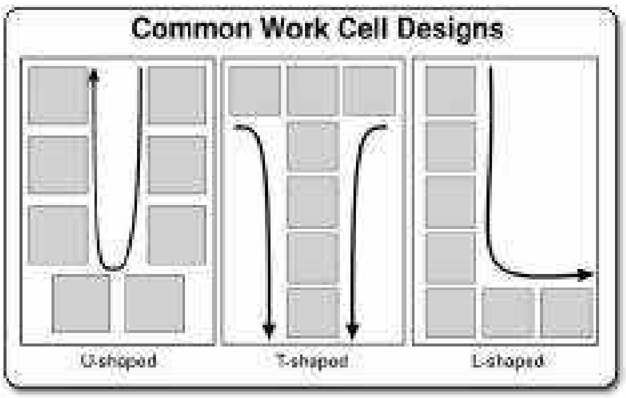

EXHIBIT 48.1 U-, T-, and L-shaped work cells are commonly employed to optimize the use of space and improve workflow.

Place workstations (desks or machines where work takes place) as close together as possible, in an arrangement that minimizes transportation and motion and optimizes flow. Depending on the type of work performed, certain layouts will work better than others (Exhibit 48.1). Regardless

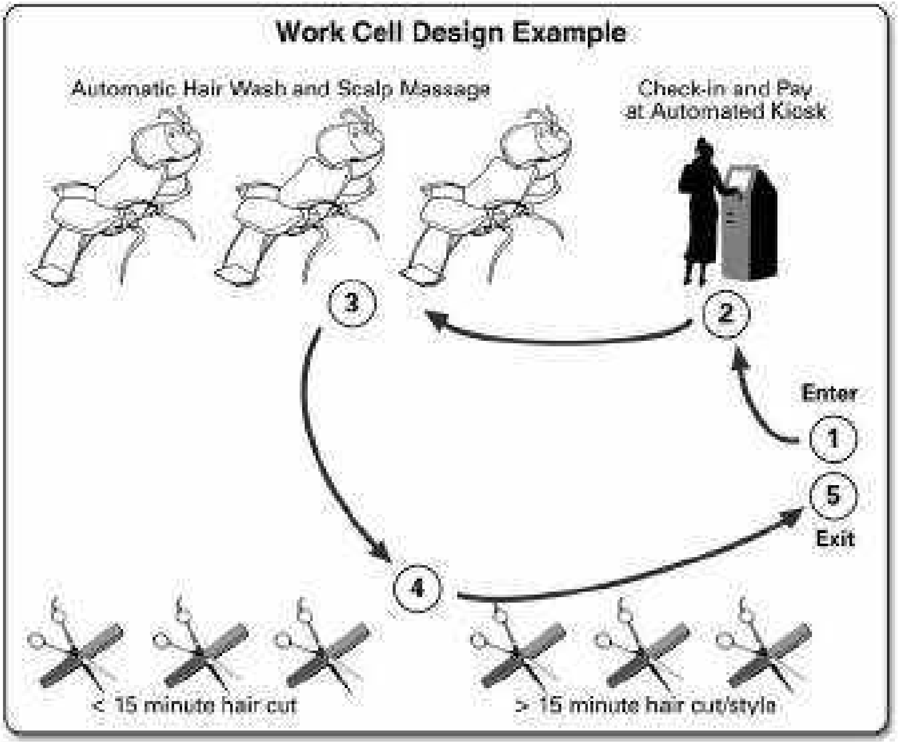

EXHIBIT 48.2

of the design you choose, be careful not to sacrifice safety or quality for efficiency's sake.

In our example, the work cell design at RayRay's is carefully laid out to direct the customers along a designated path (Exhibit 48.2). After checking in and paying, clients proceed to a booth where their hair is washed and their scalps massaged by a specially designed machine. This allows the stylist, the critical resource, to remain dedicated to the hair-cutting and styling process.

6. Apply 5S

5S stands for Sort, Store, Shine, Standardize, and Sustain. Use this method to keep your workstations clean and to standardize item locations. At RayRay's, for instance, the stylists use certain items every day including scissors, a comb, clippers, styling gel, and so on. These frequent use items are placed in readily accessible locations at the hair-cutting workstations. Items used less frequently are kept in a centralized, but out of the way location.

7. Test Design

When you're ready to put everything into place, conduct a test run of the work cell design and all the associated processes to make sure you can meet takt time and that everything goes as planned.

Resource

For a thorough reference on work cell design, see:

Hyer, N., and U. Wemmerlov. *Reorganizing the Factory: Competing through Cellular Manufacturing*. Portland, OR: Productivity Press, 2002.

Mistake Proofing

Install measures to prevent human and system error.

Mistake proofing uses a device or procedure to reduce or eliminate the possibility for an error to occur. For example, every vehicle in Canada is fitted with a device that senses dusk and automatically turns the headlights on, a simple act that has reduced accidents.

In the realm of innovation, mistake proofing helps you combat the possibility that your product or service doesn't function properly due to unforeseen events, equipment failure, and other factors. Mistake proofing also makes it easier for employees to perform their work correctly and ensures immediate recognition and repair when a mistake is made.

Mistake proofing can be as straightforward as a checklist or warning label, or as complex as a computerized system that regulates a nuclear power plant. Regardless of the situation, you should strive to apply the maximum level of mistake proofing that is both affordable and feasible for your innovation.

The Mistake Proofing technique can be leveraged early in the innovation process to help you scope your opportunity and generate ideas. For instance, a new feature in some automobiles makes the car brake automatically if it senses that you're about to hit the vehicle in front of you. The mistake-proofing strategy of *preventing accidents* was leveraged early on when the job to be done was identified.

Steps

Scenario: Producers of home security systems must take care to mistake-proof their offerings. After all, if the system is confusing to use or fails to perform as designed, it could lead to a costly or even a dangerous situation. In this example, we'll look at a few areas that, if neglected, could lead to potential errors in a home alarm system.

> No matter how well you design your new product or service, and its associated processes, there will still be opportunities to make mistakes. Each mistake, in turn, costs time and money to fix, and you risk losing customers as a result.

1. Identify Potential Mistakes

Review your innovation and its associated processes to determine where mistakes are likely to cause a defect or error:

- Use Design Failure Mode and Effects Analysis (Technique 40) to determine what is likely to go wrong with your innovation, as well as the extent of the damage you can expect if it does.
- Use a Process or Value Stream Map (Technique 46) in conjunction with a process FMEA to discover potential mistakes related to how you produce or deliver your innovation.
- Also look for technical or physical contradictions that could cause defects or errors (see Structured Abstraction, Technique 23), and Separation Principles, Technique 24), for more information about contradictions).

For our home-alarm example, potential mistakes fall into two categories: *False Positives,* where the alarm goes off when it's not supposed to, and *Failures,* where the alarm fails to trigger when a security breach occurs (Exhibit 49.1).

Potential Mistakes for Home Alarm System

False Positive	Failure
Motion sensitivity too high	Motion sensor hindered
Power surge	Power failure
Incorrect code	Not armed (human failure)
No code entered	Not armed (device failure)
Premature notification	Notification failure

EXHIBIT 49.1

10 Situations That Lead to Mistakes

1. Tool or equipment error.
2. Measurement error.
3. Misunderstanding or lack of training.
4. Poor procedures and control plans.
5. Forgetfulness or distraction.
6. Incorrect or missing parts/supplies.
7. Set-up errors.
8. Unclear specifications or expectations.
9. Ignoring the rules or willful sabotage.
10. Low safety standards.

2. Prioritize Potential Mistakes

Prioritize the list of potential failure points to determine which ones are most worth your time and effort to prevent. One way to do this is using a Design FMEA (Technique 40) to calculate a Risk Priority Number (RPN), and then address issues with high RPNs as well as those with higher severity ratings.

In an ideal world we'd make perfect products and provide flawless service, but that's not reality. You will have to choose which imperfections you'll try to prevent, and which ones you can let go. For instance, we could approach our alarm system example by focusing on the failure-type mistakes first, since the consequences of an error in this realm are more severe than for the false positives.

Mistake proofing was originated by Dr. Shigeo Shingo, a Japanese industrial engineer well versed in manufacturing best practices. Dr. Shingo coined the term *poka* (errors) *yokeru* (to avoid), or what we now call *poka-yoke*.

3. Determine Root Cause

Use a Cause & Effect Diagram (Technique 53) to determine the root cause for each potential error. This is a critical step in mistake proofing that is often missed because too many people confuse errors with *defects*. For example, *motion sensor failure* is a defect; *motion sensor zone set incorrectly* is an error. You can only truly solve a problem at the error level, so make sure you understand the difference.

Safety and risk considerations are often at the center of mistake proofing. Imagine the risk associated with unveiling new investment software, or with implementing a new surgical procedure. Both the financial and health care industries have a host of mistake-proofing measures in place to avoid costly errors and litigation.

---

4. Choose a Mistake-Proofing Strategy

For each root cause, identify an appropriate mistake-proofing strategy. You can devise a strategy using other techniques in this book, such as Value Quotient (Technique 3) to understand your offering's ideal state, and any number of ideation techniques to generate ideas for moving closer to this ideal. The exact approach, however, will depend on the specific mistake you're trying to prevent.

For example, we could prevent a homeowner from forgetting to activate the front-door security alarm by automatically arming the system. Of course, this would introduce problems when the homeowner wanted to enter or leave. Perhaps this problem could be solved by installing a fingerprint-sensitive doorknob that allows authorized individuals to enter and leave at will without setting off the alarm. Even so, you would still have to consider how to mistake-proof this solution.

Don't confuse *correction* with *prevention,* which is the ultimate goal of mistake proofing. Many people assume, for instance, that a battery backup is a mistake-proofing strategy for combating power failures. However, a battery only corrects or minimizes the damage caused by losing power; it doesn't *prevent* power loss in the first place. Thus, while it may be the best option available to you at the time, it's not as good as a power source that never fails.

---

5. Test the Mistake-Proofing Solution

The final step is to actually create and test your mistake-proofing solution. You can do this before you move on, or as part of a prototyping or piloting process.

> It is not one poka-yoke device, but the application of hundreds of these very simple fail-safing mechanisms that, day after day, has brought the quality miracle to industries around the world. Each one is relatively simple—something you easily could do on your own. But it is the totality, the hundreds of devices, that is almost frightening to behold.
>
> —Dr. Shigeo Shingo

Design of Experiments

Analyze input and output variables to identify the critical few.

Design of Experiments (DOE) is a complex but powerful method of validating your innovative solution during the design process or prior to entering full production. For example, we could run a DOE to identify the optimal settings for a new ultralight, high-mileage vehicle. The DOE would tell us the effect on gas mileage of varying factors such as tire pressure, fuel octane rating, speed, and road conditions.

DOE is an alternative to best-guess or one-factor-at-a-time experiments, which are time- and resource-intensive, and may not produce the optimal solution in the end. By using DOE to test more than one factor at a time, you'll end up with better, more reproducible solutions in less time, and you'll expend fewer resources. However, the approach does require rigorous statistical analysis and should only be used with support from statisticians or others who have been trained in DOE.

Steps

Scenario: Suppose you're designing a small robot that picks up metallic objects (screws, staples, metal shavings, etc.)—and one of the key components for the robot is an electromagnet. DOE can help you determine the electromagnet configuration that will best meet your design criteria.

1. Determine Response Variables

Responses are the *outputs* that you will study during the experiment. Identify the key responses you want to measure, but keep in mind that as the number of responses goes up, so does the experiment complexity. In our example, *electromagnetic force* is the primary response; we need to hit a target force of 20 units while keeping costs low.

DOE is a team-oriented event that benefits from a variety of backgrounds (design, operations, statistics, etc.).

---

2. Identify Factors

Factors are the *inputs* you will vary during the experiment to determine the effect on the response. Use a Cause & Effect Matrix (Technique 54) to help you identify all possible factors that contribute to the responses you listed in step 1. Then, narrow down the list based on cost and time constraints. Typically, two to seven factors work best.

For our example, we could identify 50-plus factors that affect electromagnet design, but those most relevant to our chosen response are *battery type, circuit design,* and *wire length*. We also want to investigate interactions between these factors. Does one circuit perform significantly better with a particular battery, and the other circuit perform better with the other battery? If so, this would be an interaction between the circuit and battery type.

3. Determine Factor Levels

Levels are the specific settings that determine at what point you will take your measurements, and how far apart each measurement will be. Levels can be categorical (on/off, up/down, type A/B/C, etc.) or quantitative (length, weight, pounds per square inch, etc.). Experimenting with too many levels will create a large number of trials. Experimenting with too few levels might cause you to miss an important peak on a curve. For the electromagnet DOE, we chose two levels for each factor (Exhibit 50.1).

Electromagnet DOE Design

Circuit Type	Battery Type	Wire Length
Series (−1)	Gen. Purpose (−1)	2 Feet (−1)
Parallel (+1)	Gen. Purpose (−1)	2 Feet (−1)
Series (−1)	Alkaline (+1)	2 Feet (−1)
Parallel (+1)	Alkaline (+1)	2 Feet (−1)
Series (−1)	Gen. Purpose (−1)	4 Feet (+1)
Parallel (+1)	Gen. Purpose (−1)	4 Feet (+1)
Series (−1)	Alkaline (+1)	4 Feet (+1)
Parallel (+1)	Alkaline (+1)	4 Feet (+1)

EXHIBIT 50.1

4. Select Experiment Design

The experiment design specifies which factors you will combine during the experiment and in what combination. One of the most commonly used designs is called *full factorial,* which simply tries all possible combinations of factors and levels. Although a full factorial is not as efficient as other designs, it provides reliable information on effects and interactions. To conduct our electromagnetic trials, we chose a full factorial design of three factors at two levels each, which calls for eight trial combinations ($2 \times 2 \times 2$).

Screening designs test only a fraction of the possible combinations in return for less knowledge about interactions. For example, a DOE with 11 factors at two levels each would require 2^{11}, or 2,048 combinations. A highly efficient screening design could reduce the 2,048 possible combinations to only 12.

---

5. Determine Sample Size

The sample size is the number of trials you need to run to detect significant differences between factors and levels. Detecting smaller differences requires larger sample sizes. For the electromagnet experiment, we want to detect differences in force effects of five or more units, so three replications (24 trials) should provide a sufficient sample size.

Sample size calculations are frequently accomplished by statistical software, but might also be limited by the amount of resources available to run the experiment.

---

6. Assign Factors to Design Array

Statisticians have created a battery of standard design arrays to ensure integrity in experimenting. These arrays allow quick set up through many software packages. Additional on-demand computer-generated designs are also available for special needs. For our electromagnet, we can use a standard eight-run array (Exhibit 50.2). Converting the minus and plus coded values gives us the combinations to run (Exhibit 50.1).

Sample Design Array						
Factors			Interactions			
A	B	C	AB	AC	BC	ABC
−	−	−	+	+	+	−
+	−	−	−	−	+	+
−	+	−	−	+	−	+
+	+	−	+	−	−	−
−	−	+	+	−	−	+
+	−	+	−	+	−	−
−	+	+	−	−	+	−
+	+	+	+	+	+	+

EXHIBIT 50.2

7. Determine Experiment Sequence

The sequence in which you will run trials is important because you don't want uncontrolled factors to change in the same pattern as one or more of the factors in your trial. This would create a false analysis of the data. To help prevent such confounding, you can randomize the order of the trials by rolling dice, pulling numbers out of a hat, or using computer-generated random sequences.

8. Prepare Data Collection Method

Before running the experiment, make a data collection sheet for each trial with the run order and factors, as well as a place to record results and comments (Exhibit 50.3).

Data Collection Sheet - Electromagnet DOE										
Standard	Run Order			Factors			Force			Observations
Order	B1-1st Shift	B2-2nd Shift	B3-3rd Shift	Circuit Type	Battery Type	Wire Length	B1	B2	B3	Assembly
1	3	15	17	Series	Gen. Purpose	2	6	4	5	Difficult—bent clip B1
2	8	10	20	Parallel	Gen. Purpose	2	18	14	16	Easier than series
3	1	13	18	Series	Alkaline	2	6	5	7	Difficult—about 30 seconds
4	4	14	23	Parallel	Alkaline	2	12	13	17	Easy—12 seconds
5	2	9	22	Series	Gen. Purpose	4	7	6	8	Difficult—need new clip B3
6	5	16	24	Parallel	Gen. Purpose	4	24	25	23	Easy—about 15 seconds
7	6	11	19	Series	Alkaline	4	11	12	10	B3—Wire length—2" short—Easy
8	7	12	21	Parallel	Alkaline	4	24	19	26	B2—New lot of Alkaline batteries

EXHIBIT 50.3 In this DOE, eight experiments (*Standard Order* column) were repeated by three shifts (*Run Order* column), resulting in 24 total trials.

9. Run the Experiment

Finally, the moment arrives. Make sure each trial is closely observed by one or more team members. Sometimes observations are more important than the data. In our example, the assembly of the electromagnets proves to be easier with parallel circuits than with series circuits. This is a key observation to note.

10. Analyze Results

When analyzing DOE data, you're looking to quantify the effect each factor has on the response(s), as well as any interaction effects caused by a combination of factors. For a 2 × 2 × 2 example, the effects can easily be calculated by averaging the data at the +1 levels, and subtracting the averages of the −1 levels. This calculation works for both averages and interactions according to the coded table.

Factor Effects Analysis

Circuit Type	Average Force
(+1) Parallel	19.25
(−1) Series	7.25
Difference (Effect)	12.00
Battery Type	**Average Force**
(+1) Alkaline	13.50
(−1) General Purpose	13.00
Difference (Effect)	0.50
Wire Length	**Average Force**
(+1) 4 Feet	16.25
(−1) 2 Feet	10.25
Difference (Effect)	6.00

EXHIBIT 50.4

Exhibit 50.4 shows the analysis from our electromagnet DOE. The four Parallel Circuit (+1) combinations averaged 19.25 force units. The four Series Circuit (−1) combinations averaged 7.25 force units. Thus, the effect of Circuit Type is 19.25 − 7.25 = 12 force units. Using the same type of math, the effect of battery type is 0.5 force units and the effect of wire length is 6 force units. Thus, the circuit type factor produced the greatest effect, with the wire length factor producing a moderate effect.

Interaction Effect Analysis

CL Interaction Calculation

Interaction Level	Circuit Type x Wire Length (CL)	Average Force
+1 (−1 x −1)	Series (−1) x 2 Feet (−1)	5.5
+1 (+1 x +1)	Parallel (+1) x 4 Feet (+1)	23.5
−1 (−1 x +1)	Series (−1) x 4 Feet (+1)	9
−1 (+1 x −1)	Parallel (+1) x 2 Feet (−1)	15
CL Interaction		
+1 Average		14.5
−1 Average		12
	Difference (Interaction Effect)	2.5

EXHIBIT 50.5

In addition, Exhibit 50.5 shows that there is a circuit type/wire length *interaction effect* of 2.5 force units. Further analysis conducted with the help of a statistical software program would show that circuit type, wire length, and the interaction between them are the three most statistically significant factors.

Several software programs are available to help you design and track DOEs including Minitab, Sigma XL, Design Expert, and JMP.

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11. Verify Results

Verification is a necessary step in DOE. Not only do you need to verify your best combinations, you also want to demonstrate that you can manipulate factors to produce a specific response. This is particularly true if the best combination of factors was *predicted* but not actually run during the experiment. You can verify the DOE results by running individual trials to confirm the best combinations. Or, you can run a small experiment using only a few of the significant factors to demonstrate your ability to change the response.

Resource

To take your understanding of DOE to the next level, read:

Montgomery, D. *Design and Analysis of Experiments*. 6th ed. Hoboken, NJ: John Wiley & Sons, 2004.

Conjoint Analysis

Compare solution attributes to cull out customer preferences.

Conjoint Analysis is a simplified experimental technique for determining the best combination of attributes to include in a product or service design—based on the tradeoffs customers are willing to make. For example, you could have a new laptop computer that gives more benefits and costs less than what competitors offer. But before you release it you might want to find out what customers prefer in terms of the product's attributes, and what price they are willing to pay for them.

Conjoint Analysis is used when you need to optimize a design prior to releasing it for production or delivery to customers. But it can also be used further upstream when making initial design tradeoffs prior to producing a prototype or pilot. The biggest challenge is to generate viable attribute options that the customer can realistically evaluate, using the help of an expert for more sophisticated analyses.

Originating in mathematical psychology, Conjoint Analysis was developed by marketing professor Paul Green at the Wharton School of the University of Pennsylvania.

Steps

Scenario: An adventure equipment company is considering different alternatives for a down jacket with a built-in global positioning system (GPS) to avoid storing maps and fumbling with them when your fingers get cold. Called the *PosJacket*, the new product could have any number of combined attributes. What tradeoffs are customers willing to make? What is the best combination of attributes for the PosJacket product?

1. Formulate an Attribute List

Attributes are the features associated with your product, or the key elements of interest to consumers. Each attribute can assume different levels, representing different options. Our PosJacket has the following set of features and levels:

- GPS System: Completely removable, semi-removable, or integrated (not removable).
- Price: \$350, \$450, \$750.
- Weight: 8 pounds, 5 pounds, 3 pounds.

With this list of attributes, there are $3 \times 3 \times 3 = 27$ possible jacket combinations. Product levels are assumed to be mutually exclusive; therefore, a design concept may only assume one of the levels for each attribute.

Levels should have a concrete/unambiguous meaning. For example, better to say \$750 than "very expensive." Better to say "8 pounds" than "5 to 10 pounds." The first descriptions leave meaning up to individual interpretation, while the second descriptions do not.

2. Define Concept Products or Solutions

We don't have to ask our focus group to evaluate each possible product attribute permutation. By referring to published design tables, or with the aid of software programs, you can find an efficient subset of the total possible combinations of product concepts. For our study, one efficient *design plan* yielded the PosJacket attribute combinations shown in Exhibit 51.1.

PosJacket Attribute Combinations

	GPS System			Price			Weight		
	Removable	Semi	Integrated	$350	$450	$750	8 pounds	5 pounds	3 pounds
Jacket #1			x			x		x	
Jacket #2		x				x			x
Jacket #3	x				x				x
Jacket #4		x		x			x		
Jacket #5			x		x		x		
Jacket #6			x	x					x
Jacket #7	x			x				x	
Jacket #8		x			x			x	
Jacket #9	x					x	x		

EXHIBIT 51.1 (Downloadable)

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Note that not all possible combinations are represented, but only those that fit the specific design plan. Each row in the table represents a product concept we'll ask our focus group to evaluate. Each "x" corresponds to a level each jacket prototype represents. For example, Jacket #1 has an integrated GPS, costs $750, and weighs 5 pounds.

Of course, only those combinations that are realistic will make it to the prototyping stage. For instance, a removable GPS jacket weighing 3 pounds for a price of $350 will not be profitable; therefore, this option is not offered.

The design plan in our example has clever *independence* properties:

- Each level appears exactly once with every other level. For example, 3 pounds appears an equal number of times (once) at each of the levels of GPS system and price. Such a design reflects complete independence of attributes and is termed *orthogonal*.
- An orthogonal design makes it possible to estimate the independent effect of each attribute with a relatively high degree of precision. For example, it would be difficult to distinguish separate effects if the 3-pound weight always appeared at the lowest price. Would the preference for such a concept be due to desiring low weight or low price?

3. Collect Data

Convene a focus group and ask respondents to express the trade-offs they're willing to make by rating, sorting, or choosing among hypothetical concepts and their associated attribute levels. To evaluate the PosJacket, we ask participants to evaluate each of the nine possible three-way combinations according to the design plan. Respondents rate on a 0 to 10 point scale, with 0 meaning a completely undesirable offering and 10 meaning an extremely desirable offering. One respondent's feedback is shown in Exhibit 51.2.

PosJacket Ratings

Jacket #1	Jacket #2	Jacket #3
Integrated GPS $750 price 5 lbs weight Score: 3	Semi GPS $750 price 3 lbs weight Score: 8	Removable GPS $450 price 3 lbs weight Score: 9
Jacket #4	**Jacket #5**	**Jacket #6**
Semi GPS $350 price 8 lbs weight Score: 2	Integrated GPS $450 price 8 lbs weight Score: 2	Integrated GPS $350 price 3 lbs weight Score: 10
Jacket #7	**Jacket #8**	**Jacket #9**
Removable GPS $350 price 5 lbs weight Score: 6	Semi GPS $450 price 5 lbs weight Score: 5	Removable GPS $750 price 8 lbs weight Score: 1

EXHIBIT 51.2 (Downloadable)

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4. Calculate Utilities

Preference values, called *utilities,* are calculated from the feedback of each respondent. Utilities represent the trade-offs made while selecting between different attribute levels. Because each attribute level appeared exactly once with every other level in the study, there is a simple way to estimate attribute level utilities. (Of course, conjoint studies in the real world are rarely so straightforward). We've constructed this example so that the utility estimation may be done with simple arithmetic.

For our illustration, the utility score for each attribute level is simply the average score for jackets that are included at this level. In our example, three PosJackets—#4, #6, and #7—were priced at $350. The average respondent score awarded to these was 6. Using the same approach, we can calculate utilities for each attribute level (Exhibit 51.3).

To project which product a respondent would choose, add up the level utilities for each product concept. The product concept with the highest sum of utility values may be regarded as the chosen preference. So looking at Exhibit 51.3, we see that the *integrated* (5.00), *$350* (6.00), *3-pound* (9.00) jacket is the preferred choice.

PosJacket Utility Ratings

Attribute		Level	Utility
Attribute	GPS	Removable	5.33
		Semi	5.00
		Integrated	5.00
	Price	$350	6.00
		$450	5.33
		$750	4.00
	Weight	8 pounds	1.67
		5 pounds	4.67
		3 pounds	9.00

EXHIBIT 51.3 (Downloadable)

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5. Calculate Importance Scores

Where utilities characterize choices between product levels, *importance scores* signify the relative worth or impact of each attribute on product choice. They are derived by calculating the difference between the best and worst utility scores for each attribute for each respondent, then averaging the results for all respondents. This defines the impact each attribute has on choice (according to the levels included in the study). The raw differences can be converted to percentages. Obviously the weight attribute has the greatest influence on product choice for the PosJacket example:

GPS System:	5.33 − 5.00 = 0.33	3%
Price:	6.00 − 4.00 = 2.00	21%
Weight:	9.00 − 1.67 = 7.33	76%
	9.67	100%

To elegantly present the results of a Conjoint Analysis, the values derived from respondents can be converted to a market simulator (*what-if* tool). Some software programs worthy of investigation are SAS, SPSS, and Sawtooth.

Utility values and importance scores can mean quite a lot to the trained eye, but could be challenging for others not familiar with the details. Conjoint

Analysis recognizes that people make trade-offs, and that different people make different trade-offs. If you know what those trade-offs are, you have a powerful tool to predict consumer behavior.

Resource

Try this supplemental paper if you need more on Conjoint Analysis:

Krieger, A., P. Green, and Y. Wind. *Adventures in Conjoint Analysis: A Practitioner's Guide to Trade-Off Modeling and Applications*. 2004. http://marketing.wharton.upenn.edu/ideas/pdf/Green/Monograph/Adventures-Introductory%20Materials.pdf.

Process Behavior Charts

Monitor process performance to keep the new solution in control.

Process Behavior Charts are used to monitor the performance of a process, product, service, or solution at the output (Y) and input (X) levels, answering the simple question: Is my process running as expected? For example, the mortgage loan approval process has several inputs that eventually result in the output of an approved loan. Process Behavior Charts can be used to monitor these input and output variables as a mechanism for helping manage loan turnaround times.

Use Process Behavior Charts to monitor the performance of your new innovation as it goes into production or commercialization after its design. By doing this, you create the visibility that is necessary to ensure your new innovation has successfully made the transition from the drawing board into the real world.

We only cover the most basic chart types here, so it would be necessary to have help from a process expert or statistician if your needs are more sophisticated. As well, you may need or benefit from Process Behavior Chart software if not performing your own calculations.

Process Behavior Charts are often called *control charts,* but this convention implies that a control function is performed; on the contrary, Process Behavior Charts only perform a monitoring function. The control function is performed by virtue of a good Control Plan (Technique 55).

Steps

Scenario: SkiBlades use ski-boot technology to lace up in-line (single line of wheels) roller skates. Just pull on a super thin-but-strong cord and your SkiBlades tighten around your foot. When fully tight, you release your pull and the excess thin cord retracts back into a small coil, while your boot remains very tight around your foot. Making these blades consistently requires keeping a number of production variables under control.

The general sequence for constructing Process Behavior Charts is the same for all types of data, but there is some variation depending upon whether *attribute data* (data you can count) or *variable data* (data on a scale) are involved. We'll show you the steps and some details for each type of Process Behavior Chart.

Attribute Data

During pilot production of SkiBlades, some became defective when the pull-cord broke away from the boot. After some early improvements, the pull-cord problem stabilized at just a few defects per day. But to enable continued monitoring, the production team develops a *C-chart.*

1. Gather and Plot the Data

- Determine the frequency of data collection (daily for our example).
- Record the defect counts.
- Plot the defect data on a time series chart (i.e., number of boots scrapped per day as a result of broken pulls).

2. Calculate Control Limits

- Calculate the process average (the average defect count) and add this to the chart.
- Calculate the upper and lower control limits (UCL and LCL); these are the *statistical signals* that will show when the process is not running in its usual mode.

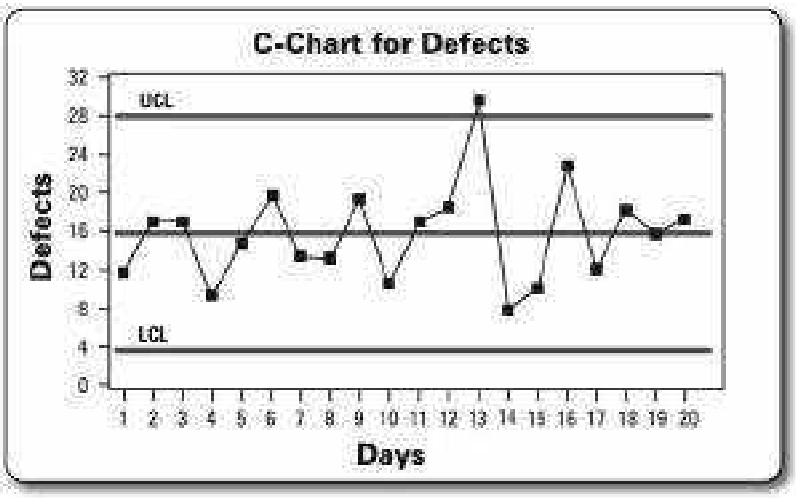

EXHIBIT 52.1

Many statistical programs (such as Minitab, SigmaXL, and JMP) automatically calculate control limits for the various types of Process Behavior Charts. If you're curious or want to perform your own calculations, see the resources listed at the end of this technique.

The C-chart in Exhibit 52.1 shows time series data in defects per day, the average number of defects, and the upper and lower control limits for the process. Note that day 13 is above the UCL, indicating a day with an unusually high defect rate.

When a process is in control, the control limits show the ordinary amount of variation, called *common cause variation*. When measurements fall outside of the limits, the variation is extraordinary, called *special cause variation*.

3. Interpret the Chart According to Established Rules

Here you are looking for *rule violations,* which are Process Behavior Chart readings that indicate the process is out of control and needs help.

Exhibit 52.1 shows a *rule one* violation: There is a large shift in the process that should be investigated immediately. On day 13, the chart shows a much higher than normal defect rate, outside the UCL.

A *rule two* violation is when the process operates above or below its average performance for an extended period of time, specifically for nine or more consecutive measurement cycles. When this happens, investigating the causes could lead to permanent process improvement and defect reduction, even when the process has shifted in a favorable manner.

Even if the shift is favorable, the process needs attention so it becomes more stable and predictable.

A *rule three* violation is when the process drifts in one direction or the other for a duration of at least six measurement cycles. So if SkiBlade defects go up or down consistently for six days, then it's time to investigate the causes and fix the process.

Variable Data

Many processes have characteristics that are measured on a variable scale rather than counted on a discrete scale. There is much more information in variable data than in count data, so charts made from these yield more signals or information than their attribute counterparts.

One of the most common types of Process Behavior Charts for variable data is the Xbar/R chart, or average and range chart. While the overall procedure for constructing this chart is the same as for the C-chart, a few additional calculations are necessary due to the nature of variable data.

The SkiBlades defect rate was mostly steady, with one exception on day 13. A team of process experts then discovered a correlation between fluctuations in the temperature of the resin curing oven and the defective pulls that broke away from the boots. At the team's recommendation, the temperature controller was replaced with a more modern unit, and the oven temperature was recorded and monitored using a Process Behavior Chart.

1. Gather and Plot the Data

- Determine the frequency of data collection and the size of the subgroup. A subgroup is defined as a few measurements gathered from the same logical grouping (i.e., data from the same machine on same shift in short period of time).

- For the oven temperature data, five measurements were taken each day for 20 days, and this constituted the subgroups.
- Record the raw variable data.
- Compute the average and range of each subgroup. Plot the subgroup averages and ranges.

2. Calculate the Control Limits

- Calculate the process average (the average Xbar) and the average range, and add them to the charts.
- Calculate the upper and lower control limits (UCL and LCL) for the average chart and the range chart; these are the statistical signals that will show when the process is not running in its usual mode. Add the control limits to the charts (Exhibit 52.2).

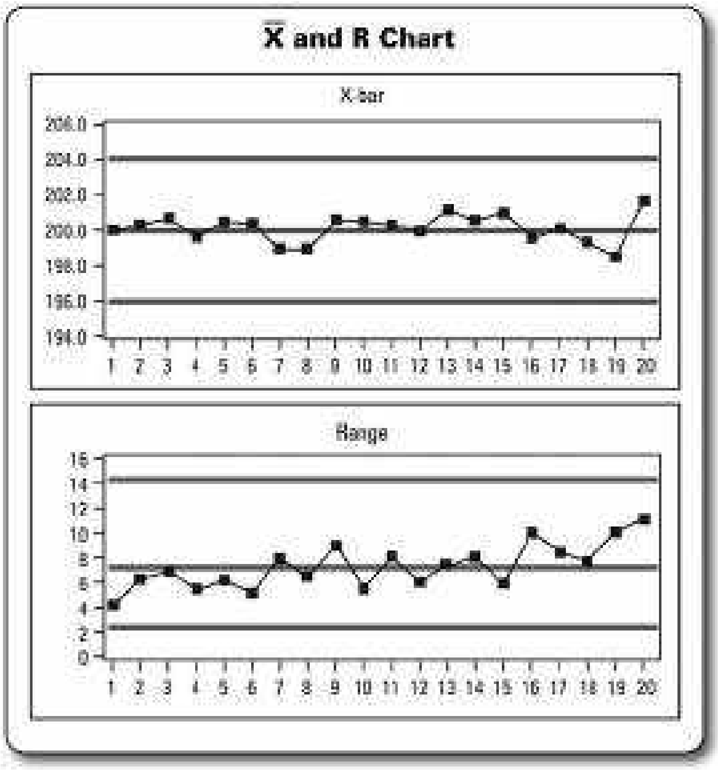

EXHIBIT 52.2

Use such statistical software as Minitab, SigmaXL, and JMP to calculate control limits for Xbar/R charts. If you're curious or want to perform your own variable Process Behavior Chart calculations, see resources at the end of this technique.

Variable behavior charts are also interpreted according to the rules shown for the C-charts, but, due to the richness of information inherent in variable data, there are additional rules for detecting more subtle changes.

Exhibit 52.2 shows that the curing temperature process is now running in control and, if the team is right, there should be a reduction in boot-pull defects. (Recall that the SkiBlades team replaced the curing oven's temperature controller with a more modern unit.)

Since the Xbar/R Charts for the oven cure data show that the curing process is now in control, there should be a corresponding shift downward in the defect rate. This improvement in the defect rate can be illustrated by combining defect data from before and after the process change onto the same C-chart.

3. Interpret the Chart According to Established Rules

Two additional Process Behavior Chart rules come into play when dealing with variable data. For these rules, the area between the process mean and the control limits is divided into thirds, that is, 1σ, 2σ, and 3σ zones, as shown in Exhibit 52.3. (σ stands for *standard deviation,* the variance or spread of a given data set).

A *rule four* violation occurs when two of any three data points reside more than two standard deviations from the process mean. This indicates that the process has unnecessarily shifted higher or lower, and the out-of-control state should be addressed.

A *rule five* violation occurs when the process has shifted higher or lower to a smaller degree than a rule four pattern. The fourth point of any five points that resides more than one standard deviation beyond the mean indicates that the process shifted—obviously sometime before the first point fell beyond the one standard deviation zone.

When out-of-control conditions are identified, you can use any number of other techniques in this book to help you figure out what happened and

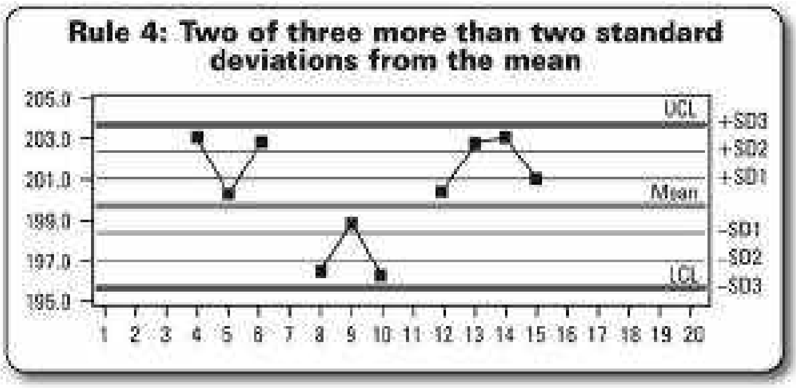

EXHIBIT 52.3

how to prevent it from happening again. Some of these include Cause & Effect Diagram (Technique 53), Design of Experiments (Technique 50), Conjoint Analysis (Technique 51), and Measurement Systems Analysis (Technique 47).

Resources

For more information and Process Behavior Chart calculations, see:

Wheeler, D. J., and D. S. Chambers. *Understanding Statistical Process Control*. Knoxville, TN: SPC Press, 1992.

The National Institute of Standards and Technology (NIST) has a good online resource for Process Behavior Charts called the *Engineering Statistics Handbook*. The portion on Process Behavior Charts can be found at:

National Institute of Standards and Technology (www.itl.nist.gov/div898/handbook/pmc/section3/pmc3.htm).

Cause & Effect Diagram

Investigate the root causes of performance problems.

A Cause & Effect (C&E) Diagram enables you to brainstorm and categorize the variables that might be causing poor performance in your new process, product, service, or solution. Say you produce a high-tech oven that monitors the internal temperature of whatever you're cooking and tells you when the food is ready. If the oven occasionally misses the mark, you need to know whether the problem is with the temperature gage, the humidity sensor, the notification system, or the food itself. A C&E Diagram helps you determine the root cause of the problem (output) by systematically identifying all the potential causes (inputs).

If your innovation isn't performing as expected or specified, or if you want to anticipate what could go wrong with your design before going into production, you can use a C&E Diagram. Just make sure that your team is knowledgeable about the system or process in question, and that they're open to getting to the root cause of any issues.

Process capability (see Technique 37) is the metric by which you know if you are having any performance issues or defect problems to solve. Once you use process capability to determine this, you then use a Cause & Effect Diagram to start analyzing the problem.

Steps

Scenario: Let's say you have a new service that rents DVD movies to customers through the mail. Recently, you've detected a decrease in customer satisfaction and retention. Using a C&E Diagram, you can systematically identify all the potential causes that may be contributing to low customer satisfaction.

1. State the Effect

Draw a horizontal arrow from left to right. Next to the arrow's point, write the *effect* (the problem you're looking to solve).

The Cause & Effect Diagram is also called a *fishbone diagram* because of its resemblance to a boned fish. Fishbone diagrams were first demonstrated in the 1940s by Dr. Kaoru Ishikawa, a Japanese engineer. He wanted a simple, graphical way to show the relationships between the inputs and outputs of a process.

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2. Choose Cause Categories

Draw diagonal lines that connect to the horizontal arrow in the middle (Exhibit 53.1). These represent *cause* categories. You can use the traditional categories below or make up your own. Another common category set is Policies, Place, People, and Procedure.

3. Identify Inputs

For each of the main categories, use a Process or Value Stream Map (Technique 46) to help you brainstorm all the causes, or inputs, that may be contributing to the problem. You can go category by category, or brainstorm freely and list the cause under the appropriate category. Write each input on its own line that extends from the category line (Exhibit 53.2). Continue until you have listed all the potential causes.

For instance, our DVD-by-mail customers could be dissatisfied because delivery takes too long. Or maybe the order process is too cumbersome. Both of these factors would be listed under the Method category.

You can have the same input under more than one category, but be careful not to list slightly reworded duplicate inputs under the same category.

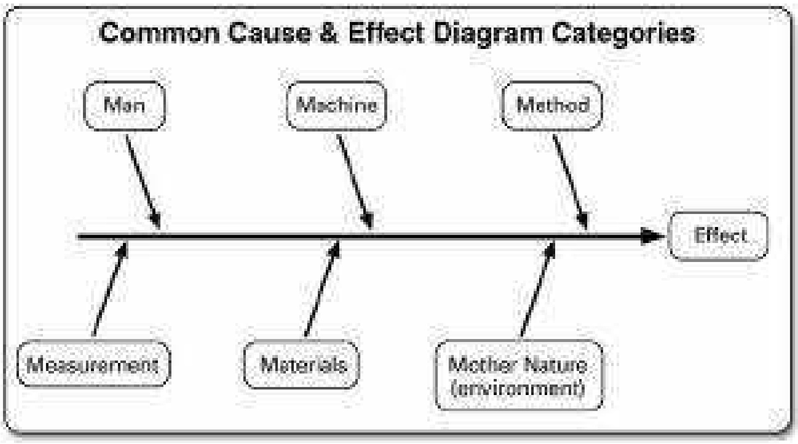

EXHIBIT 53.1 (Downloadable)

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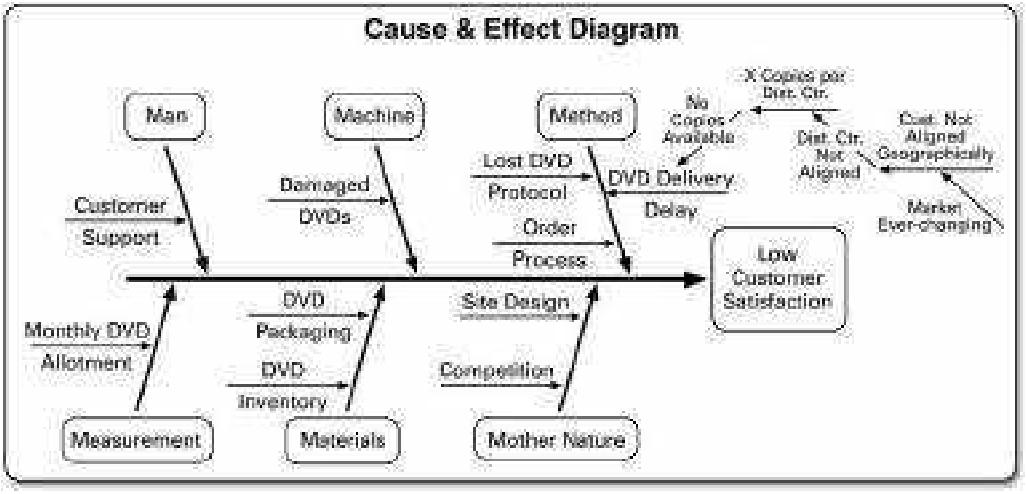

EXHIBIT 53.2 Cause & Effect Diagram (Downloadable)

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4. Ask Why

Now, for each input (potential cause), drill down by asking, "Why would this input cause the effect in question?" Repeat this process until an underlying reason cannot be articulated. For example, asking why DVD delivery may be delayed, we might determine the following:

- *Why?* There are no copies of the DVD available.
- *Why?* We only have *X* number of this DVD in the nearest distribution center.
- *Why?* The distribution centers are not aligned with our customer base.
- *Why?* Because our customer base grew disproportionate to geographic populations.
- *Why?* Because the target market for our service is ever-changing as the service matures and more people take advantage of DVDs by mail.

5. Discover Root Causes

Continue to drill down on each possible cause, asking, "Why?" When you finish, you will have narrowed down the potential causes to the main root causes. These can be further investigated using a Cause & Effect Matrix (Technique 54) to determine which inputs have the greatest impact on customer-centric outputs and, thus, need to be addressed to maintain customer expectations.

Cause & Effect Matrix

Identify the key input-output relationships in need of attention.

A Cause & Effect (C&E) Matrix helps you determine which critical process inputs have the most impact on process outputs. For example, you might have a new product that stores an Exabyte of data on a very small device. However, the process used to create the device might have an extremely poor yield. You could use a C&E Matrix to identify which factors you should focus on to improve the yield.

In essence, a C&E Matrix allows you to qualitatively determine the importance of cause-and-effect relationships between process inputs and outputs. This can be especially beneficial when you don't have enough quantitative data to define cause and effect, as may be the case with a new product, service, or process. The only caveat is that participants must be familiar with the process, its inputs, and its customer-driven outputs.

You can use a Cause & Effect Matrix at any stage of your innovation process when you need to understand the relationship between inputs and outputs, or figure out which factor has critical influence.

Steps

Scenario: In the DVD-by-mail example from the Cause & Effect Diagram (Technique 53), we looked for the root causes (inputs) contributing to customer dissatisfaction. We can also use a Cause & Effect Matrix to discover which process inputs affect customer satisfaction *the most* and, therefore, need attention and improvement.

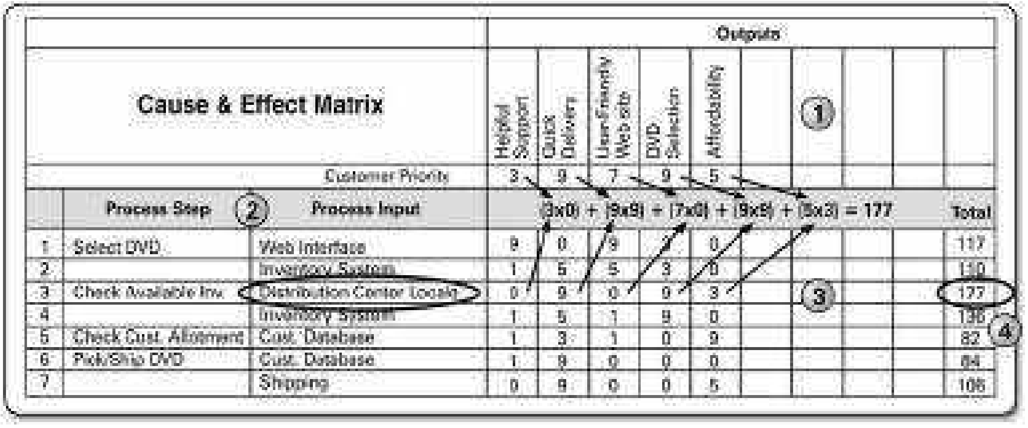
1. Identify and Rank Process Outputs

List the customer-driven outputs across the top of the C&E Matrix (Exhibit 54.1). The outputs should be synonymous with the customers' performance and perception expectations (see Technique 30 for more information). Underneath each output, rank it on a scale of 1 (less important to the customer) to 10 (more important). If it takes too long to get consensus, use 1, 5, and 9 for the rankings to give the outputs more relative separation.

If the team disagrees as to which outputs are important to the customer, make sure the customer is well-defined—is it the end user, an intermediary, or a fixer? For more on customer types, see Performance and Perception Expectations (Technique 30).

2. Identify Process Steps and Inputs

In the far left column of the C&E Matrix, enter the process steps that contribute to the outputs listed on top. Also list the inputs for each process step.



Cause & Effect Matrix

			Outputs									
			Helpful Support	Quick Delivery	User-Friendly Web site	DVD Selection	Affordability					
		Customer Priority	3	9	7	9	5					
	Process Step	Process Input	(3x0) + (9x9) + (7x0) + (9x9) + (5x3) = 177									Total
1	Select DVD	Web Interface	9	0	9	3	0					117
2		Inventory System	1	5	5	3	0					110
3	Check Available Inv.	Distribution Center Locati	0	9	0	9	3					177
4		Inventory System	1	5	1	9	0					136
5	Check Cust. Allotment	Cust. Database	1	3	1	0	9					82
6	Pick/Ship DVD	Cust. Database	1	9	0	0	0					84
7		Shipping	0	9	0	0	5					106

EXHIBIT 54.1 (Downloadable)

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You can gather this information from your Process Map or Value Stream Map (Technique 46), or even a Cause & Effect Diagram (Technique 53).

To save time, the facilitator can complete steps 1 and 2 beforehand, allowing the group to focus on evaluation (steps 3 and 4).

---

3. Rank Process Inputs

As a group, rank the potential contribution, or effect, of each input on each output. Use 0, 1, 3, 5, or 9, with 0 as no impact on the output, and 9 as maximum impact. It's important that all team members share the definitions associated with the ratings. Enter the results in the body of the matrix. For example, the DVD-by-mail team believes the *Distribution Center Locale* input has a significant impact on both the *Quick Delivery* and the *DVD Selection* outputs, so they rated these effects a 9.

If you have a complicated process, you can do a *macro* C&E Matrix using just the process steps (omitting the process inputs). This will tell you which steps have the most impact on the outputs. Then you can do a more detailed C&E Matrix using the inputs for only the critical process steps.

---

4. Calculate Cumulative Effect

For each process input row, multiply the impact value against the output priority for that column (Exhibit 54.1). Do this for each input/output combination, then add the results and put the total in the far right column. The highest totals represent the critical inputs to the process, and the ones you need to focus on to solve the problem.

A Cause & Effect Matrix enables the numerical representation of process inputs and outputs, and the relationships between them. This quantifies the knowledge of each process expert.

Control Plan

Ensure that your new solution becomes commercialized as planned.

A Control Plan is critical to ensuring that your innovation will be produced or delivered according to your careful design, regardless of location, personnel, environment, or other variables that you won't be able to control. The plan helps you mitigate risk when moving from a controlled environment (such as a lab) into an operational environment (like the factory floor).

Customers have been conditioned to expect consistency thanks to businesses like Starbucks, McDonald's, and countless others that strive to deliver the same product regardless of location. Control Plans enable any organization to replicate the customer experience by clearly documenting how to keep the process in control, what to do if it goes out of control and who is responsible for putting it back in control—all of which results in a reproducible process that delights customers and maximizes profits.

It takes many hours, even days, to complete a thorough Control Plan. This time can be minimized if you have already applied several techniques including Process Map/Value Stream Map (Technique 46), Design FMEA (Technique 40), and Measurement Systems Analysis (Technique 47).

Steps

Scenario: Imagine a drive-through fast-food chain that recognizes customers using facial recognition software, and predicts their order based on their most recent and most frequent preferences. A Control Plan, if adhered to, will ensure that customers receive the same high-quality service no matter which drive-through location they visit.

1. Process Step

Refer to your Process or Value Stream Map. Each key process step should have a row on the Control Plan. In our example, the process of taking a customer's order at the drive-through would entail many process steps—facial recognition, order processing, payment, and so on. We'll fill out our sample Control Plan (Exhibit 55.1) using the process step *facial recognition*.

We've included a recommended Control Plan form (Exhibit 55.1). But remember, the information collected in the plan can vary. Don't make it too complicated. For instance, if process capability is overkill for your process, leave it off the plan.

2. Output

The output is the desired result of the process step. It could be an outcome or event, or it might be the next step in the process. You may have more than one output for a given process step. However, if all your process steps have several outputs, your process steps are probably too high-level. For our drive-through example, if the process step is *facial recognition,* the outputs are *cycle time* and *accurate identification.*

3. Input

The input is different from the process step. Inputs are determined by asking, "What are the key inputs that make the *output* possible?" It's normal to have several inputs for any given output; however, only list the inputs that directly affect the output. You don't have to list inputs that are assumed, such as the presence of the customer.

Include inputs that you can't necessarily control, such as weather conditions that cause poor visibility. You don't have to go crazy with scenarios, but if it's likely to happen and if it will cause the process to go out of control, document it and try to plan for it.

Control Plan

Process Step	Output	Input	Spec Limit	Process Capability	Measurement System	Current Control Method	Who	When/ Where	Reaction Plan	Transition Plan
Facial Recognition	Cycle Time	Camera	1.5 - 3.5 Seconds	1.33 Cpk	Time	Camera System	Manager on Duty	1 per Month/ Sample of Stores	1 - Restart 2 - Tech Support	Drive-up Plan.doc
	Accurate Identification	Image	80 - 90% Accuracy	4 σ (sigma)	Report	Software Algorithm	Tech Support	1 per Month/ Sample of Stores	Contact Vendor	Drive-up Plan.doc
		Database Record	Yes/No	6 σ (sigma)	Report	Manual	Employee Taking Orders	1 per Month/ Sample of Stores	Add Customer to Database	Drive-up Plan.doc

EXHIBIT 55.1 (Downloadable). This example shows the Control Plan for just one step (facial recognition) from our sample fast-food, drive-through process.

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4. Specification Limit

Now that you've identified the key inputs, the rest of the plan will concentrate on how to keep the process in control. Specification (spec) limits are proven standards or measurements that set the boundaries for each input or output. When the output is operating within these boundaries (*in spec*), the process remains in control. When the output operates outside spec limits, the process goes out of control. Spec limits can be a variable range (such as the 1.5 to 3.5 second range for our drive-through camera to snap a picture), or an attribute (we use *yes/no* for our database input because the driver's image is either in the database or it's not).

5. Process Capability

Process capability is the ability of the process to meet or exceed the specification limits you've defined. Capability is based on the number of times the process output failed (defect rate) or succeeded (yield). For more details, see Process Capability (Technique 37).

6. Measurement System

What type of measurement system will you use to gauge whether the process output is within spec limits? Measurement systems can be as simple as a stopwatch or as complex as an electronic data-capture process. Keep in mind that the simplest solution is usually the best; the goal is to provide an exemplary product or service, not to create elaborate measurements that delay delivery.

A Measurement Systems Analysis (Technique 47) will make sure your measurement system is accurate and doesn't introduce variation into the process.

7. Current Control Method

How will you know when the process goes out of control? The control method typically results from a process Failure Mode and Effects Analysis (FMEA), where you have determined what could go wrong (how the process could go out of control), and what will be done to correct it if it does. For instance, if our drive-through camera cycle time is too slow, the system automatically alerts management.

8. Who

When you identify clear roles and accountability prior to delivering a new product or service, you can better predict and control the customer experience. This field simply documents who (or what) is responsible for keeping the process step in control. It could be an employee, a supervisor, a supplier, or even a machine setting or software program.

9. When and Where

This area documents two important elements: when (how often) will you measure the process to determine if it's in control, and where will the measurement data be recorded? Depending on what you're measuring, the *when* may be a designated frequency (daily, weekly, etc.). Or, it could be based on the number of transactions (e.g., products manufactured or customers served).

Either way, measurement data needs to be recorded consistently and accurately to help you compare data points over time. If your process is complicated, you'll want to employ Process Behavior Charts (Technique 52) to quickly and visually track when the process goes out of control.

10. Reaction Plan

We already have who, where, and when, so this section documents the *how*—how you will get the process back in control if it goes outside the spec limits. In our example, when the camera process goes out of control, the manager restarts the camera. If that doesn't work, she contacts technical support.

> The *how* is often the hidden delighter in the customer experience. Customers will be infinitely more forgiving when something goes wrong if the response is appropriate and is delivered in a predictable manner.

11. Transition Plan

A *Transition Plan* includes any additional information, above and beyond the Control Plan, needed to move from a pilot or small-scale production to full-scale production and delivery. Typically this documentation is detailed and so is merely referenced in the Control Plan. In our example, the Transition Plan might include tech support and vendor contact information, and suggested scripts for taking orders or soliciting customers to add to the facial-recognition database.

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