CHAPTER 3

OPTIMIZATION IN ACTION

We live in an Optimization-ripe era. For much of human history, competition for goods and services was primarily regionalized, and resources seemed almost boundless. Expanding global empires, the Age of Exploration, and Manifest Destiny all reflected the drive of a few powerful nations to dominate a resource-rich world. Following World War II, the United States was left the uncontested master of the industrial universe, driven to satisfy the pent-up demand for goods and services at home and abroad. Given the situation, who needed to worry about competition and resource conservation? Certainly not the United States.

But what a difference a few decades make! Today, the world is marked by ferocious global competition for every imaginable product and service. Each year, the World Economic Forum publishes a report evaluating the global competitiveness of countries around the world. Its 2010 ratings range from 2.58 to 5.60, based on a composite rating for each country, which include such factors as infrastructure, macroeconomic stability, education levels, market efficiency, financial sophistication, technology readiness, business sophistication, and innovation. For many years, the United States, together with a handful of highly industrialized nations, dominated the ratings. In the 2009–2010 report, however, 19 countries had ratings of 5 or higher, and for the first time the United States fell from the vaunted first position to number two.[1] No doubt about it: businesswise, the world has become a very competitive place.

As for unbounded resources, the stress imposed on the world's environment and its resources by seven billion inhabitants shows itself every time we read the news, listen to or watch a news broadcast, or travel. Some optimists argue that the world could support nearly twice as many inhabitants. However, as Jared Diamond points out in his book *Collapse*, such arguments fail to persuasively show how so many inhabitants could be supported. Today, citizens in the United States, Western Europe, and Japan consume 32 times more fossil fuel—and extrudes 32 times more waste—than do inhabitants of the Third World. If all the members of the Third World were to adopt the living standard of the industrialized nations, the impact on resources would increase by a factor of 12.[2] It takes blind faith—never mind optimism—to believe that this could be feasible without vastly improving the efficiencies of our resource use.

Given the hyper-competitive, resource-drained world in which we live, Optimization holds great promise. Two resources that the world is not short of are data and computing power, the very stuff of Optimization. Today, companies such as Amazon Web Services and Elastic Compute Cloud are leading the way in providing customers with vast amounts of low-cost computation and storage on demand, much as utility companies supply water and electricity. With computing power and data increasingly being commoditized, let's take a look at how a variety of organizations are using Optimization to manage their assets and extract greater value from scarcity.

What Is the Real Value of Your Assets?

Accountants have a fairly narrow definition of *assets*. To optimizers, assets include *any resource that an organization owns or controls that can potentially add value to the business*. Some are traditional accounting assets, such as buildings, equipment, and inventory. Others are human assets, such as your employees, vendors, and customers. Still others are intangible assets, such as your reputation, brand, customer loyalty, intellectual property, and access to capital. Whatever the asset, optimizers are driven to maximize its yield.

Identifying assets can be tricky. What you see may not immediately reveal the true value of what you have. Take a national long-haul trucking company. Its highest-cost assets are its fleet of trucks, but the real value of these assets comes from how well they are loaded and deployed: Where should you position them to get the most freight? Which loads should you accept? Which should you turn down? Are they loaded coming and going, or do they have to deadhead one way?

If you are a printer, your presses are clearly large and expensive assets. But their real value is driven by how you decide to load and run them: Are you able to keep them running at full capacity a high percentage of the time? Are you able to provide printing capacity to the most profitable customers on a reliable basis? Can you organize the printing queue in ways that minimize packing and shipping costs?

For a grocer, shelf space is a key asset, but not all shelf space is equal. No matter what you place at eye level, at the front of the store, it sells much more; put the same product near the floor, in the furthest corner, and you will spend more time dusting than restocking. For airlines, planes are clearly assets. But what determines the planes' true value—and competitively makes or breaks the airline—are the thousand and one decisions that an airline makes about pricing, plane positioning, flight crew assignments, and maintenance schedules.

At Ann Taylor Stores Corporation, time and people are key assets, so maximizing value from them becomes everything. To improve the value per hour from its sales force, the company installed an optimization program that stipulates which employees should work, when, and for how long, with the best sales performers scheduled for the busiest hours.[3] Optimizing workforce management—it makes great sense, given the criticality of human assets to most organizations' success.

No matter which of your assets you focus on, the goal of an optimizer is not simply to utilize the asset. After all, what is the value of running a machine 100 percent of the time if it works on low-value activities, creates bottlenecks, or produces a product that fails to meet specifications or customer requirements? The goal of an optimizer is not simply to keep an asset busy, but to *utilize the asset in a way that adds the greatest value to an organization's long-term profitability.*

How well you accomplish this goal typically depends on a series of complex and often repetitive decisions that juggle constraints and balance multiple interdependent objectives. For example:

- Which prospects should your sales force focus on?
- Should you expand your office space at headquarters or invest in a regional office?
- How much raw material should you order to balance customer demands and inventory expenses?
- What products should you discount this week, where, and what will be the likely cross-impact on other offerings?
- If you add a "plus" feature to a "regular" product or service, do you drive up high-margin volume?
- Should your employees be stocking shelves or waiting on customers?
- Which employees should you pull away from their current assignments to serve on the committee preparing a new proposal?

These and hundreds of other repetitive decisions continuously add or subtract value from your enterprise. Optimization can improve the quality of each of those decisions, each time they are made, adding millions and even billions to the bottom line, as McDonald's, UPS, Marriott, Walmart, Amazon, Google, and other early adopters have discovered.

Decisions: Man—or Woman—Versus Machine

Optimization is about making decisions and choices. What sets today's optimizers apart is their ability to use voluminous data, computers, and software to make decisions about assets better, faster, and more consistently than others can. And therein lies their power: optimizers give us computer programs that are capable of making *accurate and lightning-fast recommendations.*

Computers have become the paper, pencils, and filing cabinets of the modern enterprise. They are used in the workplace to gather, store, and manage data. But when it comes to the moment of truth, when a choice must be made among competing alternatives, the old-

fashioned "computer" that sits atop our shoulders is all too often the decider. Most software programs juggle data and supply us with volumes of well-organized information at the push of a button. They tell us what is happening, but not what we should do about it. They do not make recommendations. But optimization software is different. Beyond analyzing data, it takes the next step: *deciding on and making a specific recommendation.* This is what distinguishes it from the vast majority of software used by businesses today.

Before we look at some concrete examples of how companies are strengthening their competitive position through decision-making software, let's examine how people and computers stack up against one another as decision makers.

Where Computers Shine

A person can juggle a few dozen permutations, or combinations, of data. Optimization software can juggle millions or even billions.

To understand why this is such an important capability, assume that you are managing an emergency room and have to decide the order in which three patients, all of whom arrived around the same time, will be examined. The total number of combinations is six, or three factorial (written as "3!"). Not too tough a problem to sort out. But now let's make it a little more complex. By increasing the number of patients to 10, you increase the number of possible orders in which to attend to them over 3 million (10! or 3,628,800). Add just three more patients, and the number of possible combinations rises to over 87 billion (13! = 87,178,291,200).

To put 13! into perspective, suppose you tried each combination in your head and could do so at the rate of 10 per second. If you did that 24/7 and never slept, you could get through 13! combinations in about three centuries. Not too bad. But 13 isn't that large a number of patients to consider. Suppose we upped the ante to 20 patients, such as might occur following a natural disaster. At the same speed, 20! would take you over *11 billion centuries.*

So how do emergency room (ER) personnel cope? They use simple rules of thumb to help set priorities, such as "first come, first served" or "move forward anyone who has lost consciousness." Even if there are more efficient and better combinations, no unaided human being has time to consider even a tiny fraction of the possible arrangements.

By being able to search many thousands or millions of times more possibilities than humans, computers can make better recommendations. But examining or testing permutations is just one significant advantage in the decision-making process that computers and optimization software possess. There are others.

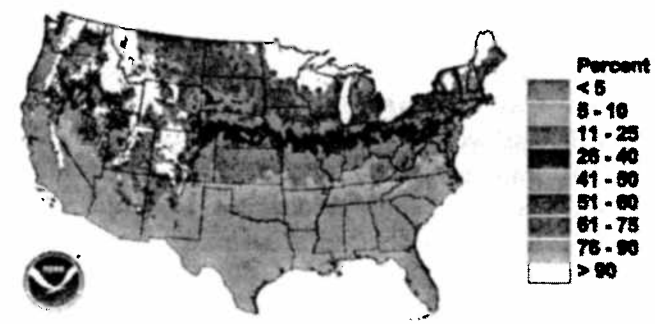
One is the ability to access extremely large and complex databases at lightning speed. When I am considering buying a book on Amazon, its optimization software can instantly combine my current selection with a search of millions of past purchases to create a profile of my interests and then suggest other books I might like, based on what other recent shoppers "like me" have purchased. Imagine a salesperson in a bookstore trying to compete with Amazon's software just using his own memory and reading experience. When making an optimal decision depends on accessing, reviewing, and sorting large amounts of pertinent information, the computer wins hands down.

The power of a computer to make decisions extends beyond simply accessing and sorting information. Computers typically are also better than humans at combining information. One important area mentioned in Chapter 2 is combining probabilities. People are fairly capable of estimating simple probabilities in areas in which they have experience. For example, if I were to ask you what the chances are that this year your hometown will have a white Christmas—defined by at least one inch of snow on the ground—your guess would probably be fairly accurate. If you live in the United States, you can test this by first making an estimate and then checking your accuracy on the map in Figure 3.1.

However, if I asked what the chances are of a white Christmas *and* the day being sunny, you would likely have a much harder time making an estimate. The answer would require not only knowing two likelihoods, but knowing how to combine them correctly.

Here is another example of just how difficult it is for us to juggle multiple probabilities. Suppose I were to estimate the probability that a person randomly sitting next to you has the same birthday as you. Most people would come up with an answer of 1 chance out of 365, which would be fairly accurate (although not perfect, since birthdays are not distributed evenly throughout the entire year). But now suppose you are sitting in a room with 22 of your closest friends. What are the chances that 2 people in this relatively small group have the same birthday, assuming that none of them are twins? Surprisingly,

FIGURE 3.1 Probability of a White Christmas Based on 1961–1990 Climate Normals[4]



the answer is 50-50. If you should be so lucky as to be together with 56 friends, there is a 99 percent probability that two of them were born on the same day.[5] Most people are surprised by such a high probability. Our intuitions are simply not wired to accurately estimate probability problems of this nature. A computer, however, can easily compute the answer with a relatively simple program. Optimal solutions often require estimating and combining probabilities.

Computers Lack Biases

Another advantage that machines have over people in many decision situations is that machines exhibit a lot fewer biases in their judgments. If you search Wikipedia for a "list of cognitive biases," you will encounter a list of 105 different judgment biases that humans have been shown to exhibit.[6] Scanning the list may convince you to turn all decision-making over to your computer. Here are just a few of the 105 that have been well documented in humans, but not computers:

- **Confirmation bias** refers to people's tendency to confirm their preconceptions or hypotheses independent of the likelihood that they are true. At least three mechanisms that support this bias have been documented by psychologists: (1) selectively collecting new evidence, (2) interpreting evidence in a biased fashion, and (3) selectively recalling information from memory. These biases have been found to be particularly pronounced when people are dealing with emotional decisions or decisions related to the core beliefs that shape their day-to-day expectations.

- **Mere exposure effect** is the tendency for people to develop a preference for things merely because they are familiar with them. This effect has been shown to occur for a wide variety of stimuli, from Chinese characters to geometric figures to other people. It has also been shown to occur without conscious awareness or thought. People frequently select an alternative simply because they have seen it before, not because it is the best answer.
- **Outcome bias** is people's tendency to judge the quality of a decision by its ultimate outcome instead of by how well the evidence was weighed at the time the decision was made. People frequently fail to consider when information first became available. For example, when evaluating the decision to launch a new product that turned out to be a poor seller, the team carrying out the postmortem often considers market dynamics that only became apparent *after* the product was launched.
- **Availability heuristic** refers to people's tendency to estimate the frequency of an event or object within a population, based on how easily an example can be brought to mind. As a result, people generally overestimate the frequency of vivid, unusual, or emotionally charged events.
- **Actor-observer bias** refers to people's frequent tendency to explain others' behavior by personal rather than situational factors. Beware of conclusions such as, "That's just the kind of person she is." Not surprisingly, just the opposite bias occurs when people provide explanations of their own behavior. Here, you are most likely to hear something like, "I just had to do it. Given the situation, I had no other choice."
- **Illusory correlation** refers to people's frequent perception of correlations when none exist. Often, this occurs when multiple unique events stand out in memory. For example, when someone says, "The only time I forget my pencil is when we have a test," it is most likely an illusory correlation resulting from a few easily remembered pencil-less test days. Computers, on the other hand, use a formula, rather than how easily they can retrieve a fact from memory, to compute correlations.

A review of the complete list of judgment biases leaves little doubt that in many situations judgments by computers are much more likely to be dependable than those of their human creators!

One final area in which computers win out over humans when making decisions is stamina. Computers can run 24/7 without wearing down, they seldom stay out late drinking or partying, and they are not prone to emotional swings. As a consequence, not only can they frequently make better judgments than humans, but the quality of their judgments and decisions tends to be much more consistent.

Where Humans Shine

The intent here is not to imply that computers always make better decisions than people. There are clearly times when humans make better decisions than machines—at least up until now.

One area in which humans shine is when a decision must be based on deep knowledge, where the rules are not yet fully understood. One example would be the world of art appraisal. An expert art appraiser's knowledge is so broad and deep that to date no computer program can surpass, or even mimic, an expert appraiser's ability. As Malcolm Gladwell documents in *Blink*, there are instances in which art experts reach conclusions instantaneously, so quickly that they themselves are unable to explain how they did it.[7] But expert advantage may be short-lived, as we will see momentarily in a case related to selecting the next great music hit. Don't be surprised to increasingly see computers prove the experts wrong.

Another related area in which computers struggle to keep pace with humans is when relevant data are not formally available in a digital form at the time the decision has to be made. Despite high levels of automation, many decisions are made in part by humans calling their peers or superiors on the phone, holding impromptu face-to-face meetings, or accessing other data sources that may be difficult to load into a computer in a timely fashion.

To date, computers are also woefully behind humans in their ability to read emotions with nuance and to codify social and body language. Humans seem likely to continue to lead in decision making when emotions play an important determining role. However, Professor Rosalind Picard, founder and director of MIT's Affective Computing Research Group, argues that it is only a matter of time before computers will begin to acquire components of emotional intelligence and be able to read our emotions and adjust their responses accordingly.[8] This may be both good and bad news. At some point, we might have to argue with anxious computers, never mind irrational bosses!

Humans also shine in cases where the participatory nature of the decision-making process itself helps achieve results. It has been widely observed that American executives typically make decisions faster than their Japanese counterparts, but implementing those decisions is another story. The Japanese, on the other hand, tend to be slower at making decisions, given their cultural imperative to build consensus among all those who have a stake in the decision—*ringisei*. When it comes to speed of implementation, however, they typically beat their American counterparts.

Or to choose a more fanciful example, consider elections. Most of us would like the optimal candidate to win, but few of us would delegate our right to vote to some type of election-optimizer software program. Besides abridging a fundamental political right, protracted campaigning—an important, though some would argue painful, part of the selection process—would be eliminated. This would deny citizens the opportunity to vet candidates and to have candidates build coalitions necessary for winning elections—and for governing.

It is also the case that in the right circumstances humans can be much more creative than computers. While computer optimization can make remarkably efficient and correct decisions, it cannot think outside the box. In fact, it *is* the box! Optimization programs are limited in their range of "thinking" by the rules built into the model. Faced with an "unsolvable" problem, optimization programs report back that there is "no feasible solution." Sometimes a brilliant (or desperate) human will figure out which rules can and should be broken and will brandish a creative sword that can cut the Gordian knot. Humans excel at developing state-of-the-art solutions to problems that have not yet been solved or fully understood.

Rapidly changing circumstances that escape the framework of the optimization software designers can also prove challenging for computers that are making decisions. In addition to their day jobs, human decision makers live in a broader environment of information, which

includes everything from formal company briefings to informal discussions to simply reading the news. Sometimes, the rules change in a way that is obvious to a person, while a computer could only become aware of such a change if it were reprogrammed. This is especially true for an unanticipated Black Swan event, such as the 9/11 terrorist attacks. A human flight controller could immediately conclude that the best course of action is to clear the skies, while a computer might well continue to instruct planes to take off and land.

What should we conclude from our brief comparison of human versus machine decision making? One conclusion, which we will discuss in later chapters, is that decision making should not be viewed as an either-or situation in which man and woman are pitted, antagonistically, against machines. Humans and computers each bring something to the decision table. The key is finding the best ways in which they can work together to make the quickest and most accurate judgments.

Another conclusion: in certain decision situations, computers are likely to outshine their human counterparts. These include decisions:

- That can be facilitated by comparing or testing a large number of permutations
- Where quickly sorting, screening, retrieving, and synthesizing information from large databases is necessary
- That do not depend on large amounts of inaccessible information, such as a person might build up over a lifetime of experiences
- That require the combining of probabilities
- Whose solution is not heavily dependent on emotions or emotional intelligence
- In which protracted discussion is not needed to obtain buy-in or commitment
- For which stamina or 24/7 monitoring is of value
- That can be modeled or optimally solved through the use of mathematics

Optimization: From Learjets to Hit Songs

Let's look more closely at how a variety of companies have used computers and optimization software to make decisions that have increased the value of their assets and improved their organization's competitive position.

Scheduling: Come Fly with Me

If you have ever been involved in scheduling—even something as simple as a multiparty conference call—you know how quickly despair can set in. Juggling everyone's schedule is the stuff that migraines are made of, but it is a piece of cake compared to the complex schedules of delivery services, trucking companies, railroads, delivery services, and airlines. These companies represent just some of the Main Street industries that can reap enormous benefits from optimization thinking. Let us look at one company that has successfully optimized its major asset: an international fleet of jets designed to transport corporate movers and shakers.

If you're not president of your company or relatively high up on the corporate food chain, you've probably never heard of ArgentAir. When they're not traveling by corporate jet, chances are that many senior executives, their clients, prospects, and guests are being shuttled around by ArgentAir. (The company name has been changed to protect confidentiality.) ArgentAir is an independent business unit of a Zurich-based multinational: a diversified company that operates in a wide range of industry segments, including financial services, technology, aviation, energy, and heavy-equipment manufacturing. ArgentAir operates on the subscription principle: each of its passengers signs up for a minimum number of air miles over a five-year period of time. The benefit: a plane is available to each subscriber whenever and wherever he or she needs it.

At first blush, ArgentAir does not appear to have much in common with, say, Walmart. ArgentAir caters to high-end business travelers, while Walmart serves the lower- and middle-class masses. Unlike Walmart, which rose to the top in a mature industry, ArgentAir operates in a relatively new industry segment. But look beneath the surface and you will see that both companies have the same business philosophy, which is what makes them both so successful.

Like Walmart, ArgentAir's competitive advantage comes from its unparalleled operational expertise. Walmart optimizes every asset decision: what, where, when, and how much to buy, store, distribute, and sell. ArgentAir's primary assets are its fleet of planes and its pilots. To get the most out of these assets, like Walmart it employs Optimization to make critical allocation decisions.

ArgentAir cannot afford to fail the busy executives whom it serves, but unlike commercial flyers, each individual passenger-schedules his or her own flight, often requesting arrival and departure times and airports on as little as four hours' notice. ArgentAir completes hundreds of thousands of flights annually, on 500 aircraft, to over 125 countries around the globe. The resulting complexity makes efficient scheduling a major challenge. Yet ArgentAir has become a rapidly growing and highly profitable passenger air carrier by optimizing decisions related to moving its fleet around the world in order to manage complexity and meet the needs of demanding customers.

For any airline, a key statistic is the percentage of capacity utilization. For a commercial airline, 100 percent utilization would mean that every seat on every plane was filled. For ArgentAir, where each customer takes a personal trip on a jet, utilization takes on another meaning.

Because ArgentAir customers can request a trip from a wide number of jet-capable airports throughout the world to almost any other, crews and planes—often empty—must be repositioned to meet the customer, thereby reducing the fleet's utilization. If the customer's stay is short, the dispatcher may choose to keep the plane waiting at the airport until the customer is ready to depart. For longer stays, the dispatcher may instruct the crew to fly the plane to another destination and pick up a second customer. Another plane is then scheduled to pick up the first customer for the return flight.

Moving an empty plane to another airport to pick up a passenger is called a shuttle, and shuttles, or empty air-hours, are expensive! Depending on the size of the aircraft, an empty air-hour of a private jet costs between $1,000 and $5,000, which includes the cost of jet fuel, the crew, and wear and tear on the plane. Similarly, when a plane sits idle on the ground, referred to as lagging, it is an underutilized asset. This makes reducing empty air-hours and lag time primary measures of success for ArgentAir. Each day, ArgentAir publishes and reviews the previous day's statistics. Each 1 percent reduction in empty air-miles saves the company $15 million dollars a year. If the fleet were to grow or the price of fuel to rise—as it has—the prize would be even larger.

Prior to using Optimization, ArgentAir took fairly conventional steps to manage its complex scheduling. First, it divided its large number of jets into smaller fleets comprising similar types of planes. Each fleet was then assigned a scheduler charged with developing a schedule two days in advance of each flight date. The goal: pick up and deliver all their passengers at the scheduled times, minimizing empty air-hours and lag time for planes in the fleet. The smaller number of planes in each fleet helped make the task more manageable compared to scheduling all the company's planes. ArgentAir also developed a software program, Scan, which enabled schedulers to place their flights and crews on a screen that looked something like a Gantt chart on steroids and reposition or replace flights when they found a more efficient route. Scan monitored the action and alerted the scheduler if an international or local-country rule—such as keeping a crew member on duty longer than allowed—had been violated.

The system was efficient, but not optimized. The flight schedules were built by people, not computers. More shuttles than necessary continued to occur, and as many as 35 percent of the flights were empty-air ones. Furthermore, the fleets created organizational "silos" that resulted in inefficiencies. There were times, for example, when it might be much more efficient for a plane from another fleet to pick up and deliver an executive or his or her team. Not only would such a switch eliminate an empty flight; it could result in a free upgrade for the customer. Unfortunately, the fleet silos kept this from happening as often as it should: either a fleet scheduler did not know about all the available planes in another fleet, or schedulers protected the planes in their own fleet to cover late requests. It was a good practice for the fleet, but not for ArgentAir as a whole.

Enter the optimizers. Or more precisely, enter a team of optimizers. At ArgentAir, the team included consultants from our company, an in-house champion who had designed ArgentAir's information technology (IT) system, the head of fleet operations, several subject matter experts from the airline, and a university professor. The goal: develop optimization software to recommend schedules that would maximize utilization while minimizing customer dissatisfaction—no easy task when dealing with executive-suite-size egos.

Early in the discussions, the team grappled with a number of nettlesome issues. For example, during times of high demand the ArgentAir fleet schedulers in Rome, Italy, and Lisbon, Portugal, might find themselves facing the inevitable zero-sum question regarding moving scarce assets to some customers and not to others. What were the rules by which the "Who should get which jet?" decision should be made?

And many rules must be considered. Some are related to the planes: how many passengers they hold, how fast they fly, and so on. Other rules are mandated by in-country aviation regulations. For example, in the United States, the Federal Aviation Administration (FAA) mandates that pilots who are not night certified can fly only during daylight hours, certain airports do not allow landings and takeoffs at certain times of the day or night, pilots can be on duty only so many hours before they must rest. There are union regulations to consider, and company policies: treat all customers as if they were owners—which, during the period of their subscription, they are. If you have recently disappointed a customer, you will want to move mountains—and planes—to avoid a repeat experience.

Another complicating factor: the well-heeled executives who use ArgentAir often think nothing of changing their plans—and the flight they booked—at the last minute, and they are none too pleased if the airline cannot accommodate them. Weather and air-traffic patterns, neither of which is under the control of ArgentAir, are yet another source of constant uncertainty and change. And aircraft, which are maintained to the highest safety standard in the industry, are absolutely not allowed to take off unless the pilot in command gives the green light. With so many constraints, choosing when and where to fly each jet and crew at the moment of truth—when an executive calls and wants a jet *now*—is a challenging decision of Herculean proportions.

The optimization team assembled at ArgentAir was up to the challenge. It realized that the ideal approach would be to develop not one schedule optimizer, but three—to resolve the three distinct aspects of the scheduling problem. The first program was called the IScheduler. It was capable of building an optimal schedule two days in advance of flight day. It took approximately 15 minutes to run and would recommend an optimal schedule for the entire ArgentAir fleet of planes. The second program, Retrofit, was used to "repair" the schedule when late customer requests, airplane maintenance, weather delays, or a sick crew member suddenly required an adjustment to be made. Retrofit would consider the schedule interruption and recommend a dozen prioritized alternatives for making adjustments in ways that minimized shuttles. Retrofit runs in fewer than five seconds, which is required for operational acceptance, and searches for solutions with the highest value and minimal impact on other schedules. The third piece of software—Shuttle Optimizer—ran continuously in the background, reviewing each schedule or asset change to find ways to reduce the number of shuttles even further without stranding any customer. Whenever a scheduler made a request, Shuttle Optimizer would display a list of recommended adjustments to the schedule to optimize it even further.

And the bottom-line results? When the optimizing team first arrived, the number of empty trips each day ranged from 30 to 40 percent of the daily flights. The optimization programs were able to reduce this number by approximately 10 percent, saving the company roughly $150 million a year. But Optimization improved competitiveness in other ways, too. Schedules that previously took hours to construct are now developed in minutes, freeing schedulers to work on other tasks. Furthermore, since the optimization programs look across all the fleets when making recommendations, they see many more opportunities to upgrade customers while eliminating shuttles. It is a win-win situation: reduced costs for the company, improved service for the customers.

Allocating Space: All the Ads That Fit in Print

As the ArgentAir example illustrates, Optimization is a powerful approach to driving up the value yield from a scarce and expensive asset. Space is another asset that can be as scarce as equipment and no less contentious: shelf space, space in shipping containers and freight cars, seats in auditoriums and arenas, and space in magazines and newspapers. Take ad space. It is a precious and limited asset, both for businesses needing to reach a target audience and for those who own the media outlet. Allocating ad space in a publication also represents a decision that has to be made over again each time a new edition hits the street, making it a prime candidate for Optimization. One major metropolitan newspaper with which Princeton Consultants worked provides a case in point.

Like most major newspapers, this one was not a single paper: there were several editions—regional, city, suburban, and so on. A retailer selling exclusively within the city is not likely to want placement in the suburban edition, while a large regional chain of stores would likely opt for wider coverage. To complicate things even more, some advertisers insist that their ads appear in a certain sequence, such as on three consecutive right-hand pages. Others want a campaign in which a single ad runs for x number of consecutive days.

While the paper would like to say yes to every request, doing so is not as easy as it sounds. There are often many constraints and rules that govern the way a newspaper positions ads: competitors' ads cannot be placed on the same page, an ad cannot be run near an article about the advertiser, and certain types of ads are not "appropriate" for placement in the paper's main news section.

Given the complexity of the editions and the number of rules, laying out the paper's ads was tricky business. And as the paper began to expand its use of color, the exercise became even more challenging, since only so much color could be included in each run of the paper.

For many years, placing of the ads was done manually by two employees whose role was so critical and specialized that the two could never be on vacation simultaneously. Over the years, these two individuals had created written scenarios—nearly 64 of them! The scenarios represented alternative preset configurations for laying out the paper, depending on news content, planned inserts, and, of course, the type and number of ads being requested. Each night, the two employees decided which scenario would best accommodate all the requested ads for the edition and proceeded to lay out the paper accordingly. Ads that did not meet the scenario's specs were shelved, leaving advertisers guessing until morning about the fate of their ads. Sometimes, when the newpaper could not immediately assure an advertiser where, when, and how a submitted ads might be published, the advertiser took his or her business elsewhere. The result: lost revenue and lost customers who headed for more reliable advertising venues.

Realizing that it was time to replace this antiquated system, the paper's management asked Princeton Consultants to develop a program that would optimize available advertising space. Our company's consultants worked side by side with the paper's subject-matter experts—the employees who had created the scenarios—and support staff to design software that would rationalize the ad-placement process and drive up the value of available advertising space. Early on in the project, the consultants probed deeply into the experience and judgment of the two layout men, being sure to incorporate into the program every rule and constraint under which they operated.

As you might suspect, the optimization software came up with many more than the fixed 64 permutations that were featured in the scenarios. More important, it could reconfigure the paper on the fly, identifying an optimal layout as each new ad request came in. As a result of Optimization, the paper did not have to buy more presses, hire more people, or discount its rates to increase revenue. Just getting more ads into the paper each day did it. Placing ads with the paper also became much more customer friendly. Now, an advertiser could call and ask for an ad and find out almost immediately if it would appear in the next day's paper, eliminating surprises.

Production Planning: Let a Thousand Flowers Bloom

Next time you admire an arrangement of lilies or some other ornamental flowers, you may say a silent prayer of thanks that you are not in the business of growing and distributing them. Many of the world's ornamental flowers come from Brazil, where competition is fierce, especially since the government began giving grants for the production of flowers to help increase the incomes of small- and medium-sized nurseries and exporters.

One of Brazil's oldest and largest wholesale producers of bulb flowers is the Jan de Wit Company, located in the "City of Flowers": Holambra, Brazil, 160 kilometers due north of São Paulo. The company began growing lilies on a small scale in 1992—one of the first companies to do so in Brazil. By 2000, when the company began to consider Optimization to help in its production planning, it had 18,745 square meters of greenhouses, 1,032 square meters of cold-storage rooms, and a team of approximately 30 employees.[9]

It is difficult to overstate the complexities of production planning at Jan de Wit. As with many businesses, planning begins with an attempt to project demand. For Jan de Wit, this involves two types of sales: auction and intermediation. Auction represents a daily cash market at which distributors can bid on flower purchases. It accounts for approximately half of Jan de Wit's sales. Quantities and prices can vacillate considerably, reflecting such things as fashion trends, economic conditions, and competitors' production volumes. Prices, of course, also fluctuate, affecting Jan de Wit's optimal product mix.

The other half of Jan de Wit's sales are through intermediation, which operates like a futures market. Specialized agents negotiate buy-and-sell contracts between distributors and producers for the short, intermediate, and long term. Based on history—and what Jan de Wit can surmise about the market—the company attempts to identify market opportunities by analyzing weekly sales quantities and prices for each lily variety.

Projecting demand is just the first in a long list of challenges in production planning. To produce the lilies, Jan de Wit needs bulbs, most of which are furnished by bulb wholesalers in Holland. A year's order can include annual imports of 3.5 million bulbs, comprising 50 different varieties. All bulbs must be purchased during the three-month bulb-harvesting season. Thereafter, the Dutch suppliers send part of the order on a predetermined monthly schedule. Each arriving batch contains a set number of bulbs from a specific harvesting year, producer, and variety. Once the bulbs arrive and are sorted, they must be prepared, which means they are held at the correct temperature for approximately two months. Next, the bulbs are planted in a place where they will remain at the correct temperature for two weeks, until the stem roots form. Only then can they be moved to a greenhouse. Of course, temperature, growth rate, and care requirements can all vary at any step in the process. Depending on the variety, the bulb size, and planting week, the production cycle can last anywhere from 6 to 16 weeks.

The bottom line? To produce an optimal production plan, Jan de Wit Company must schedule the correct planting of the right bulbs during the right week in the right greenhouse environment to meet projected market demand, which must include seasonal fluctuations for such holidays as Easter, Mother's Day, and Christmas. Some additional constraints on planning decisions include bulb inventory and production-cycle variations stemming from plant variety, bulb size, bulb origin, sprout length, and planting week. Technical requirements produce yet one more layer of complexity, with such constraints as number of bulbs per pot or box, bulb spacing, and bed-usage limitations associated with each type of greenhouse.

The way in which Optimization first found its way into the Jan de Wit Company illustrates how operations research concepts are spreading to smaller companies. José Vicente Caixeta-Filho, a professor at the University of São Paulo, published a short article in a student journal entitled, "Modeling, Through Operations Research, in Agribusiness." Jan Maarten van Swaay-Neto, a flower-business-management consultant who had not previously heard of Operations Research, read the article and called Caixeta-Filho to discuss possible applications to the flower business. He went on to take one of Caixeta-Filho's classes on linear programming, which was being offered to graduate students in applied economics. At the end of the course, he wrote a final paper entitled "Gladiolus Bulb Production" and extended an invitation to Caixeta-Filho to develop more accurate approaches to applying mathematical models to flower production problems.

This initial collaboration led to further efforts to apply the techniques, first at a company named Terra Viva and then at Jan de Wit. Reflecting today's abundance of computing power, the decision-support system was programmed on a Windows-compatible computer, using Visual Basic and Microsoft's Access database. The team used linear programming to maximize contribution margin (revenue minus variable costs). The actual set of equations in the linear program generated a solution matrix involving 120,000 rows and 420,000 columns.

The results of using optimization software to aid production planning speak for themselves. The first year that Jan de Wit used the software, revenue grew 26 percent, while contribution margin improved 32 percent. Return on owner's equity increased from 15.1 percent to 22.5 percent—a 49 percent improvement. This growth was managed with the addition of a single employee. All this was accomplished in spite of the fact that during that year the Brazilian flower market experienced excess capacity and reduced auction prices. The company also found that by improving its planning and control of production it was able to increase its short-, medium- and long-term supply agreements, locking in prices and profits years in advance.

Finally, there was the saving in planning time. Prior to implementing the optimization software, Johannes de Wit, the general manager and owner of Jan de Wit Company, planned production himself. With the new system, he found that he was able to delegate the planning process, which now takes only a fraction of the time it once required. Clearly, implementation of the planning system has increased the company's competitiveness. De Wit commented, "Companies in the flower business that don't wake up to planning-and-control systems

risk almost unsurpassable capital losses, endangering their continuity and damaging the market."[10]

Smart Pricing

Pricing decisions are tailor made for Optimization, for three reasons. First, Optimization can help increase the speed with which prices can be set. This can often produce a competitive advantage, especially in large B2B transactions. How would your customers and prospects react if you could give them a price quote in seconds? What would such agility do for your company's reputation? How many more prospects would call you for a quick quote?

Second, Optimization can help you better understand the true costs of your decisions, thereby allowing you to make better pricing decisions. There are many methodologies to measure operating costs. ABC and other accounting systems help you find the "actual" cost of each element of your business. But what about the *opportunity* costs of business decisions? In its attempt to maximize long-term profitability, Optimization goes beyond looking at the cost of each decision in and of itself to assess the opportunity costs of one decision versus another. It asks, "What will it cost me over the longer term and in terms of missed opportunities if I choose A instead of B, and vice versa?"

Assume that you run a trucking company based in Chicago, and you want to know the cost of hauling a load of freight to Los Angeles compared to that of hauling it to New York. An accountant would calculate the difference by totaling all the direct and indirect costs of each trip: gas, tolls, the driver's salary, depreciation on the truck, and so on, and then comparing the two. Do this and you will probably find that your out-of-pocket costs are not much different in either direction; it is pretty much a toss-up whether to take the business that sends your truck east or that which sends it west.

Optimizers would look at the decision much differently. They would argue that the accountant's calculations are only part of the story. They do not include a calculation of the opportunity cost of each trip. Determining this requires asking a very different question: "If I had a truck in L.A., what could I then do with it compared to what I could do with a truck in New York?" Perhaps there is a large amount of freight in L.A. that needs to be shipped, and people are paying top dollar to move it. Meanwhile, in New York there are only empty shipping containers. In trucking, when planning the outbound trip, or head haul, you always think of the return trip, or back haul. So if it is going to prove more difficult to bring a full truckload back from New York, driving there instead of to L.A. is a far more costly choice—even if the gas, tolls, and other actual costs run about the same. It also suggests that you should charge a different price for heading east than for heading west.

Or, going back to our work with the metropolitan newspaper, if a customer asks for a two-page spread in the middle of the paper, before saying yes, consider the probability that later on you might be able to sell the same space to someone else at a higher price, perhaps as part of a broad package of ads. What is the cost of saying yes to one versus the other? Or more precisely, what are the opportunity costs of these different decisions? That is where the real money is made or lost—and that is why optimizers focus on it.

Third, if you choose to—and if your industry allows for it—Optimization can help you institute yield management, or scientific variable pricing. Yield management is the name for the technique used in many industries to scientifically vary the price of a product or service to maximize the amount of revenue that can be extracted from a marketplace. It exploits the famous supply-and-demand curves that we learned about in Economics 101: namely, that sellers are willing to sell the same product or service to different customers for different prices, and that different buyers are willing to pay different prices for the same products or services. In Economics 101, we learned that this would lead to a *single* "market equilibrium price," where the supply-and-demand curves crossed. In contrast, yield managers set *different* prices for the same basic commodity when selling to different types of customers or at different periods, with the goal of achieving maximum profits.

We see variable pricing designed to improve asset yields all the time: for example, the early-bird special that restaurants give to folks who agree to eat earlier in return for a discount. Yield management differs from this sort of ordinary pricing differentiation by varying prices continuously: repricing daily or even hourly. Yield management started in industries such as airlines and hotels: businesses with essentially fixed capacity that has a limited shelf life. After the plane takes off, the unsold seats are not sellable; the next day, a hotel cannot sell the previous day's rooms.

Not surprisingly, these industries pioneered the use of Optimization to vary prices as seats and rooms filled up. When recommending price changes, optimization software keeps track of how much space remains and the likelihood that it will remain unsold as it reaches its "expiration date."

What makes yield management tricky, however, is that yield managers are not trying to maximize daily revenue; they seek to optimize *long-term profits.* Simply selling to the highest bidder will indeed give you the highest short-term revenue, but it may also drive away customers who, over the long term, would likely spend more money. If you keep calling an airline or hotel, and they never have a seat or room at a price you are willing to pay, eventually you stop calling. Whether in B2B or B2C transactions, people experiment and learn to make repeated purchases from those who can offer them both consistently good price *and* availability. The best optimization software takes multiple factors—including customers' buying patterns—into account when setting a price.

Money Management at Marriott

We recounted some of the story behind Marriott's success in Chapter 1. On May 20, 1927, two young men, J. Willard "Bill" Marriott and Hugh Colton, opened a nine-stool A&W root beer stand on 14th Street in northwest Washington, D.C. Over the next 82 years, led first by Bill Marriott and then by his son, J. Willard "Bill," Jr., those nine stools grew into Marriott International, a global lodging and hospitality company, which by 2010 had over 137,000 associates; more than 3,400 properties in 70 countries; and was processing 75 million room-reservation requests per year across its 18 hotel and resort brands, generating more than $11 billion in revenue.[11]

In 1957, Marriott opened its first hotel in Arlington, Virginia. The 365-room Twin Bridges Motor Hotel rented its rooms for $10 to $13 a night, depending on the number of occupants in the room and whether or not they needed a cot or a crib. Right from the start, Marriott showed an interest in—and talent for—"revenue management." The Twin Bridges had a drive-up registration booth. Whenever the hotel approached being fully booked, the desk clerk would lean out the window and turn away any car that did not have at least four people in it. The result? A lot more rooms were booked at a premium price of $13. In fact, this simple revenue management practice was estimated to generate as much as 44 percent additional revenue at absolutely no cost to the hotel.

Today, Marriott's revenue management practices are far more sophisticated. In fact, in the 1980s, following the lead of the airline industry, Marriott introduced the first computerized revenue management system in the lodging industry. The need for such a system is driven by the fact that "rooms" represent perishable inventory. As with airline seats and departure times, once a room has been empty for a night, the revenue it might have brought in is lost forever. The room cannot be sold twice the next day to recapture the lost income—at least not without creating irate customers.

This initial computerized revenue management system worked extremely well, helping Marriott adjust its prices as needed to improve occupancy rates. However, the system only worked when booking individual travelers. By the second half of the current decade, almost 50 percent of Marriott's business came from catering services and group bookings for such events as business meetings, conferences, and weddings. While the scale of the group business had increased exponentially, how group business was sold had not changed very much. Marriott's booking agents, or sales managers, as they are called, were booking groups using paper calendars and spreadsheets that displayed hotel occupancy levels and rates: "While the sophistication of the systems used to sell to the individual traveler increased substantially, how group business was sold had not changed very much," according to Sharon Hormby, Marriott's senior director of total yield systems.[12]

Given the volume of business that Marriott was facing, this presented multiple challenges for the sales teams. For one, while the spreadsheets were updated weekly, they were obsolete by the time they were distributed. In addition, there was no simple way to evaluate the financial trade-offs for booking a group at a reduced room rate as opposed to waiting to fill as many rooms as possible with reservations from individual travelers. There were simply too many mediating factors, alternative scenarios, and unknown data points to allow the sales managers to make good decisions.

Marriott's answer: replace the spreadsheets, paper calendars, and pricing decisions of the sales managers with a Total Hotel Revenue

Management optimizing software program. Fortunately, Marriott's Total Yield Systems Group could draw on a rich reservoir of data from the company's reservation system. Looking across only two years of data, they were able to examine 800,000 group reservation requests at 200 different hotels, together with 180 different descriptor variables such as group composition, group size, how far in advance a reservation is requested, customer segmentation, audio-visual requirements, offered price, and, perhaps most important, whether Marriott had won or lost the business with the price it offered.

The wealth of historical data allowed Marriott's Yield Management Group to develop price sensitivity curves for each segment of customers, including how different factors influence the group's likelihood of booking a property. Moreover, the data allowed the programming team to develop models for predicting group demand at different hotels throughout the year. When these models are considered together with data that shows hotel profitability at different room rates, the software can recommend an optimal price to ensure profitability while maximizing the chances of winning the business.

Here is how the optimization software works:

1. When a prospect calls requesting a group reservation, a sales manager enters the request into the computer system, along with any available additional information about the group's characteristics.
2. The software then determines the projected occupancy and profitability of the hotel that is being requested, during the desired week, excluding the group's request in the calculation.
3. Next, the computer repeats the calculations, this time including the assumption that the group has been booked and the inventory consumer by the group is not available for sale. The computer then calculates the displacement costs, or the expected difference in profitability for the hotel when the group is booked compared to its not being booked. If this number is negative, the computer recommends a group rate high enough to offset the difference.

Most impressive, the computer calculations are just about instantaneous, displaying the room price to the sales manager, thereby enabling her to provide an immediate price quote. The computer can also make recommendations for other nearby hotels in the Marriott family where the group can book a reservation at a lower price if the quoted rate exceeds the group's budget.

Here's the best part of the Group Price Optimizer (GPO): conservative estimates indicate that the GPO increased revenues by $46 million in 2008 and by $75 million in 2009, even though bookings declined as a result of a depressed economy. Sales managers fully support the system and report that the information that the computer provides allows them to offer alternatives that keep prospective customers from shopping the competition. If you do not want to take time to talk with a sales manager, Marriott has recently developed QuickGroup, a program that allows prospects to shop and make small-group reservations directly on Marriott's website.

All in all, the GPO has helped put muscle behind Marriott's brand promise of providing "the right product to the right customer at the right time for the right price."

Order in the Queue: Don't Stop the Presses!

While most people read magazines, few have any idea how complex the publishing business has become. Your local *Newsweek* that arrives in the mail is not just one magazine. Rather, it is a collection of magazines under a single title. By that, I mean that people in different regions of the country get different inserts, different ads, and different blow-ins: those annoying little cards that flutter to the floor no matter how hard you try to keep them between the pages. Not only regional, but also demographic differences determine an edition's structure. If your age and neighborhood demographics suggest that you have young children, your issue may carry an ad for baby diapers on page 23, while your parents in the retirement community across town are looking at a Depends ad on page 23 of their issue. If your subscription is about to run out, you will even get a different cover alerting you to the fact. Who figures out how to put all these things together and get them shipped to the right address?

The answer: a printing company such as Quad/Graphics, which was started 39 years ago in an abandoned millwork factory in Pewaukee, Wisconsin. Today, it is the second-largest printer in the Western Hemisphere, with 28,000 employees and $4.8 billion in annual sales. Quad/Graphics' big break came in 1978, when it landed a contract with *Newsweek*.[13]

Quad/Graphics' challenge in printing *Newsweek* and many other products is even more daunting than simply putting together a dozen different regional and demographic editions. It is a little-known fact that the shipping costs involved in getting a magazine to your doorstep can be significantly greater than the cost of printing it. The U.S. Postal Service, however, offers a discount if magazines arrive packaged in a way that bundles together those that are to be delivered on a single postal route. Consequently, not only do different editions of a title need to be printed; they need to be printed and assembled in an optimal order, which has them streaming off the presses and saddle-stitchers in batches that match specific postal routes.

To add further complexity to an already complex situation, small specialty magazines such as *Dog Fancy* or *Bird Talk* have too limited a circulation to receive significant volume discounts from distributors and the U.S. Postal Service. To survive, they must be produced in a way that allows them to be interleaved with the other magazines for each individual subscribing household. This reduces sorting time by the U.S. Postal Service and entitles the publishers to get discounts. Thus, when Quad/Graphics runs the saddle-stitchers for a magazine like *Newsweek*, it may include other titles that get sandwiched into the correct postal-route bundle.

Quad/Graphics produces all these titles and title versions using a binding line with multiple slots, or pockets, that are filled with different magazine parts needed for a particular run of the title. The binding line can be programmed to pull material from different slots to assemble a specific edition or magazine at just the right moment in time to position it with other magazines headed for the same household. What really makes the process difficult to manage is the fact that often there are not enough pockets on the assembly machines to handle all the different magazine parts needed for complete production of an issue. From time to time, the machines must be halted to reload the pockets—an expensive procedure. To maximize productivity, the pockets need to be loaded in ways that minimize the number of times the machines must be stopped and the pockets reloaded.

Each production center has a scheduler, or planner, whose primary job is to decide how the pockets should be filled and the runs scheduled each day to minimize press stoppages. With so many moving parts, it's not an easy task. Before Optimization, the scheduler would work with a spreadsheetlike matrix, in which the columns represented different press runs and the rows represented magazine components. A dot was placed in each column in the row of the components to be used in that run. A large number of dots next to each other in one row reflected good planning. This indicated that two or more concurrent runs would use the same component, thereby eliminating the need for changeovers. Scheduling involved repositioning rows and columns in ways that grouped dots together to minimize changeovers. Producing a solution was complicated and time consuming and tended to produce suboptimal solutions. Executives at Quad/Graphics were not only concerned with the length of the planning process and questionable solutions, but they worried about having available only a limited number of people who understood the scheduling task. If one of them were to be hit by the proverbial truck, production would suffer.

Enter the optimization team. Because the scheduling challenge was so complex, the team decided that a symbiotic decision process, in which the schedulers and the optimizing software worked together interactively, would be best. The problem was sufficiently complex that no single algorithm or approach could provide an optimal solution in every scheduling situation. This led the team of optimizers to devise an "algorithm of algorithms," which evaluated the situation and decided which of several other algorithms was most likely to produce the best solution, given the production constraints. Once the selected algorithm had been applied, it recommended a scheduling solution for the human scheduler to review and approve. If schedulers saw a problem, they could adjust the constraints and rerun the optimization program to get a quick alternative.

The schedulers at Quad/Graphics did not need much convincing that the software was capable of producing superior solutions. They could immediately see that the run lengths of dots and spaces on the planning grid created by the software were significantly longer than those provided by the human planners. The reduction in machine stoppages and changeovers averaged approximately 10 percent, a significant savings when you think about a $4.8 billion business. The software increased Quad/Graphics' competitiveness in other ways as well. The improved efficiency increased printing capacity without any additional capital investments. The improved bundling generated lower postal rates, which allowed Quad/Graphics to increase the competitiveness of its bids for additional work. Innovations such as this have allowed Quad/Graphics to earn *Newsweek*'s "Printer of the Year" designation for the past two years: an award based on final-product quality, paper consumption, turnaround times, and equipment speed.

Marketing Dollars: Sing a Song of Sixpence

There is no accounting for human taste . . . or is there? Certainly, the world of music appears to represent an eclectic universe impossible to quantify. And in fact, music has traditionally been a "gut feel" industry, not known for data-based decision making or mathematical modeling.

This began to change in a big way in 2000, when Nolan Gasser, a Stanford graduate student, planted the seeds for the Music Genome Project. The project grew partly out of Gasser's doctoral-dissertation study of Renaissance music and a drive to ". . . really understand what made that music tick."[14] His systematic study of the structure of music resulted in his teaming up with two friends, John Kraft (a tech entrepreneur who had already started and sold a company) and Tim Westergren (a composer of music for low-budget films) in an effort to "codify" 20th-century pop music.

Their codification involved decomposing a piece of music into its large-scale aspects of melody, harmony, rhythm, form, instrumentation, voice, and text. Each of these broader categories, in turn, could have as many as 50 elements. Voice, for example, could be decomposed into such dimensions as smooth, rough, gravelly, or nasal—to name just a few. The outcome of the effort was approximately 250 "genes" for every song in the original pop-rock set of tunes. The ratings of each piece of music were done by music lovers who were trained and tested for their ability to listen and consistently rate the dimensions of test songs on a five-point scale. Typically, a trained rater needed around 30 minutes to create a song's complete genome.

So what do you do with a large database of "rated" songs? For one, launch an Internet radio station. In 1999, Tim Westergren founded Savage Beast Technologies, which in 2005 morphed into Pandora Internet Radio. The idea behind Pandora was a radio station that plays only music that each individual listener likes.

Here's how it works. When you log in, you are invited to create your own radio station. You do this by entering the name of an artist, song, or composer that you like. If you are feeling expansive, you can enter two or three more. Pandora's computers then select other musical compositions that are similar to your selection, based on the Genome rating system. Like different types of music on different days? No problem. Pandora allows you to create multiple radio stations, each one seeded with a different type of music. As 2009 drew to a close, Pandora had a database of 750,000 titles, which was expanding at approximately 10,000 tunes a month and which spanned 18 genres—from classical to country to jazz to hip-hop. While the station may not be able to accommodate all your tastes, its software can make excellent recommendations of music that you are almost certain to like. Today, Pandora has 39 million listeners enjoying its optimized recommendations and is reporting the addition of around 65,000 new sign-ups a day, more than half from mobile-device users.

Matching individual tastes in music is one thing, but could a mathematical algorithm make an accurate prediction about the next great musical hit? Mike McCready, CEO of Polyphonic HMI—who was soon to spin off Music Intelligence Solutions, Inc.—believed that it could. In 2003, the management team of this Barcelona-based company was prepared to launch its optimization tool, Hit Song Science (HSS), to do just that.[15]

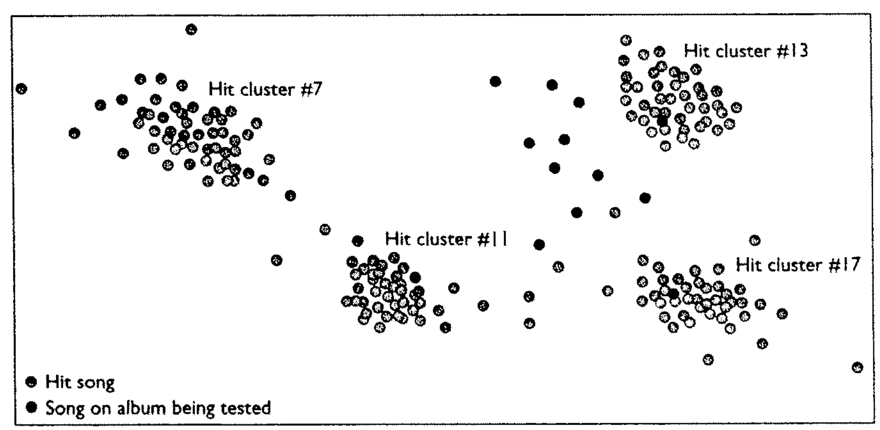
As you might imagine, picking the next great song has always been an extremely tough and expensive business, particularly when evaluating a new artist's album. The successful marketing of a new album depends on picking the right single release, since radio airplay is the primary advertising vehicle. The goal is to have the single appear on Billboard's weekly Top 40 chart. This ensures wide exposure. Making and marketing a single to give it a shot at the Top 40 can cost $300,000 or more. However, only around 10 percent of the singles released each year make the list. You had better be good at singles picking if you want to survive in the music-promotion business.

Different promoters approach single selection in different ways. It is reported that Antonio "L.A." Reid used to round up kids from the streets of New York and ask them to rate new songs and artists. Another famous record executive, Clive Davis, was known for trusting his own judgment and no one else's. Many promoters use "call-out" research, which involves contacting people on the phone and having them listen to and rate 15- to 30-second-long fragments of music. With a mere one-in-ten success rate, certainly none of these approaches could be considered optimal.

Enter McCready and Optimization. Just as Google spurned Yahoo!'s use of human experts to rate Web pages, Music Intelligence Solutions relies only on computers and mathematical algorithms to "listen" to and evaluate songs in 25 different dimensions, such as beat, chord progression, duration, fullness of sound, harmony, melody, octave, rhythm, sonic brilliance, and tempo. Based on the computer-generated scores, each song is then mapped onto a multidimensional grid called the "music universe." When Polyphonic initially evaluated millions of songs, including almost all music labels' releases from 1950 on, it found that hit songs of different genres tended to cluster together in the multidimensional space. New songs could then be evaluated and placed in the universe to see how close they came to a "hit cluster," as represented in Figure 3.2. Each song in the album receives a "closeness" rating, reflecting its distance from a hit cluster, with songs that are rated higher than 7 having a very high chance of becoming hits.

How accurate are the software's predictions? In McCready's initial research, he and his team analyzed music released over a six-month period. The software correctly predicted whether a single would reach the Singles Top 40 8 out of 10 times. Given the current success rate of 1 out of 10, the software certainly seemed promising.

FIGURE 3.2 A Hit-Song-Science Mapping of a New Album to Its Hit Clusters[16]



It was now time for reality testing. In 2002 the company tested the first album by a then-unknown artist, Norah Jones. The industry pundits did not give her sultry rendition of "Come Away with Me" much of a chance of success, but Hit Song Science predicted that eight songs on the album would be winners. The album was a runaway success and the winner of eight Grammy awards!

Skeptics remain, but an increasing number of music executives are coming to accept the fact that a computer can improve their decision making. Ken Bunt, an executive with Disney's Hollywood Records, told *Harvard Business Review* that, "This business has always been run by instinct and gut, and even my own colleagues might have a hard time believing this, but my experiences with Hit Song Science have been fantastic. HSS has been extremely accurate on the tracks that we have taken to commercial radio."[17] At a cost of $300,000-plus per miss and a 90-percent failure rate, it is hard to understand why every music executive is not interested in adding the software to his or her toolkit.

Music Intelligence Solutions has extended the HSS service to the individual singer-songwriter through its website: http://uplaya.com. If you log on, you can upload your own creation and assess its hit potential. One satisfied customer of the service is Ben Novak, a New Zealand singer/songwriter.[18] After HSS had given his song a high score, it caught the eye of a record executive, who convinced British pop star Lee Ryan to record the song. It quickly rose on the charts and ended up number 12 in Britain and number 2 in Italy.

Final Note

Whether it is used to manage ad space or schedule planes or pick the next megahit, Optimization is being used to improve asset values and increase competitiveness across the industrial landscape. Wherever complex, repetitive decisions are being made about how to deploy or use high-value assets, Optimization has proven to be a powerful *prescriptive* tool to drive up the value of these decisions. It represents a giant evolutionary step away from pitting humans against machines and toward creating a new partnership, in which the combined intelligence of both are applied to our most complex problems and decisions.

Given its power and wide potential, you would think that Optimization has become one of the very first weapons that corporate leaders

reach for in today's war for competitive advantage. Surprisingly, this is not the case. Optimization remains very much an afterthought—or even a *non*thought—in too many management arsenals.

In Chapter 4, we will look more closely at exactly how Optimization is different from other productivity-improvement methods, including typical IT investments. We will explore more closely some of the reasons why quants and their optimization toolkits have often been ignored or unwelcome in the boardroom. We will go inside the minds of quants to understand the ways in which they think differently from the typical manager or executive, and we will examine the differences between good and great optimizers. Finally, we will present a series of questions that you can use to identify barriers to adopting Optimization in your own organization.