



Fourth Edition

Healthcare Operations Management

Daniel B. McLaughlin | John R. Olson | Luv Sharma

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To my wife, Sharon, and daughters, Kelly and Katie, for their love and support throughout my career.

—Dan McLaughlin

To my father, Adolph Olson, who passed away in 2011. Your strength as you battled cancer inspired me to change and educate others about our healthcare system.

—John Olson

Dedicated to my wife and parents for their never-ending support. Neither this work, nor any success in my life, could have been achieved without their shine of wisdom and warmth of love.

—Luv Sharma

The first edition of this book was coauthored by Julie Hays. During the final stages of the completion of the book, Julie unexpectedly died. As Dr. Christopher Puto, dean of the Opus College of Business at the University of St. Thomas, said, “Julie cared deeply about students and their learning experience, and she was an accomplished scholar who was well respected by her peers.” This book is a final tribute to Julie’s accomplished career and is dedicated to her legacy.

—Dan McLaughlin and John Olson

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PREFACE

This book is intended to help healthcare professionals meet the challenges and take advantage of the opportunities found in healthcare today. We believe that the answers to many of the dilemmas faced by the US healthcare system, such as increasing costs, uneven quality, and the opportunity of emerging technologies, lie in organizational operations—the nuts and bolts of healthcare delivery. The healthcare arena is filled with opportunities for significant operational improvements. We hope this book encourages healthcare management students and working professionals to find ways to improve the management and delivery of healthcare, thereby increasing the effectiveness and efficiency of tomorrow's healthcare system.

Many industries outside healthcare have successfully used the programs, techniques, and tools of operations improvement for decades. Leading healthcare organizations have now begun to effectively employ the same tools. Although numerous other operations management texts are available, few focus on *healthcare* operations, and none takes an *integrated* approach. Students interested in healthcare process improvement have difficulty seeing the applicability of the science of operations management when many texts focus on industrial applications rather than on patients, providers, and payers.

This book covers the basics of operations improvement and provides an overview of significant trends in healthcare. We focus on the strategic implementation of process improvement programs, techniques, and tools in the healthcare environment, with its complex web of reimbursement systems, physician relations, workforce challenges, and governmental regulations. This integrated approach helps healthcare professionals gain an understanding of strategic operations management and, more important, its applicability to the healthcare field.

How This Book Is Organized

We have organized this book into five parts:

1. Introduction to Healthcare Operations
2. Setting Goals and Executing Strategy

3. Performance Improvement Tools, Techniques, and Programs
4. Applications to Contemporary Healthcare Operations Issues
5. Putting It All Together for Operational Excellence

Although this structure is helpful for most readers, each chapter also stands alone, and the chapters can be covered or read in any order that makes sense for a particular course or student.

The first part of the book, Introduction to Healthcare Operations, begins with an overview of the challenges and opportunities found in today's healthcare environment (chapter 1). We follow with a history of the field of management science and operations improvement (chapter 2). Next, we discuss two of the most influential environmental changes facing healthcare today: evidence-based medicine and value-based purchasing, or simply value purchasing (chapter 3). We conclude this part with an overview of technology in healthcare with an emphasis on the electronic health record (chapter 4).

In part II, Setting Goals and Executing Strategy, chapter 5 highlights the importance of tying the strategic direction of the organization to operational initiatives. This chapter outlines the use of the balanced scorecard technique to execute and monitor these initiatives toward achieving organizational objectives. Typically, strategic initiatives are large in scope, and the tools of project management (chapter 6) are needed to successfully manage them. Indeed, the use of project management tools can help to ensure the success of any size project. Strategic focus and project management provide the organizational foundation for the remainder of this book.

The next part of the book, Performance Improvement Tools, Techniques, and Programs, provides an introduction to basic decision-making and problem-solving processes and describes some of the associated tools (chapter 7). Most performance improvement initiatives (e.g., Six Sigma, Lean) follow these same processes and make use of some or all of the tools discussed in chapter 7.

Good decisions and effective solutions are based on facts, not intuition. Chapter 8 provides an overview of data analysis techniques to enable fact-based decision making. This includes a discussion of the newer tools of big data: advanced analytics and operational dashboards.

Quality tools such as Six Sigma and Lean are specific philosophies or techniques that can be used to improve processes and systems. Quality improvement using Six Sigma methodology (chapter 9) is the latest manifestation of the use of quality improvement tools to reduce variation and errors in a process. The Lean methodology (chapter 10) focuses on eliminating waste in a system or process.

The fourth section of the book, Applications to Contemporary Healthcare Operations Issues, begins with an integrated approach to applying the

various tools and techniques for process improvement in the healthcare environment (chapter 11). We then focus on a special and important case of process improvement: patient scheduling in the ambulatory setting (chapter 12).

Supply chain management extends the boundaries of the hospital or healthcare system to include both upstream suppliers and downstream customers, and this is the focus of chapter 13. The need to “bend” the healthcare cost inflation curve downward is one of the most pressing issues in healthcare today, and the use of operations management tools to achieve this goal is addressed in chapter 14.

Part V, Putting It All Together for Operational Excellence, concludes the book with a discussion of both emerging trends in healthcare delivery (chapter 15) and strategies for implementing and maintaining the focus on continuous improvement in healthcare organizations (chapter 16).

Many features in this book should enhance reader understanding and learning. Most chapters begin with a vignette, called Operations Management in Action, that offers a real-world example related to the content of that chapter. Throughout the book, we use a fictitious but realistic organization, Vincent Valley Hospital and Health System, to illustrate the tools, techniques, and programs discussed. Each chapter concludes with questions for discussion, and parts II through IV include exercises to be solved.

We include abundant examples throughout the text of the use of various contemporary software tools essential for effective operations management. Readers will see notes appended to some of the exhibits, for example, that indicate what software was used to create charts and graphs from the data provided. Healthcare leaders and managers must be experts in the application of these tools and stay current with the latest versions. Just as we ask healthcare providers to stay up to date with the latest clinical advances, so too must healthcare managers stay current with both basic and emerging software tools.

Acknowledgments

A number of people contributed to this work. Dan McLaughlin would like to thank his many colleagues at the University of St. Thomas Opus College of Business. Specifically, Dr. Ernest Owens provided guidance on the project management chapter, and Dr. Michael Sheppeck assisted on the human resources implications of operations improvement. Dean Stefanie Lenway and Associate Dean Michael Garrison encouraged and supported this work, and they continue to support the growth of the healthcare programs at our University.

Dan would also like to thank the outstanding professionals at Hennepin County Medical Center in Minneapolis, Minnesota, who provided many of the

practical and realistic examples in this book. They continue to be invaluable healthcare resources for all of the residents of Minnesota.

John Olson would like to thank his many colleagues at the University of St. Thomas Opus College of Business—in particular, the dedicated team of the Business Analytics program. Establishing projects with organizations such as Welia Health and Fairview Health in data analytics has helped to understand the challenges faced by these organizations.

The dedicated employees of the Veterans Administration (VA) have helped John embrace the challenges that confront healthcare today. Many of the chapters in this book were inspired by VA staff's ability to overcome any situation. John acknowledges their dedication to serving US veterans and the amazing, high-quality service they deliver.

Luv would like to thank his colleagues at the University of South Carolina and the Ohio State University. In addition, he would like to thank his former coworkers and collaborators at the Cleveland Clinic, Wexner Medical Center, Hackensack University Medical Center, and the World Health Organization. His work experience and research collaborations have expanded understanding of innovations and emerging trends in healthcare.

John, Luv, and Dan also want to thank the skilled professionals of Health Administration Press for their support, especially Jennette McClain, acquisitions editor; Andrew Baumann, editorial production manager; and James Fraleigh, who edited this fourth edition.

Finally, this book still contains many passages that were written by Julie Hays and are a tribute to her skill and dedication to the field of operations management.

Instructor Resources

This book's instructor resources include PowerPoint slides; an updated test bank; teaching notes for the chapter content and the end-of-chapter exercises; and Excel files and cases for selected chapters with accompanying teaching notes. Each of the case studies is one to three pages long and is suitable for one class session or an online learning module.

For the most up-to-date information about this book and its instructor resources, visit ache.org/HAP and for the book's order code (24481).

This book's instructor resources are available to instructors who adopt this book for use in their course. For access information, please email hapbooks@ache.org.

Student Resources

Case studies, exercises, tools, and web links to resources are available at ache.org/books/OpsManagement4.

INTRODUCTION TO HEALTHCARE OPERATIONS

THE CHALLENGE AND THE OPPORTUNITY

The Purpose of This Book

Excellence in healthcare derives from four major areas of expertise: clinical care, population health, leadership, and operations. Although the first three are critical to an organization's success, this book focuses on operations—how to deliver high-quality health services in a consistent, efficient manner.

Many books cover operational improvement tools, and some focus on using these tools in healthcare environments. So why have we devoted a book to the broad topic of healthcare operations? Because we see a need for organizations to adopt an *integrated* approach to operations improvement that puts all the tools in a logical context and provides a road map for their use. An integrated approach uses a clinical analogy: First, find and diagnose an operations issue. Second, apply the appropriate treatment tool to solve the problem.

The field of operations research and management science is too deep to cover in one book. In *Healthcare Operations Management*, only those tools and techniques currently being used by organizations are covered, in part so we may describe them in enough detail to enable students and

OVERVIEW

The challenges and opportunities in today's complex healthcare delivery systems demand that leaders take charge of their operations. A strong operations focus can reduce costs, increase safety—for patients, visitors, and staff alike—improve patient outcomes, and allow an organization to compete effectively in an aggressive marketplace.

Many organizations in the US healthcare system have achieved success recently by executing a few critical strategies. First, attract and retain talented clinicians. Next, add new technology and specialty care services. Last, find new methods to maximize the organization's reimbursement for these services. In most organizations, new services, not ongoing operations, were the key to success.

However, that era is ending. Payer resistance to cost increases and a surge in public reporting on the quality of healthcare are driving a major change in strategy. The passage of the Affordable Care Act in 2010 represented a culmination of these forces. The pandemic of 2020–21 strained the US healthcare system in ways organizational strategic plans never anticipated. Yet the pandemic also accelerated the adoption of many systemic improvements—especially in digital health. To succeed in this new environment, a healthcare enterprise must focus on significantly improving its core operations.

This book is about improvement and how to get things done. It offers an integrated, systematic approach and a set of contemporary operations-improvement tools that can be used in any organization to make significant gains. These tools have been successfully deployed in much of the global business community for more than 40 years and now are being used by leading healthcare delivery organizations.

This chapter outlines the purpose of the book, identifies challenges that healthcare systems currently face, presents a systems view of healthcare, and provides a comprehensive framework for using operations tools and methods in healthcare. It also introduces Vincent Valley Hospital and Health System, the fictional healthcare delivery system used in examples throughout the book.



On the web at
[ache.org/books/OpsManagement4](https://www.ache.org/books/OpsManagement4)

practitioners to use them in their work. Each chapter provides many references for further reading and deeper study. We also include additional resources,

case studies, exercises, and tools on the companion website that accompanies this book.

This book is organized so that each chapter builds on the previous one and is cross-referenced. However, each chapter also stands alone, so a reader interested in Six Sigma can start in chapter 9 and then move to the other chapters in any order she wishes.

This book does not specifically explore quality in healthcare as defined by the many agencies that have as their mission ensuring healthcare quality, such as The Joint Commission, the National Committee for Quality Assurance, the National Quality Forum, and some federally funded quality improvement organizations. In particular, *The Healthcare Quality Book: Vision, Strategy, and Tools* (Nash et al. 2019) delves deeply into this perspective and may be considered a useful companion to this book. However, the systems, tools, and techniques discussed here are essential to completing the operational improvements needed to meet the expectations of these quality assurance organizations.

The Challenge

Health spending is projected to grow from 2019 to 2028 at an average annual rate of 5.4 percent and to reach \$6.2 trillion per year by 2028. As a result, the health share of gross domestic product is expected to rise from 17.7 percent in 2018 to 19.7 percent by 2028 (Centers for Medicare & Medicaid Services 2019). Healthcare spending thus will increasingly pressure the federal budget.

Waste in the System

Although every national health system faces challenges, one of the most prominent for the United States is cost. The US healthcare system is the most expensive in the world. If waste could be removed from this system, it would no longer rank as nearly the most expensive country, though it would still be in the top quartile of costs of the countries in the Organisation for Economic Co-operation and Development (2021). Shrank, Rogstad, and Parekh (2019) replicated an earlier study by the Institute of Medicine that identified six categories of waste (exhibit 1.1). The potential savings if these wastes were eliminated range from \$760 billion to \$935 billion per year—approximately 25 percent of annual healthcare costs (exhibit 1.2).

EXHIBIT 1.1

Waste in the US Healthcare System: Estimated Costs and Potential for Savings

Berwick and Hackbarth Definition	Targeted Cost Components	Targeted Intervention Components
1. Failure of Care Delivery		
“Waste that comes with poor execution or lack of widespread adoption of known best care processes, including, for example, patient safety systems and preventive care practices that have been shown to be effective. The results are patient injuries and worse clinical outcomes.”	Clinician- or hospital-related inefficiency: variability in care, inefficient use of high-cost clinicians or hospitals	Clinical pathways, centers of excellence, physician/hospital benchmarking, bundled payment models
	Practice- and system-based inefficiency: inefficient clinic processes, redundant testing	Quality improvement initiatives
	Medical errors or adverse events	Patient safety initiatives or hospital-acquired condition reduction
	Lack of adoption of preventive care practices	Primary, secondary, and tertiary prevention initiatives
2. Failure of Care Coordination		
“Waste that comes when patients fall through the slats in fragmented care. The results are complications, hospital readmissions, declines in functional status, and increased dependency, especially for the chronically ill, for whom care coordination is essential for health and function.”	Unnecessary ED visits or admissions	Interventions focused on reducing admissions: urgent care, telehealth or retail clinics, observation units, ED co-pay increases, high-user interventions
	Unnecessary readmissions	Transitions of care and readmission initiatives, hospital readmissions reduction program
	Avoidable complications	Effective care management for medically complex patients

(continued)

EXHIBIT 1.1

Waste in the US Healthcare System: Estimated Costs and Potential for Savings (continued from previous page)

Berwick and Hackbarth Definition	Targeted Cost Components	Targeted Intervention Components
3. Overtreatment or Low-Value Care		
“Waste that comes from subjecting patients to care that, according to sound science and the patients’ own preferences, cannot possibly help them—care rooted in outmoded habits, supply-driven behaviors, and ignoring science. Examples include excessive use of antibiotics, use of surgery when watchful waiting is better, and unwanted intensive care at the end of life for patients who prefer hospice and home care.”	Overtreatment or overuse of low-value treatments (medications and procedures) Overtesting or overdiagnosis Overuse in end-of-life care	Clinician facing: choosing wisely, clinician feedback, clinical pathways, stepped care, incorporating low-value care in quality measures, shared decision making Insurance facing: prior authorization (for medications, testing, procedures) Pharmacy focused: prior authorization, formulary design, exclusivity or closed classes, indication-based pricing, generics or biosimilars, early palliative care and hospice efforts
4. Pricing Failure		
“Waste that comes as prices migrate far from those expected in well-functioning markets, that is, the actual costs of production plus a fair profit. For example, because of the absence of effective transparency and competitive markets, US prices for diagnostic procedures such as MRI and CT scans are several times more than identical procedures in other countries.”	Variability and inflation in pricing of medications, testing, procedures, devices, and durable medical equipment	Insurance facing: efforts to standardize prices of services, value-based benefit design, negotiations for services Pharmacy focused: drug price negotiations, value-based contracting for drugs and services Patient facing: cost transparency initiatives

EXHIBIT 1.1
Waste in the US Healthcare System: Estimated Costs and Potential for Savings (continued from previous page)

Berwick and Hackbarth Definition	Targeted Cost Components	Targeted Intervention Components
5. Fraud and Abuse		
“Waste that comes as fraudsters issue fake bills and run scams, and also from blunt procedures of inspection and regulation that everyone faces because of the misbehaviors of a very few.”	Costs of fraud and abuse	Interventions that address costs of fraud and abuse
6. Administrative Complexity		
“Waste that comes when government, accreditation agencies, payers, and others create inefficient or misguided rules. For example, payers may fail to standardize forms, thereby consuming limited physician time in needlessly complex billing procedures.”	Billing and coding costs Physician administrative burden Insurance administrative burden, inefficiencies	Interventions to facilitate billing and coding Elimination of processes that do not improve quality and access to care and do not reduce costs Streamlining administrative personnel and processes

Source: Adapted from Shrank, Rogstad, and Parekh (2019), table 1.
Note: CT = computed tomography; MRI = magnetic resonance imaging.

EXHIBIT 1.2Annual Cost
Estimates
of Waste

	Costs, \$US Billion	
Domain	Annual Estimates	Total Range
1. Failure of Care Delivery		
Hospital-acquired conditions and adverse events	5.7–46.6	102.4–165.7
Clinician-related inefficiency (variability in care, inefficient use of high-cost physicians)	8.0	
Lack of adoption of preventive care practices (obesity, vaccines, diabetes, hypertension)	88.6–111.1	
2. Failure of Care Coordination		
Unnecessary admissions and avoidable complications	5.9–56.3	27.2–78.2
Readmissions	21.25–21.93	
3. Overtreatment or Low-Value Care		
Low-value medication use	14.4–29.1	75.7–101.2
Low-value screening, testing, or procedures	17.2–27.9	
Overuse of end-of-life care	44.1	
4. Pricing Failure		
Medication pricing failure	169.7	230.7–240.5
Payer-based health services pricing failure	31.4–41.2	
Laboratory and ambulatory pricing	29.7	
5. Fraud and Abuse		
Fraud and abuse in Medicare	58.5–83.9	58.5–83.9
6. Administrative Complexity		
Billing and coding waste	248	265.6
Physician time spent reporting on quality measures	17.6	
Total		760–935

Source: Adapted from Shrank, Rogstad, and Parekh (2019).

All the wastes identified by this study, other than pricing failure, can be addressed by the concepts and tools contained in the following chapters. The challenge for healthcare leaders is to embrace these concepts and engage their organizations in making needed changes. This can lead to both organizational financial success and a contribution to supporting the overall economy of the United States.

Quality

The quality of care in the United States is improving, but challenges remain—especially in the disparities of care some residents of the country receive. The *National Healthcare Quality & Disparities Report* published by the **Agency for Healthcare Research and Quality (AHRQ 2020)** reported these key findings for data collected in 2018:

- **Access:** From 2000 through 2016–2018, more than half (11 of 20) of access measures showed improvement, 25 percent (5 of 20) did not show improvement, and 20 percent (4 of 20) showed worsening. For example, there were significant gains in the percentage of people who reported having health insurance.
- **Quality:** Quality of healthcare improved overall from 2000 through 2018, but the pace of improvement varied by priority area:
 - **Person-Centered Care:** Almost half (14 of 29) of person-centered care measures were improving overall.
 - **Patient Safety:** Nearly half (12 of 26) of patient safety measures were improving overall.
 - **Healthy Living:** Almost 60% (41 of 70) of healthy living measures were improving overall.
 - **Effective Treatment:** More than 40% (15 of 36) of effective treatment measures were improving overall.
 - **Care Coordination:** Nearly 40% (3 of 8) of care coordination measures were improving overall.
 - **Care Affordability:** Forty percent (2 of 5) of affordable care measures were improving overall.
- **Disparities:** Overall, some disparities were getting smaller from 2000 through 2016–2018, but disparities persist and some even worsened, especially for poor and uninsured populations in all priority areas.
 - Racial and ethnic disparities vary by group:
 - ◆ For about 40% of quality measures, Blacks (82 of 202) and American Indians and Alaska Natives (47 of 116) received worse care than Whites. For more than one-third of quality measures, Hispanics (61 of 177) received worse care than Whites.

Agency for Healthcare Research and Quality (AHRQ)

A federal agency that is part of the Department of Health and Human Services. It provides leadership and funding to identify and communicate the most effective methods to deliver high-quality healthcare in the United States.

- ◆ For nearly 30% of quality measures, Asians (52 of 185) received worse care than Whites, but Asians received better care than Whites for nearly one-third (56 of 185) of quality measures.
- ◆ For one-third of quality measures, Native Hawaiians/Pacific Islanders (24 of 72) received worse care than Whites.
- Disparities vary by residence location:
 - ◆ For nearly a quarter (24 of 102) of quality measures, residents of large central metropolitan areas received worse care than residents of large fringe metropolitan areas.
 - ◆ For one-third of quality measures, residents of micropolitan and noncore areas received worse care than residents of large fringe metropolitan areas.
 - ◆ For a little less than 20% of quality measures, medium and small metropolitan residents received worse care than residents of large fringe metropolitan areas. (AHRQ 2020)

The Opportunity

Although the current US healthcare system presents numerous challenges, opportunities for improvement are emerging as well. A number of major trends provide hope that significant change is possible. The following trends represent this groundswell:

- Informatics systems are maturing, and big data and analytics tools are becoming ever more powerful.
- Digital health, including process automation, telehealth, robots, and the Internet of Medical Things will begin to replace human labor in healthcare. Digital applications are now becoming pervasive in all aspects of the healthcare system and will provide a strong platform for the transformation of healthcare operations.
- Supply chains and the relationships among health plans, healthcare systems, and individual providers are changing through mergers, partnerships, and acquisitions.
- Primary care is being redesigned with new provider models and new tools, such as telemedicine, home care, and mobile applications.
- Medicine itself is undergoing rapid change with the adoption of precision medicine tools, such as pharmacogenomics, to individualize patient treatments, and these advances are being embedded in delivery systems through the adoption of the practice of evidence-based medicine.
- A new emphasis on population health management and consumer engagement will lead to healthier environments and lifestyles.

- Addressing the disparities in health outcomes and the impact of the social determinants of health for populations with social, economic or environmental disadvantages has become an increasingly urgent goal.

Evidence-Based Medicine

The use of **evidence-based medicine (EBM)** for delivering healthcare in the United States is the result of many years of work by some of the nation's most progressive and thoughtful practitioners. EBM has produced an array of care guidelines, care patterns, and shared decision-making tools for caregivers and patients.

Big Data and Analytics

Healthcare delivery has been slow to adopt information technologies, but many organizations have now implemented electronic health record (EHR) systems and other automated tools. Although their implementation has sometimes been organizationally painful, EHRs are now becoming mature enough to have a substantial positive impact on operations.

In addition, data science computer engineering has evolved to provide significant new tools in the following areas:

- Data storage and retrieval—high volume, high velocity, and high variety of data types
- New analytical tools for reporting and prediction
- Portable and wearable devices
- Interoperability of devices and databases

Chapter 8 describes a set of analytical tools to fully exploit these new resources.

Active and Engaged Consumers

Consumers are assuming new roles in their own care through the use of health education and information and by partnering effectively with their healthcare providers. Personal maintenance of wellness through a healthy lifestyle is one essential component. Understanding one's disease and treatment options and having an awareness of the cost of care are also important consumer responsibilities.

Patients are becoming good consumers of healthcare by finding and considering price information when selecting providers and treatments. Many employers offer high-deductible health plans with accompanying **health savings accounts (HSAs)**. This type of **consumer-directed healthcare** is likely to grow and increase pressure on providers to deliver cost-effective, customer-sensitive, high-quality care. The healthcare delivery system of the future will support and empower active, informed consumers.

evidence-based medicine (EBM)

The conscientious and judicious use of the best current evidence in making decisions about the care of individual patients.

health savings account (HSA)

A personal monetary account that can only be used for healthcare expenses. The funds are not taxed, and the balance can be rolled over from year to year. HSAs are normally used with high-deductible health insurance plans.

consumer-directed healthcare

Healthcare systems in which the consumer (patient) is well informed about healthcare prices and quality and makes personal buying decisions on the basis of this information. Health savings accounts are frequently included as a key component of such systems.

A Systems Look at Healthcare

The Clinical System

To participate in the improvement of healthcare operations, healthcare leaders must understand the series of interconnected systems that influence the delivery of clinical care (exhibit 1.3). In the **patient care microsystem**, the healthcare professional provides hands-on care to the patient. Elements of the clinical microsystem include

patient care microsystem

The level of healthcare delivery that includes providers, technology, and treatment processes.

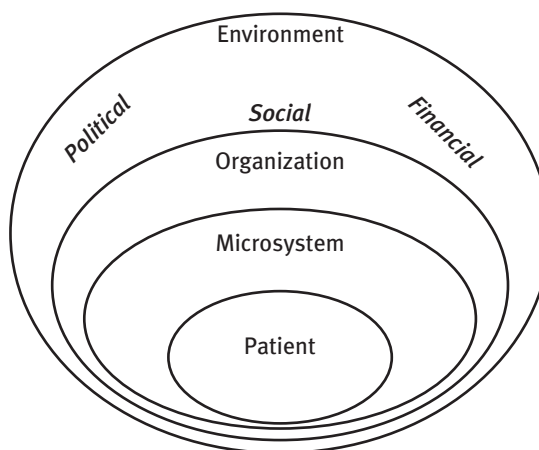
- the team of health professionals who provide clinical care to the patient,
- the tools that the team has at its disposal to diagnose and treat the patient (e.g., imaging capabilities, laboratory tests, drugs), and
- the logic for determining the appropriate treatments and the processes to deliver that care.

Because common conditions (e.g., hypertension) affect numerous patients, clinical research has been conducted to determine the most effective ways to treat these patients. Therefore, the organization and functioning of the microsystem often can be optimized. Process improvements can be made at this level to ensure that the most-effective, least-costly care is delivered. In addition, the use of EBM guidelines can help ensure that the patient receives the correct treatment at the correct time.

The *organizational infrastructure* also influences the effective delivery of care to the patient. Ensuring that providers have the correct tools and skills is an important element of infrastructure.

EXHIBIT 1.3

A Systems View of Healthcare



Source: Adapted and updated by the authors based on Ferlie, E., and S. M. Shortell. 2001.

"Improving the Quality of Healthcare in the United Kingdom and the United States: A Framework for Change." *Milbank Quarterly* 79 (2): 281–316.

The EHR is one of the most important advances in the clinical micro-system for both process improvement and the wider adoption of EBM.

Another key component of infrastructure is the leadership displayed by senior staff. Without leadership, progress and change do not occur.

Finally, the *environment* strongly influences the delivery of care. Key environmental factors include governmental policy, social factors such as social determinants of health, and financial factors such as payer policies. An organization's strategy is frequently influenced by such factors (e.g., a new Medicare regulation).

Many of the systems concepts regarding healthcare delivery were initially developed by Avedis Donabedian. These fundamental contributions are discussed in depth in chapter 2.

System Stability and Change

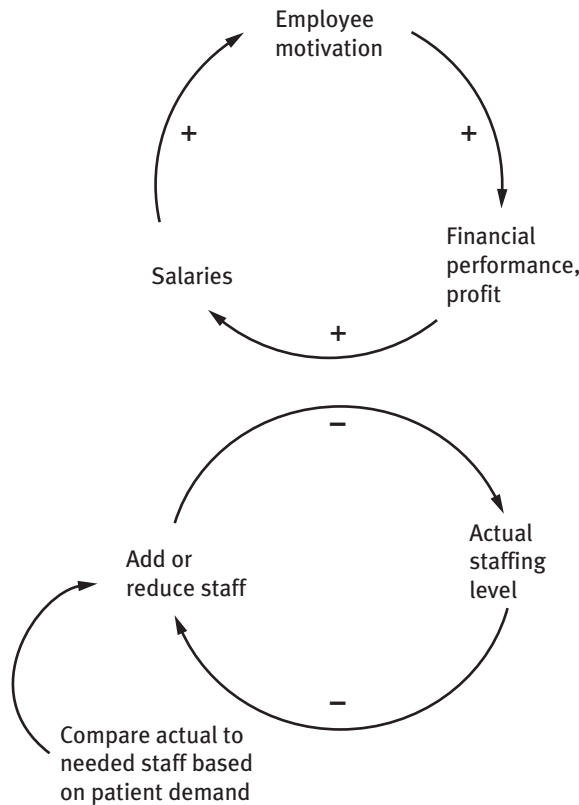
Elements in each layer of this system interact. Peter Senge (1990) provides a useful theory for understanding the interaction of elements in a complex system such as healthcare. In his model, the structure of a system is the primary mechanism for producing an outcome. For example, the presence of an organized structure of facilities, trained professionals, supplies, equipment, and EBM care guidelines leads to a high probability of producing an expected clinical outcome.

No system is ever completely stable. Each system's performance is modified and controlled by feedback (exhibit 1.4). Senge (1990, 75) defines *feedback* as "any reciprocal flow of influence. In systems thinking it is an axiom that every influence is both *cause* and *effect*." As shown in exhibit 1.4, increased salaries provide an incentive for employees to achieve improvement in performance level. This improved performance leads to enhanced financial performance and profitability for the organization, and increased profits provide additional funds for higher salaries, and the cycle continues. Another frequent example in healthcare delivery is patient lab results that directly influence the medication ordered by a physician. A third example is a financial report that shows an over-expenditure in one category that prompts a manager to reduce spending to meet budget goals.

A more complete definition of a feedback-driven operational system includes an operational process, a sensor that monitors process output, a feedback loop, and a control that modifies how the process operates.

Feedback can be either reinforcing or balancing. *Reinforcing feedback* prompts change that builds on itself and amplifies the outcome of a process, taking the process further and further from its starting point. The effect of reinforcing feedback can be either positive or negative. For example, a reinforcing change of positive financial results for an organization could lead to increases in salaries, which would then lead to even better financial performance

EXHIBIT 1.4
Systems with
Reinforcing
and Balancing
Feedback



because the employees are highly motivated. In contrast, a poor supervisor could cause employee turnover, possibly resulting in short staffing and even more turnover.

Balancing feedback prompts change that seeks stability. A balancing feedback loop attempts to return the system to its starting point. The human body provides a good example of a complex system that has many balancing feedback mechanisms. For example, an overheated body prompts perspiration until the body is cooled through evaporation. The clinical term for this type of balance is *homeostasis*. A treatment process that controls drug dosing via real-time monitoring of the patient's physiological responses is an example of balancing feedback. Inpatient unit staffing levels that determine where in a hospital patients are admitted is another. All of these feedback mechanisms are designed to maintain balance in the system.

A confounding problem with feedback is delay. Delays occur when interruptions arise between actions and consequences. In the midst of delays, systems tend to "overshoot" and thus perform poorly. For example, an emergency department might experience a surge in patients and call in additional

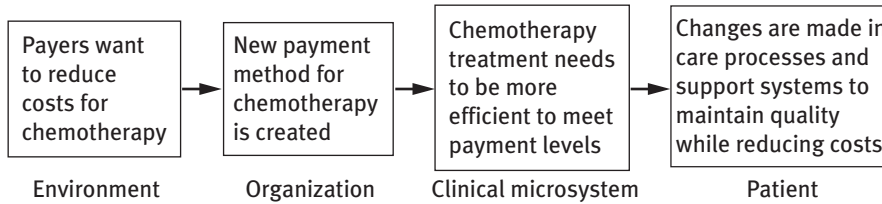


EXHIBIT 1.5
Linkages Within
the Healthcare
System:
Chemotherapy

staff. When the surge subsides, the added staff stay on shift but are no longer needed, and incur unnecessary expense.

Healthcare leaders who focus on improving their operations must understand the systems in which change resides. Every change will be resisted and reinforced by feedback mechanisms, many of which are not clearly visible. Taking a broad systems view can improve the effectiveness of change.

Many subsystems in the total healthcare system are interconnected. These connections have feedback mechanisms that either reinforce or balance the subsystem's performance. Exhibit 1.5 shows a simple connection that originates in the environmental segment of the total health system. Each process has both reinforcing and balancing feedback.

This general systems model can be converted to a more quantitative system dynamics model, which is useful as part of a predictive analytics system. This concept is addressed in more depth in chapter 8.

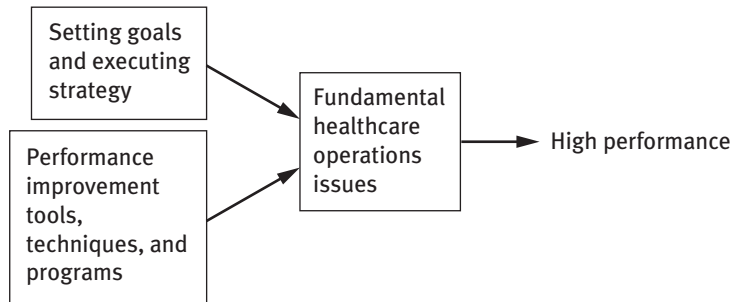
An Integrating Framework for Operations Management in Healthcare

The five-part framework of this book reflects our view that effective operations management in healthcare consists of highly focused strategy execution and organizational change accompanied by the disciplined use of analytical tools, techniques, and programs (exhibit 1.6). An organization needs to understand the environment, develop a strategy, and implement a system to effectively deploy this strategy. At the same time, the organization must become adept at using all the tools of operations improvement contained in this book. These improvement tools can then be combined to attack the fundamental challenges of operating a complex healthcare delivery organization.

Introduction to Healthcare Operations

The introductory chapters provide an overview of the significant environmental trends healthcare delivery organizations face. Annual updates to industry-wide trends can be found in *Futurescan: Healthcare Trends and Implications*

EXHIBIT 1.6
Framework
for Effective
Operations
Management in
Healthcare



Source: Adapted and updated by the authors based on Ferlie, E., and S. M. Shortell. 2001. "Improving the Quality of Healthcare in the United Kingdom and the United States: A Framework for Change." *Milbank Quarterly* 79 (2): 281–316.

2021–2026 (SHSMD and ACHE 2021). Progressive organizations tend to review these publications carefully, as they can use this information in response to external forces by identifying either new strategies or current operating problems that must be addressed.

Business has aggressively used operations improvement tools for the past 40 years, but the field of operations science actually began many centuries ago. Chapter 2 provides a brief history.

Healthcare operations are increasingly driven by the effects of EBM and value purchasing. Chapter 3 offers an overview of these trends and how organizations can effect change to meet current challenges and opportunities.

Digital technology has become ubiquitous and is now being broadly applied in healthcare. Chapter 4 is new to this edition and describes the current and future uses of these powerful tools.

Setting Goals and Executing Strategy

A key component of effective operations is the ability to move strategy to action. Chapter 5 shows how the use of the balanced scorecard and strategy maps can help accomplish this aim. Change in all organizations is challenging, and the formal methods of project management (chapter 6) can deliver effective, lasting improvements in an organization's operations.

Performance Improvement Tools, Techniques, and Programs

Once an organization has its strategy implementation and change management processes in place, it needs to select the correct tools, techniques, and programs to analyze current operations and develop effective adjustments.

Chapter 7 outlines the basic steps of problem solving, which begins by framing the question or problem and continues through data collection and analyses to enable effective decision making.

With powerful new approaches to analytics, enhanced software tools, and big data repositories, the ability to understand and predict organizational performance is significantly enhanced. Chapter 8 provides a comprehensive approach to the use of this essential tool of operations management.

Some projects require a focus on process improvement. Quality improvement tools (chapter 9) can be used to reduce variability in the outcome of a process. Lean tools (chapter 10) help eliminate waste and increase speed.

Applications to Contemporary Healthcare Operations Issues

This part of the book demonstrates how these concepts can be applied to some of today's fundamental healthcare challenges. Process improvement techniques are now widely deployed in many organizations to significantly improve performance; chapter 11 reviews the tools of process improvement and demonstrates their use in improving patient flow.

Scheduling and capacity management continue to be major concerns for most healthcare delivery organizations, particularly with the advent of telehealth, and chapter 12 explores both current and advanced-access scheduling systems. Specifically, the chapter demonstrates how simulation can be used to optimize scheduling. Chapter 13 explores the optimal methods for acquiring supplies and maintaining appropriate inventory levels. Chapter 14 outlines a systems approach to improving financial results, with a special emphasis on cost reduction—one of today's most important challenges.

Putting It All Together for Operational Excellence

The US healthcare system is undergoing significant change, and the pandemic of 2020–21 accelerated many of these changes. Chapter 15 outlines some of the emerging trends that will support a transformation of care delivery and population health.

In the end, any operations improvement will fail unless steps are taken to maintain the gains; chapter 16 contains the necessary tools to do so. The chapter also provides a detailed algorithm that helps practitioners select the appropriate tools, methods, and techniques to effect significant operational improvements. It demonstrates how our fictionalized case study healthcare system, Vincent Valley Hospital and Health System (VVH), uses all the tools presented in the book to achieve operational excellence. In this way, a future is envisioned in which many of the tools and methods contained in the book are widely deployed in the US healthcare system.

Vincent Valley Hospital and Health System

Woven throughout the chapters are examples featuring VVH, a fictitious but realistic health system. The

On the web at ache.org/books/OpsManagement4 

companion website contains an expansive description of VVH; here we provide some essential details.

VVH is located in a midwestern city with a population of 1.5 million. The health system employs 5,000 staff members, operates 350 inpatient beds, and has a medical staff of 450 physicians. It operates nine clinics staffed by physicians who are employees of the system. VVH competes with two major hospitals and an independent ambulatory surgery center that was formed by several surgeons from all three hospitals.

The VVH brand includes an accountable care organization to reflect the increased emphasis it has placed on population health in its community. The organization has also created a Medicare Advantage Plan. It has significantly restructured its primary care delivery segment and has contracted with a variety of retail clinics to supplement the traditional office-based primary care physicians with whom it is affiliated. It recently added an online diagnosis and treatment service, with 24-hour telehealth now available.

Three major health plans provide most of the private payment to VVH, which, along with the state Medicaid system, have recently begun a value-purchasing reimbursement initiative. VVH has a strong balance sheet and a profit margin of approximately 2 percent, but its senior leaders feel the organization is financially challenged.

The board of VVH includes many local industry leaders, who have asked the chief executive to focus on using the operational techniques that have led them to succeed in their own businesses.

Conclusion

This book is an overview of operations management approaches and tools. The reader is expected to understand all the concepts in the book (and in current use in the field) and be able to apply, at the basic level, most of the tools, techniques, and programs presented. The reader is not expected to execute at the more advanced level (e.g., Six Sigma black belt, Project Management Professional). However, this book prepares readers to work effectively with knowledgeable professionals and, most important, enables them to direct the work of those professionals.

Discussion Questions

1. Provide three examples of system improvements at the boundaries of the healthcare subsystems (patient, microsystem, organization, environment).

2. Identify three systems in a healthcare organization (at any level) that have reinforcing feedback.
3. Identify three systems in a healthcare organization (at any level) that have balancing feedback.
4. Identify three systems in a healthcare organization (at any level) in which feedback delays affect the performance of the system.

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HISTORY OF PERFORMANCE IMPROVEMENT

Operations Management in Action

During the Crimean War, a conflict waged from October 1853 to March 1856 pitting Russia against Britain, France, and the Ottoman Empire; reports of terrible conditions in military hospitals began to emerge, alarming British citizens. In response to the outcry, the British government commissioned Florence Nightingale, now widely recognized as a pioneer in nursing practice, to oversee the introduction of nurses to military hospitals to improve conditions there. When Nightingale arrived in Scutari, in Turkey, she found the military hospital there overcrowded and filthy. She instituted many changes to improve the sanitary conditions in the hospital, and many lives were saved as a result of these reforms.

Nightingale was among the first healthcare professionals to collect, tabulate, interpret, and graphically display data related to the impact of process changes on care outcomes—what is known today as evidence-based medicine. To quantify the overcrowding problem, she compared the average amount of space per patient in London hospitals—1,600 square feet—to the space in Scutari—about 400 square feet. She developed a standardized document, the Model Hospital Statistical Form, to enable the collection of consistent data for analysis and comparison. In February 1855, the patient mortality rate at the military hospital in Scutari was 42 percent. As a result of Nightingale's changes, by June of that year the mortality rate had decreased to 2.2 percent.

To present these data in a persuasive manner, she developed a new type of graphic display, the polar area diagram. The diagram was a pie chart with a monthly

OVERVIEW

This chapter provides the background and historical context for performance improvement—which is not a new concept. Several of the tools, techniques, and philosophies outlined in this text are based in past efforts. Although the terminology has changed, many of the core concepts remain the same.

The major topics in this chapter include the following:

- Background for understanding operations management
- Systems thinking and knowledge-based management
- Scientific management
- Project management
- Introduction to quality, and quality experts of note
- Philosophies of performance improvement, including Six Sigma, Lean, and others
- Introduction to supply chain management
- Introduction to big data and analytics

Although these tools and techniques have been adapted for contemporary healthcare, their roots are in the past, and an understanding of this history (exhibit 2.1) can enable organizations to move successfully into the future.

slice for mortality numbers and their causes displayed in a different color. A quick glance at the diagram “showed that except for the bloodiest month in the siege of Sevastopol, battle deaths take up a very small portion of each slice,” notes Lienhard (2016). It revealed that “the Russians were a minor enemy. The real enemies were cholera, typhus, and dysentery. Once the military looked at that eloquent graph, the modern army hospital system was inevitable” (Lienhard 2016).

After the war, Nightingale used the data she had collected to demonstrate that the mortality rate in Scutari following her reforms was significantly lower than in other British military hospitals. Although the British military hierarchy was resistant to her changes, the data were convincing and resulted in reforms to military hospitals and the establishment of the Royal Commission on the Health of the Army.

Were she alive today, Nightingale would recognize many of the philosophies, tools, and techniques outlined in this text as essentially the same as those she employed to achieve lasting reform in hospitals throughout the world.

Sources: Information from Cohen (1984), Lienhard (2016), Neuhauser (2003), and Nightingale (1858).

Background

The healthcare industry faces many challenges. The costs of care and level of services delivered are increasing; even as the population ages, we are able to prolong lives to an ever greater extent as technology advances and expertise grows. The expectation of quality care with zero defects, or failures in care, is being pursued by government and other stakeholders, driving the need for healthcare providers to produce more of a high-quality product or service at a reduced cost. This need can only be met through improved utilization of resources.

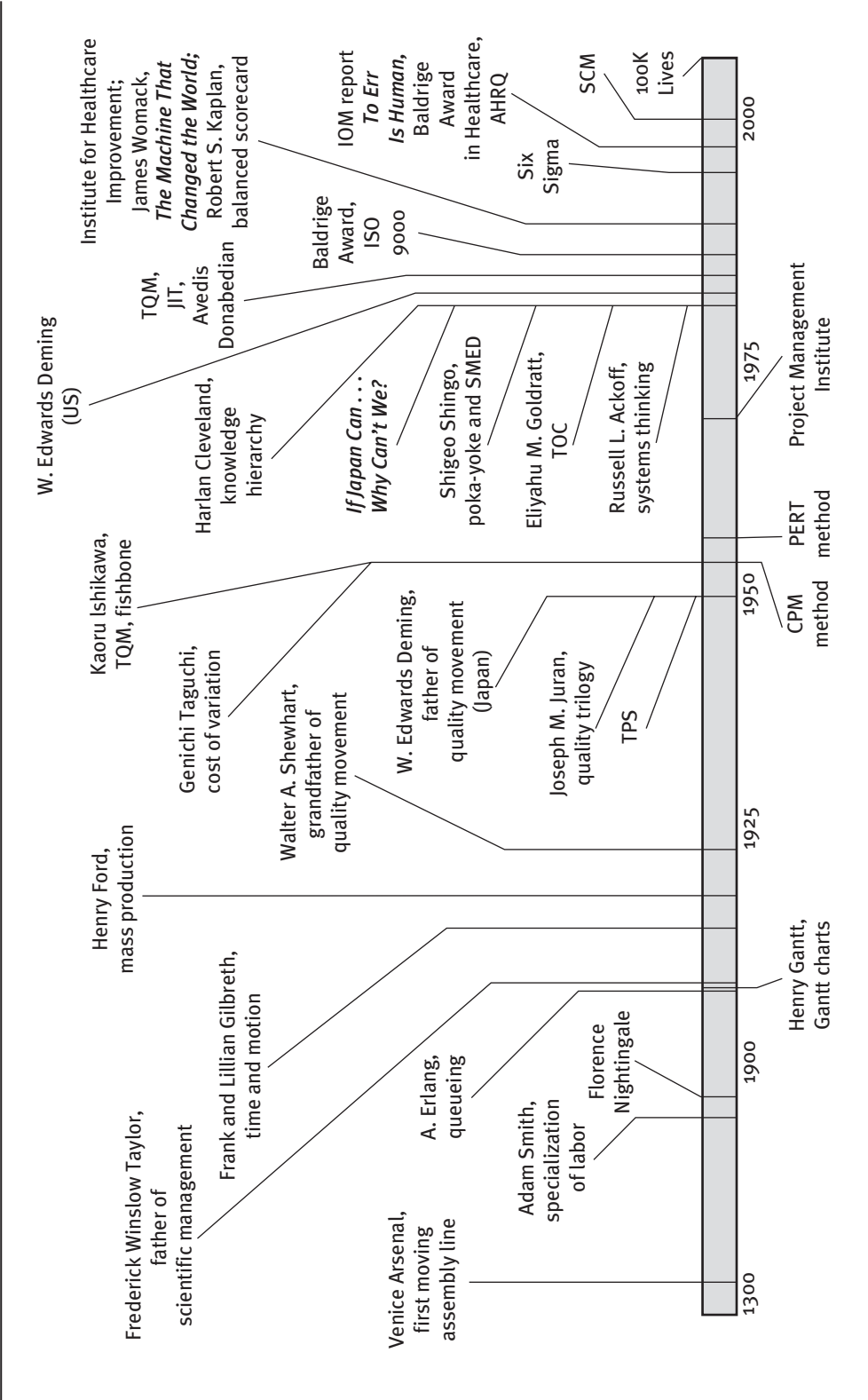
Specifically, providers must offer their services more effectively and efficiently than at any time in the past by optimizing their use of limited financial assets, employees and staff, machines and facilities, and time.

Enter operations management. Operations management is the design, implementation, and improvement of the processes and systems that create and deliver the organization’s products and services. Operations managers plan and control delivery processes and systems within the organization.

Forward-thinking healthcare leaders and professionals have realized that the theories, tools, and techniques of operations management, if properly applied, can enable their organizations to become efficient and effective care delivery environments. However, for many of the aims identified by the US healthcare system to be achieved, essentially all healthcare providers must adopt these tools and techniques, many of which have enabled other

EXHIBIT 2.1

Important Events in Performance Improvement



Note: AHRQ = Agency for Healthcare Research and Quality; CPM = critical path method; IOM = Institute of Medicine; ISO = International Organization for Standardization; JIT = just in time; PERT = program evaluation and review technique; SCM = supply chain management; SMED = single-minute exchange of die; TOC = theory of constraints; TPS = Toyota Production System; TQM = total quality management.

service industries and manufacturing sectors to improve efficiency and effectiveness. The operations management information presented in this book should similarly enable hospitals and other healthcare organizations to design systems, processes, products, and services that meet the needs of their stakeholders. Importantly, it should also allow continuous improvement in these systems and services to keep pace with the quickly changing healthcare landscape.

To improve systems and processes, however, one must first know the system or process and its desired inputs and outputs.

Knowledge-Based Management

This book takes a systems view of service provision and delivery, as illustrated in exhibit 2.2, and focuses on knowledge-based management (KBM)—using data and information toward basing management decisions on facts rather than on feelings or intuition—to frame that view. The improvement in computer systems and new analytical approaches support the increased use of KBM, especially in terms of building a knowledge hierarchy.

The **knowledge hierarchy** relates to the learning that ultimately underpins KBM. As illustrated in exhibit 2.3, the knowledge hierarchy consists of the following five categories (Zeleny 1987):

1. *Data*. Symbols or raw numbers that simply exist; they have no structure or organization. Entities collect data with their computer systems; individuals collect data through their experiences. At this stage of the hierarchy, one can presume to know *nothing* because raw data alone are not adequate for decision making.
2. *Information*. Data that are organized or processed to have meaning. Information can be useful, but it is not *necessarily* useful. It can

knowledge hierarchy
The foundation of knowledge-based management, composed of five categories of learning: data, information, knowledge, understanding, and wisdom.

EXHIBIT 2.2

Systems View of the Provision of Services for Purposes of This Book

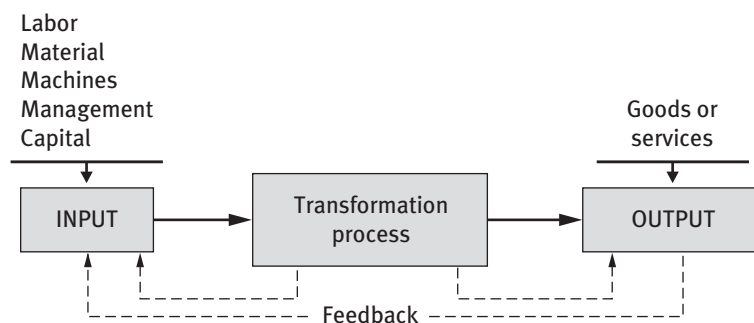
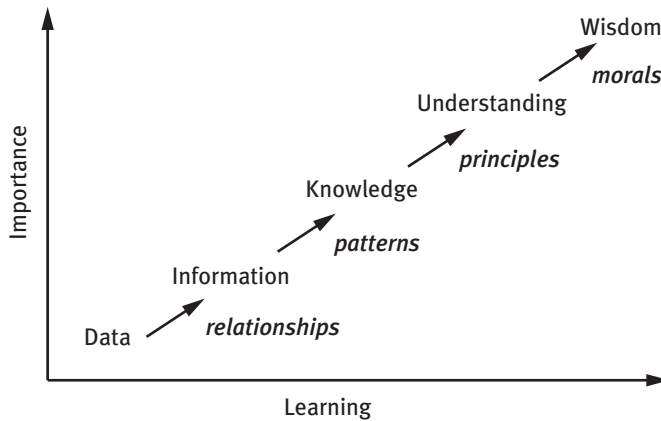


EXHIBIT 2.3
Knowledge
Hierarchy

answer such questions as who, what, where, and when—in other words, know *what*.

3. *Knowledge*. Information that is deliberately useful. Knowledge enables decision making—know *how*.
4. *Understanding*. A mental frame that allows use of what is known and enables the development of new knowledge. Understanding represents the difference between learning and memorizing—know *why*.
5. *Wisdom*. A high-level stage that adds moral and ethical views to understanding. Wisdom answers questions to which there is no known correct answer and, in some cases, to which there will never be a known correct answer—know *right*.

A simple example may help explain this hierarchy. Say your height is 67 inches and your weight is 175 pounds (data). You have a body mass index (BMI) of 26.7 (information). A healthy BMI is 18.5 to 25.5 (knowledge). Your BMI is high, and to be healthy you should lower it (understanding). You begin a diet and exercise program and lower your BMI (wisdom).

Finnie (1997, 24) summarizes the relationships in the hierarchy and notes our tendency to focus on its less important levels:

We talk about the accumulation of information, but we fail to distinguish between data, information, knowledge, understanding, and wisdom. An ounce of information is worth a pound of data, an ounce of knowledge is worth a pound of information, an ounce of understanding is worth a pound of knowledge, an ounce of wisdom is worth a pound of understanding. In the past, our focus has been inversely related to importance. We have focused mainly on data and information, a little bit on knowledge, nothing on understanding, and virtually less than nothing on wisdom.

Knowledge Through the Ages

The roots of the knowledge hierarchy can be traced to eighteenth-century philosopher Immanuel Kant, much of whose work attempted to address the questions of what and how we can know.

The two major philosophical movements that significantly influenced Kant were empiricism and rationalism (McCormick 2006). The empiricists, most notably John Locke, argued that human knowledge originates in one's experiences. According to Locke, the mind is a blank slate that fills with ideas through its interaction with the world. The rationalists, including Descartes and Galileo, argued that the world is knowable through an analysis of ideas and logical reasoning. Both the empiricists and the rationalists viewed the mind as passive, either because it receives ideas onto a blank slate or because it possesses innate ideas that can be logically analyzed.

Kant joined these philosophical ideologies by arguing that experience leads to knowing only if the mind provides a structure for those experiences. Although the idea that the rational mind plays a role in defining reality is now common, in Kant's time this was a major insight into what and how we know. Knowledge does not flow from our experiences alone, nor only from our ability to reason; rather, knowledge flows from our ability to apply reasoning to our experiences.

Relating Kant's philosophy to the knowledge hierarchy, data are our experiences, information is obtained through logical reasoning, and knowledge is obtained when we apply structured reasoning to data to acquire knowledge (Ressler and Ahrens 2006).

The intent of this text is to enable readers to gain knowledge. We discuss tools and techniques that allow the application of logical reasoning to data toward obtaining knowledge and using it to make decisions. This knowledge and understanding should help the reader provide healthcare in an efficient and effective manner.

History of Scientific Management

scientific management
A disciplined approach to studying a system or process and then using data to optimize it to achieve improved efficiency and effectiveness.

Frederick Taylor (whose work is covered in more detail later in the chapter) originated the term **scientific management** in *The Principles of Scientific Management* (Taylor 1911). Scientific management methods called for eliminating the old rule-of-thumb, individual way of performing work and, through study and optimization of the work, replacing the varied methods with the one "best" way of performing the work to improve productivity and efficiency. Today, the term *scientific management* has been replaced with *operations management*, but the concept is similar: Study the process or system and determine ways to optimize it to achieve improved efficiency and effectiveness.

Mass Production

The Industrial Revolution and mass production set the stage for much of Taylor's work. Prior to the Industrial Revolution, individual craftsmen performed all tasks necessary to produce a good using their own tools and procedures. In the eighteenth century, Adam Smith advocated for the division of labor—increasing work efficiency through specialization. To support a division of labor, a large number of workers are brought together, and each performs a specific task related to the production of a good. From Taylor's study of this system and factory mass production arose his theory of scientific management, which made industrial conditions ripe for Henry Ford's introduction of the assembly line.

Mass production allows for significant economies of scale, as predicted by Smith. Before Ford set up his moving assembly line, each car chassis was assembled by a single worker and took about 12½ hours to produce. After the assembly line was introduced, this time was reduced to 93 minutes (Bellis 2020). The standardization of products and work ushered in by the assembly line not only cut the time needed to produce cars but also significantly reduced the costs of production. The selling price of the Model T fell from \$825 to \$260 between 1908 and 1925 (Ford Motor Company 2020), allowing Ford to capture a large portion of the market.

Although Ford is commonly credited with introducing the moving assembly line and mass production in modern times, both processes were in practice several hundred years earlier. The Venetian Arsenal of the 1500s was developed to supply ships for the Crusades. “The shipyard/armory was the nerve center of the Venetian state and the largest industrial complex in the world. It employed production methods of unparalleled efficiency that long predated Henry Ford, including assembly lines and the use of standardized parts; vertical integration; just-in-time delivery; time management; rigorous accounting; strict quality control; and a specialized workforce” (Crowley 2011).

One of the first examples of mass production in the healthcare industry is Shouldice Hospital (Heskett 2003). Much like Ford, who is commonly cited as saying people could have the Model T in any color, “so long as it's black,” Shouldice, founded in 1945 in Toronto, performs just one type of surgery—routine hernia operations—and it continues to thrive with its unique approach (Heskett 2003).

Furthermore, evidence is growing in healthcare that the level of experience in treating specific illnesses and conditions affects the outcome of that care. Higher volumes of cases often result in better outcomes (Halm, Lee, and Chassin 2002). Specifically, the additional practice associated with higher volume results in better outcomes. The idea of “practice makes perfect,” or learning-curve effects, has led organizations such as the Leapfrog Group (made up of organizations that provide healthcare benefits) to list patient volume among its criteria for quality (Halm, Lee, and Chassin 2002). The Agency for

Healthcare Research and Quality (AHRQ) report *Localizing Care to High-Volume Centers* devotes an entire chapter to this issue and its impact on medical practice (Auerbach 2001).

Frederick Taylor

Taylor began his work when mass production and the factory system were in their infancy. He believed that US industry was “wasting” human effort and that, as a result, national efficiency (now called productivity) was significantly lower than it could be. The introduction to *The Principles of Scientific Management* (Taylor 1911) illustrates his intent:

Our larger wastes of human effort, which go on every day through such of our acts as are blundering, ill-directed, or inefficient, and which Mr. [Theodore] Roosevelt refers to as a lack of “national efficiency,” are less visible, less tangible, and are but vaguely appreciated. . . . This paper has been written:

First. To point out, through a series of simple illustrations, the great loss which the whole country is suffering through inefficiency in almost all of our daily acts.

Second. To try to convince the reader that the remedy for this inefficiency lies in systematic management, rather than in searching for some unusual or extraordinary man [referring to the so-called great man theory prevalent at the time].

Third. To prove that the best management is a true science, resting upon clearly defined laws, rules, and principles, as a foundation. And further to show that the fundamental principles of scientific management are applicable to all kinds of human activities, from our simplest individual acts to the work of our great corporations, which call for the most elaborate cooperation. And, briefly, through a series of illustrations, to convince the reader that whenever these principles are correctly applied, results must follow which are truly astounding.

Note that Taylor specifically mentions systems management as opposed to the individual; this is a common theme that we revisit throughout this book. Rather than focusing on individuals as the cause of problems and the source of solutions, emphasis is placed on systems and their optimization.

Taylor believed that much waste was the result of what he called “soldiering,” which today might be thought of as slacking. Further, he believed that the underlying causes of soldiering were as follows (Taylor 1911):

First. The fallacy, which has from time immemorial been almost universal among workmen, that a material increase in the output of each man or each machine in the trade would result in the end in throwing a large number of men out of work.

Second. The defective systems of management which are in common use, and which make it necessary for each workman to soldier, or work slowly, in order that he may protect his own best interests.

Third. The inefficient rule-of-thumb methods, which are still almost universal in all trades, and in practicing which our workmen waste a large part of their effort.

To eliminate soldiering, Taylor proposed instituting incentive schemes. While at Midvale Steel Company, he used time studies to set daily production quotas. Incentives were paid to those workers who reached their daily goals; those who did not reach their goals were paid significantly less. Productivity at Midvale doubled. Not surprisingly, Taylor's ideas produced considerable backlash. The resistance to increasingly popular pay-for-performance programs in healthcare today is analogous to that experienced by Taylor.

Taylor believed that "one best way" existed to perform any task and that careful study and analysis would lead to the discovery of that way. For example, while at Bethlehem Steel Corporation, he studied the shoveling of coal. Using time studies and a careful analysis of how the work was performed, he determined that the optimal amount of coal per shovel load was 21 pounds. Taylor then developed shovels that would hold exactly 21 pounds for each type of coal; workers had previously supplied their own shovels (NetMBA.com 2005). He also determined the ideal work rate and rest periods to ensure that workers could shovel all day without fatigue. As a result of Taylor's improved methods, Bethlehem Steel was able to reduce the number of workers shoveling coal from 500 to 140 (Nelson 1980).

Taylor's four principles of scientific management are to

1. develop and standardize work methods on the basis of scientific study, and use these to replace individual rule-of-thumb methods;
2. select, train, and develop workers rather than allowing them to choose their own tasks and train themselves;
3. develop a spirit of cooperation between management and workers to ensure that the scientifically developed work methods are both sustainable and implemented on a continuing basis; and
4. divide work between management and workers so that each has an equal share, where management plans the work and workers perform the work.

Although some would be problematic today—particularly the notion that workers are "machinelike" and motivated solely by money—many of Taylor's ideas can be seen in the foundations of newer initiatives such as Six Sigma and Lean, two important quality improvement approaches discussed in depth later in the book.

Frank and Lillian Gilbreth

The Gilbreths were contemporaries of Frederick Taylor. Frank, who worked in the construction industry, noticed that no two bricklayers performed their

tasks the same way. He believed that bricklaying could be standardized and the one best way determined. He studied the work of bricklaying and analyzed the workers' motions, finding much unnecessary stooping, walking, and reaching. He eliminated these motions by developing an adjustable scaffold designed to hold both bricks and mortar (Taylor 1911). As a result of this and other improvements, Frank Gilbreth reduced the number of motions in bricklaying from 18 to 5 (International Work Simplification Institute 1968) and raised output from 1,000 to 2,700 bricks a day (Perkins 1997). He applied what he had learned from his bricklaying experiments to other industries and types of work.

In his study of surgical operations, Frank Gilbreth found that doctors spent more time searching for instruments than performing the surgery. He developed a technique still seen in operating rooms today: When the doctor needs an instrument, he extends his hand, palm up, and asks for the instrument, which is then placed in his hand. This technique eliminates searching for the instrument and allows the doctor to stay focused on the surgical area, thus reducing surgical time (Perkins 1997).

Frank and Lillian Gilbreth may be more familiarly known as the parents in the book *Cheaper by the Dozen* (Gilbreth and Carey 1948) (which was made into a movie by the same title in 1950 and remade in 2003). The Gilbreths incorporated many of their time-saving ideas in their family as well. For example, they bought just one type of sock for all 12 of their children, thus eliminating time-consuming sorting.

Scientific Management Today

Scientific management fell out of favor during the Depression, partly because of the sense that it dehumanized employees, but mainly because of a general belief in society that productivity improvements resulted in downsizing and increased unemployment. Not until World War II did scientific management, renamed *operations research*, see a resurgence of interest.

In healthcare today, standardized methods and procedures are used to reduce costs and increase the quality of outcomes. Specialized equipment has been developed to speed procedures and reduce labor costs. In a sense, we are still searching for the one best way. However, we must heed the lessons of the past. If the tools of operations management are perceived to be dehumanizing or to result in downsizing by healthcare organizations, their implementation will meet significant resistance.

Project Management

The discipline of project management began with the development of the Gantt chart in the early twentieth century. Henry Gantt worked closely with Frederick Taylor at Midvale Steel and in Navy ship construction during

World War I. From this work, he developed bar graphs to illustrate the duration of project tasks and display scheduled and actual progress. These Gantt charts were used to help manage large projects, including construction of the Hoover Dam, and proved to be such a powerful tool that they are commonly used today.

Although Gantt charts were originally adopted to track large projects, they are not ideal for very large, complicated projects because they do not explicitly show precedence relationships—that is, what tasks need to be completed before other tasks can start. In the 1950s, two mathematic project scheduling techniques were developed: the **program evaluation and review technique (PERT)** and the **critical path method (CPM)**. Both techniques begin by developing a project network showing the precedence relationships among tasks and task duration.

PERT was developed by the US Navy to address the desire to accelerate the Polaris missile program. This “need for speed” was precipitated by the Soviet launch of Sputnik, the first space satellite. PERT uses a probability distribution (the beta distribution), rather than a point estimate, for the duration of each project task. The probability of completing the entire project in a given amount of time can then be determined. This technique is most useful for estimating project completion time when task times are uncertain and for evaluating risks to project completion prior to the start of a project.

The CPM technique was developed at the same time as PERT by the DuPont and Remington Rand corporations to manage plant maintenance projects. CPM uses the project network and point estimates of task duration times to determine the critical path through the network, or the sequence of activities that will take the longest to complete. If any one of the activities on the critical path is delayed, the entire project is delayed. This technique is most useful when task times can be estimated with certainty and is typically used in project management and control.

Although both of these techniques are powerful analytical tools for planning, implementing, controlling, and evaluating a project plan, performing the required calculations by hand is tedious, and use of the techniques was not initially widespread. With the advent of commercially available project management software for personal computers in the late 1970s, use of PERT and CPM increased considerably. Today, numerous project management software packages are commercially available. Microsoft Project, for instance, can perform network analysis on the basis of either PERT or CPM; the default is CPM, making it the more commonly used technique.

Projects are an integral part of many of the process improvement initiatives found in the healthcare industry. Project management and its tools are needed to ensure that projects related to quality, Lean, and supply chain management are completed in the most effective and timely manner possible.

program evaluation and review technique (PERT)

A graphic technique to link and analyze all tasks within a project; the resulting graph helps optimize the project's schedule.

critical path method (CPM)

The critical path is the longest course through a graph of linked tasks in a project. The critical path method is used to reduce the total time of a project by decreasing the duration of tasks on the critical path.

Agile project management has emerged as an option for projects where the expected outcome is unclear. Various versions of this tool are now used, primarily in information technology applications. As of 2018, about 44 percent of projects use the predictive approaches (traditional waterfall project management), 30 percent use Agile approaches, and 23 percent use hybrid approaches (Project Management Institute 2018).

Introduction to Quality

Any discussion of quality in industry—including healthcare—should begin with those recognized as originators in quality improvement methodology. Here we introduce the individuals credited with developing specific quality approaches; later in the section, we discuss some prevailing quality improvement processes. This introductory discussion establishes the background for the in-depth treatment of the concepts throughout the book.

statistical process control (SPC)

A scientific approach to controlling the performance of a process by measuring the process outputs and then using statistical tools to determine whether this process is meeting expected performance.

plan-do-check-act (PDCA)

A core process improvement tool with four elements: Plan a change to a process, enact the change, check to make sure it is working as expected, and act to make sure the change is sustainable. PDCA functions as a continuous cycle and, as such, is sometimes referred to as the *Deming wheel*.

Walter Shewhart

If W. Edwards Deming and Joseph Juran (profiled in later subsections) are considered the fathers of the quality movement, Walter Shewhart may be seen as its grandfather. Both Deming and Juran studied under Shewhart, and much of their work was influenced by his ideas.

Shewhart believed that managers need certain information to enable them to make scientific, efficient, and economical decisions. He developed **statistical process control (SPC)** charts to supply that information (Shewhart 1931). He also believed that management and production practices need to be continuously evaluated, and then adopted or rejected on the basis of this evaluation, if an organization hopes to evolve and survive. Deming's cycle of improvement, known as **plan-do-check-act (PDCA)** (sometimes rendered as plan-do-study-act), was adapted from Shewhart's work (Shewhart and Deming 1939).

W. Edwards Deming

Deming was an employee of the US government in the 1930s and 1940s, working with statistical sampling techniques. He became a supporter and student of Shewhart, believing Shewhart's techniques could be useful in nonmanufacturing environments. Deming applied SPC methods to his work at the National Bureau of the Census to improve clerical operations in preparation for the 1940 population census. As a result, in some cases productivity improved by a factor of six (Kansal and Rao 2006).

Deming taught seminars to bring his and Shewhart's work to US and Canadian organizations, where major reductions in scrap and rework resulted. However, after World War II, Deming's ideas lost popularity in the United

States, mainly because demand for all products was so great that quality became unimportant; any product, regardless of how well it was made, was snapped up by hungry consumers.

After the war, Deming traveled to Japan as an adviser for that country's census. While he was there, the Union of Japanese Scientists and Engineers invited him to lecture on quality control techniques, and Deming brought his message to Japanese executives: Improving quality reduces expenses while increasing productivity and market share. During the 1950s and 1960s, Deming's ideas were widely known and implemented in Japan, but not in the United States.

The energy crisis of the 1970s was the turning point. In part as a result of an oil embargo, the small, well-built Japanese automobiles increased in popularity, and the US auto industry saw declines in demand, setting the stage for the return of Deming's ideas. The 1980 television documentary *If Japan Can . . . Why Can't We?*, investigating the increasing competition that numerous US industries faced from Japan, made Deming and his quality ideas known to a broad audience. Much like the Institute of Medicine report *To Err Is Human* (1999) increased awareness of the need for quality in healthcare, this documentary drove US industry's attention to the need for quality in manufacturing.

Deming's quality ideas reflected his statistical background, but his experience in their implementation prompted him to expand his approach. He instructed managers in the two types of variation—*special cause*, resulting from a change in the system that can be identified or assigned and the problem fixed, and *common cause*, deriving from the natural differences in the system that cannot be eliminated without changing the system. Although identifying the common causes of variation is possible, these causes cannot be fixed without the authority and ability to improve the system, for which management is typically responsible.

Moving far beyond SPC, Deming's quality methods include a systematic approach to problem solving and continuous process improvement with his PDCA cycle. He also believed that management is ultimately responsible for quality and must actively support and encourage quality "transformations" in organizations. In the preface to *Out of the Crisis*, Deming (1986) writes:

Drastic changes are required. The first step in the transformation is to learn how to change. . . . Long term commitment to new learning and new philosophy is required of any management that seeks transformation. The timid and the faint-hearted, and people that expect quick results are doomed to disappointment. Whilst the introduction of statistical problem solving and quality techniques and computerization and robotization have a part to play, this is not the solution: Solving problems, big problems and little problems, will not halt the decline of American industry, nor will expansion in use of computers, gadgets, and robotic machinery.

Benefits from massive expansion of new machinery also constitute a vain hope. Massive immediate expansion in the teaching of statistical methods to production workers is not the answer either, nor wholesale flashes of quality control circles. All these activities make their contribution, but they only prolong the life of the patient, they cannot halt the decline. Only transformation of management and of Government's relations with industry can halt the decline.

Out of the Crisis contains Deming's famous 14 points for management. Although not as well known, he also included an adaptation of the 14 points for medical services (exhibit 2.4), which he attributed to Drs. Paul B. Batalden and Loren Vorlicky of the Health Services Research Center in Minneapolis (Deming 1986).

EXHIBIT 2.4

Deming's Adaptation of the 14 Points for Medical Service

1. Establish constancy of purpose toward service.
 - a. Define in operational terms what you mean by "service to patients."
 - b. Specify standards of service for a year hence and for five years hence.
 - c. Define the patients whom you are seeking to serve.
 - d. Constancy of purpose brings innovation.
 - e. Innovate for better service.
 - f. Put resources into maintenance and new aids to production.
 - g. Decide whom the administrators are responsible to and the means by which they will be held responsible.
 - h. Translate this constancy of purpose to service to patients and the community.
 - i. The board of directors must hold onto the purpose.
2. Adopt the new philosophy. We are in a new economic age. We can no longer live with commonly accepted levels of mistakes, materials not suited to the job, people on the job who do not know what the job is and are afraid to ask, failure of management to understand their job, antiquated methods of training on the job, and inadequate and ineffective supervision. The board must put resources into this new philosophy, with commitment to in-service training.
3.
 - a. Require statistical evidence of quality of incoming materials, such as pharmaceuticals. Inspection is not the answer. Inspection is too late and is unreliable. Inspection does not produce quality. The quality is already built in and paid for. Require corrective action, where needed, for all tasks that are performed in the hospital.
 - b. Institute a rigid program of feedback from patients in regard to their satisfaction with services.
 - c. Look for evidence of rework or defects and the cost that may accrue.
4. Deal with vendors that can furnish statistical evidence of control. We must take a clear stand that price of services has no meaning without

(continued)

adequate measure of quality. Without such a stand for rigorous measures of quality, business drifts to the lowest bidder, low quality and high cost being the inevitable result.

Requirement of suitable measures of quality will, in all likelihood, require us to reduce the number of vendors. We must work with vendors so that we understand the procedures that they use to achieve reduced numbers of defects.

5. Improve constantly and forever the system of production and service.
6. Restructure training.
 - a. Develop the concept of tutors.
 - b. Develop increased in-service education.
 - c. Teach employees methods of statistical control on the job.
 - d. Provide operational definitions of all jobs.
 - e. Provide training until the learner's work reaches the state of statistical control.
7. Improve supervision. Supervision is the responsibility of the management.
 - a. Supervisors need time to help people on the job.
 - b. Supervisors need to find ways to translate the constancy of purpose to the individual employee.
 - c. Supervisors must be trained in simple statistical methods with the aim to detect and eliminate special causes of mistakes and rework.
 - d. Focus supervisory time on people who are out of statistical control and not those who are low performers. If the members of a group are in fact in statistical control, there will be some low performers and some high performers.
 - e. Teach supervisors how to use the results of surveys of patients.
8. Drive out fear. We must break down the class distinctions between types of workers within the organization—physicians, nonphysicians, clinical providers versus nonclinical providers, physician to physician. Discontinue gossip. Cease to blame employees for problems of the system. Management should be held responsible for faults of the system. People need to feel secure to make suggestions. Management must follow through on suggestions. People on the job cannot work effectively if they dare not offer suggestions for simplification and improvement of the system.
9. Break down barriers between departments. One way would be to encourage switches of personnel in related departments.
10. Eliminate numerical goals, slogans, and posters imploring people to do better. Instead, display accomplishments of the management in respect to helping employees improve their performance.
11. Eliminate work standards that set quotas. Work standards must produce quality, not mere quantity. It is better to take aim at rework, error, and defects.

(continued)

EXHIBIT 2.4
 Deming's
 Adaptation of
 the 14 Points for
 Medical Service
*(continued from
 previous page)*

EXHIBIT 2.4

Deming's
Adaptation of
the 14 Points for
Medical Service
(continued from
previous page)

12. Institute a massive training program in statistical techniques. Bring statistical techniques down to the level of the individual employee's job, and help him to gather information about the nature of his job in a systematic way.
13. Institute a vigorous program for retraining people in new skills. People must be secure about their jobs in the future and must know that acquiring new skills will facilitate security.
14. Create a structure in top management that will push every day on the previous 13 points. Top management may organize a task force with the authority and obligation to act. This task force will require guidance from an experienced consultant, but the consultant cannot take on obligations that only the management can carry out.

Source: Deming, W. Edwards, *Out of the Crisis*, pp. 199–203, © 2000 Massachusetts Institute of Technology, by permission of The MIT Press.

The New Economics for Industry, Government, Education (Deming 1994) outlines the Deming System of Profound Knowledge. Deming believed that to transform organizations, the individuals in those organizations need to understand the four parts of this system.

1. *Appreciation for a system*: Everything is related to everything else, and those inside the system need to understand the relationships in it.
2. *Knowledge about variation*: This part of the system refers to what can and cannot be done to decrease either of the two types of variation.
3. *Theory of knowledge*: The theory highlights the need for understanding and knowledge rather than information.
4. *Knowledge of psychology*: People are intrinsically motivated and different from one another, and attempts to use generic extrinsic motivators can result in unwanted outcomes.

Deming's 14 points and System of Profound Knowledge still provide a road map for organizational transformation.

Joseph M. Juran

Juran was a contemporary of Deming and a student of Shewhart. He began his career at the Western Electric Hawthorne Works plant, the site of the famous Hawthorne studies (Mayo 1933) related to worker motivation. Western Electric had close ties to Bell Telephone, Shewhart's employer, because the company was the sole supplier of telephone equipment to Bell.

During World War II, Juran served as assistant administrator for the Lend-Lease Administration. Juran's quality improvement techniques made him

instrumental in improving the efficiency of processes by eliminating unnecessary paperwork and ensuring the timely arrival of supplies to US allies.

Juran's Quality Handbook (Juran and Godfrey 1998) was first published in 1951 and remains a standard reference for quality. Juran was among the first quality experts to define quality from the customer perspective as “fitness for use.”

His contributions to quality include the adaptation of the **Pareto principle** to the quality arena (see chapter 9 for its application in quality improvement). According to this principle, 80 percent of defects are caused by 20 percent of problems, and quality improvement should therefore focus on the “vital few” to gain the most benefit. The roots of Six Sigma programs can be seen in Juran's (1986) quality trilogy, shown in exhibit 2.5.

Pareto principle

Developed by Italian economist Vilfredo Pareto in 1906 on the basis of his observation that 80 percent of the wealth in Italy was owned by 20 percent of the population.

EXHIBIT 2.5

Juran's Quality Trilogy

Basic Quality Processes	
Quality Planning	• Identify the customers, both external and internal. • Determine customer needs. • Develop product features that respond to customer. • Establish quality goals that meet the needs of customers and suppliers alike, and do so at a minimum combined cost. • Develop a process that can produce the needed product features. • Prove the process capability—prove that the process can meet quality goals under operating conditions.
Control	• Choose control subjects—what to control. • Choose units of measurement. • Establish measurement. • Establish standards of performance. • Measure actual performance. • Interpret the difference (actual versus standard). • Take action on the difference.
Improvement	• Prove the need for improvement. • Identify specific projects for improvement. • Organize to guide the projects. • Organize for diagnosis—for discovery of causes. • Diagnose to find the causes. • Provide remedies. • Prove that the remedies are effective under operating conditions. • Provide for control to hold the gains.

Source: Juran, J. M. 1986. “The Quality Trilogy.” *Quality Progress* 19 (8): 19–24. Reprinted with permission.

Avedis Donabedian

Avedis Donabedian was born in 1919 in Beirut, Lebanon, and received a medical degree from the American University of Beirut. In 1955, he earned a master's degree in public health from Harvard University. While a student at Harvard, Donabedian wrote a paper on quality assessment that brought his work to the attention of various experts in the field of public health. He taught for a short period at New York Medical College before becoming a faculty member at the School of Public Health of the University of Michigan, where he stayed for the remainder of his career.

Shortly after Donabedian joined the University of Michigan faculty, the US Public Health Service began a project looking at the entire field of health services research, for which Donabedian was asked to review and evaluate the literature on quality assessment. This work culminated in his famous article, "Evaluating the Quality of Medical Care" (Donabedian 1966), followed by a three-volume book series, titled *Exploration in Quality Assessment and Monitoring* (Donabedian 1980, 1982, 1985). Over the course of his career, Donabedian wrote 16 books and more than 100 articles on quality assessment and improvement in the healthcare sector on such topics as the definition of quality in healthcare, the relationship between outcomes and process, the impact of clinical decisions on quality, the effectiveness of quality programs, and the relationship between quality and cost (Sunol 2000).

Donabedian (1980) defined healthcare quality in terms of efficacy, efficiency, optimality, adaptability, legitimacy, equality, and cost. He was among the first quality researchers to view healthcare as a system composed of structure, process, and outcome, providing a framework for health services research still used today (Donabedian 1966). He also highlighted many of the issues that arise when attempting to measure structures, processes, and outcomes.

Outcomes were viewed by Donabedian in terms of recovery, restoration of function, and survival, but he also included less easily measured outcome areas such as patient satisfaction (Donabedian 1966). He noted that process of care consists of the methods by which care is delivered, including gathering appropriate and necessary information, developing competence in diagnosis and therapy, and providing preventive care. Finally, he established the principle that structure is related to the environment in which care takes place, including facilities and equipment, medical staff qualifications, administrative structure, and programs. Donabedian (1966, 188) believed that quality of care is related not only to each of these elements individually but also to the relationships among them:

Clearly, the relationships between process and outcome, and between structure and both process and outcome, are not fully understood. With regard to this, the requirements of validation are best expressed by the concept . . . of a chain of events

in which each event is an end to the one that comes before it and a necessary condition to the one that follows.

Similar to Deming and Juran, Donabedian advocated the continuous improvement of healthcare quality through a cycle of structure and process changes supported by outcome assessment.

The influence of Donabedian's seminal work in healthcare can still be seen. Pay-for-performance programs (structure) reward providers for delivering care that meets evidence-based goals (assessed in terms of process or outcomes). The 5 Million Lives Campaign, and its predecessor, the 100,000 Lives Campaign (Institute for Healthcare Improvement 2006), are programs (structure) designed to decrease mortality (outcome) through the use of evidence-based practices and procedures (process). Not only are assessments of process, structure, and outcome being developed, implemented, and reported in healthcare, but the quality focus is shifting toward the systematic view of healthcare advocated by Donabedian.

Philosophies of Performance Improvement

TQM and CQI, Leading to Six Sigma

The US Navy is credited with coining the term **total quality management (TQM)** in the 1980s to describe its approach, informed by Japanese models, to quality management and improvement (Hefkin 1993). TQM has come to refer to a management philosophy or program aimed at ensuring quality—defined as customer satisfaction—by focusing on it throughout the organization and for each product or service life cycle. All stakeholders in the organization participate in a continuous improvement cycle.

TQM, referred to in healthcare as **continuous quality improvement (CQI)**, is defined differently by different organizations and individuals, but in general it has come to encompass the theory and ideas of such quality experts as Deming, Juran, Philip B. Crosby, Armand V. Feigenbaum, Kaoru Ishikawa, and Donabedian. Perhaps because TQM implementation and vocabulary vary from one organization to the next, TQM programs have decreased in popularity in the United States and have been replaced with more codified programs such as Six Sigma, Lean, and the Malcolm Baldrige National Quality Award criteria.

Six Sigma and TQM are both based on the teachings of Shewhart, Deming, Juran, and other quality experts. Both methodologies emphasize the importance of top management support and leadership, and they focus on continuous improvement as a means to ensure the long-term viability of an organization. The define-measure-analyze-improve-control cycle of Six Sigma (see chapter 9) has its roots in the PDCA cycle of TQM. Six Sigma and TQM

total quality management (TQM)

A management philosophy or program aimed at ensuring quality—defined as customer satisfaction—by focusing on it throughout the organization and for each product or service life cycle.

continuous quality improvement (CQI)

A comprehensive quality improvement and management system with three key components: planning, control, and improvement.

have been described as both philosophies and methodologies. Six Sigma can also be defined as a metric, or goal, of 3.4 defects per million opportunities, represented by its unit-based form, 6σ ; TQM does not specify a numeric goal to achieve. TQM is not defined as Six Sigma and is not supported by or associated with any certification programs.

The definition of TQM was shaped mainly by academics and is abstract and general, whereas Six Sigma has its base in industry—Motorola and General Electric were early developers—and is specific, providing a clear framework for organizations to follow. Early TQM efforts focused on quality as the primary goal; improved business performance was thought to be a natural outcome of this goal. Quality departments were mainly responsible for TQM throughout the organization. Although Six Sigma sets quality (again, as defined by the customer in terms of satisfaction) as a primary goal and focuses on tangible results, it also takes into account the effects of a Six Sigma initiative on business performance. No longer is the focus on quality for quality's sake; instead, a quality focus is seen as a means to improve organizational performance. Six Sigma training in the use of specific tools and techniques provides common understanding and common vocabulary across organizations. In other words, this method makes quality the goal of the entire organization, not just the quality department.

In essence, Six Sigma took the theory and tools of TQM and codified their implementation, providing a well-defined approach to quality that organizations can quickly and easily adopt.

ISO 9000

ISO 9000

A series of process standards developed by the International Organization for Standardization to give organizations guidelines for developing and maintaining effective quality systems.

The **ISO 9000** series of standards, first published in 1987 by the International Organization for Standardization (ISO), is primarily concerned with quality management, or how the organization ensures that its products and services satisfy the customer's quality requirements and comply with applicable regulations. In 2002, the ISO 9000 standard was renamed ISO 9000:2000, consolidating the ISO 9001, 9002, and 9003 standards into the set.

The standards are specifically concerned with the processes of ensuring quality rather than the products or services themselves. ISO standards give organizations guidelines by which to develop and maintain effective quality systems.

A significant number of US hospitals are now using the ISO 9001 Quality Management Program to achieve Medicare accreditation. This *deeming authority*, whereby the Centers for Medicare & Medicaid Services confer accreditation authority on a third party, was granted to DNV GL (2016) in 2008.

Many organizations require that their vendors be ISO certified. For an organization to be registered as an ISO 9001 supplier, it must demonstrate to an accredited registrar (a third-party organization that is itself certified) its compliance with the requirements specified in the standard(s). Organizations that are not required by their vendors to be certified can still use the standards to develop quality systems without attempting to be certified.

Baldrige Award

Japanese automobiles and electronics gained market share in the United States during the 1970s because their quality was higher and their costs were lower than those manufactured in the United States. In the early 1980s, both US government and industry believed that the only way for the country to stay competitive was to increase industry focus on quality. The **Malcolm Baldrige National Quality Award** was established by Congress in 1987 to recognize US organizations for their achievements in quality. Its aim was to raise awareness about the importance of quality as a competitive priority and help disseminate best practices by providing examples of how to achieve quality and performance excellence.

The award was originally given annually to a maximum of three organizations in each of three categories: manufacturing, service, and small business. In 1999, the categories of education and healthcare were added, and in 2002, the first Baldrige Award in healthcare was bestowed. The healthcare category includes hospitals, health maintenance organizations, long-term care facilities, healthcare practitioner offices, home health agencies, health insurance companies, and medical and dental laboratories.

The program is a cooperative effort of government and the private sector. The evaluations are performed by a board of examiners, which includes experts from industry, academia, government, and the not-for-profit sector. The examiners volunteer their time to review applications, conduct site visits, and provide applicants with feedback on their strengths and opportunities for improvement in seven categories. Additionally, board members give presentations on quality management, performance improvement, and the Baldrige Award.

A main purpose of the award is the dissemination of best practices and strategies. Recipients are asked to participate in conferences, provide basic materials on their organizations' performance strategies and methods to interested parties, and answer inquiries from the media. Baldrige Award recipients have gone beyond these expectations to give thousands of presentations aimed at educating other organizations on the benefits of using the Baldrige framework and disseminating best practices. In fact, many organizations now use the application process as a structure for their comprehensive quality improvement programs.

Just-in-Time, Leading to Lean and Agile

Just-in-time (JIT) is an inventory management strategy aimed at reducing or eliminating inventory. It is one aspect of Lean manufacturing, whose goal is to eliminate waste, of which inventory is one form. *JIT* was the term originally used for Lean production in the United States, where industry leaders noted the success of the Japanese auto manufacturers and attempted to copy it by adopting Japanese practices. As academics and organizations realized that Lean production was more than JIT, inventory management terms such as *big JIT*

Malcolm Baldrige National Quality Award

An annual award established by the US Congress in 1987 to recognize organizations in the United States for their achievements in quality.

just-in-time (JIT)

An inventory management system designed to improve efficiency and reduce waste. Part of Lean manufacturing.

and *little JIT* were employed, and JIT production became synonymous with Lean production. For clarity, the term *JIT* refers to the inventory management strategy in this text.

After World War II, Japanese industry needed to rebuild and grow, and its leaders wanted to copy the assembly line and mass production systems found in the United States. However, the country had limited resources and limited storage space. At Toyota Motor Corporation, Taiichi Ohno and Shigeo Shingo developed what has become known as the **Toyota Production System (TPS)**. They began by realizing that large amounts of capital dollars were tied up in inventory in the mass production system typical at that time.

Ohno and Shingo sought to reduce inventory by various means, most importantly by increasing the rate at which autos were assembled (known as flow rate). Standardization reduced the number of parts in inventory and the number of tools and machines needed. Processes such as single-minute exchange of die allowed for quick changeovers of tooling, increasing the amount of time that could be used for production by reducing setup time. As in-process inventory was reduced, large amounts of capital were freed for other purposes.

Customer lead time (the time a customer spends waiting for his vehicle once it has been ordered) was reduced as the speed of product flow increased throughout the plant. Because inventory provides a buffer for poor quality, reducing inventory forced Toyota to pay close attention to not only its own quality but suppliers' quality as well. To discover the best ways to reduce inventory, management and line workers needed to cooperate, and teams became an integral part of Lean.

When the US auto industry began to be threatened by the increased popularity of Japanese automobiles, management and scholars began to study this Japanese system. However, what they brought back were usually the most visible techniques of the program—JIT, kanbans, quality circles (discussed in more depth later in the book)—rather than the underlying principles of Lean. Not surprisingly, many of the first US firms that attempted to copy this system failed; however, some were successful. *The Machine That Changed the World* (Womack, Jones, and Roos 1990), a study of Japanese, European, and American automobile manufacturing practices, first introduced the term *Lean manufacturing* and brought the theory, principles, and techniques of Lean to a broad audience.

Lean is both a management philosophy and a strategy. Its goal is to eliminate all waste in the system. Although Lean production originated in manufacturing, the goal of eliminating waste is easily applied to the service sector. Many healthcare organizations are using the tools and techniques associated with Lean to improve efficiency and effectiveness.

Sometimes seen as a broader strategy than TQM or Six Sigma, Lean requires an organization to be defined by quality. To operate as a quality organization, it does not necessarily need to be Lean. However, if customers value

Toyota Production System (TPS)

A quality improvement system developed by Toyota Motor Corporation for its automobile manufacturing lines. TPS has broad applicability beyond auto manufacturing and is now commonly known as Lean manufacturing.

speed of delivery and low cost, and quality is defined as customer satisfaction, a quality focus should lead an organization to implement Lean. That said, either a Lean initiative or another type of quality improvement program can result in the same outcome.

Bringing Together Baldrige, Six Sigma, Lean, and ISO 9000

All of these systems or frameworks are designed for performance improvement, and each differs in area of emphasis, tools, and techniques. However, they all emphasize customer focus, process or system analysis, teamwork, and quality, and they all are compatible.

The importance of the organization's culture, and management's ability to shape that culture, cannot be overstated. The successful implementation of any program or deployment of any technique requires a culture that supports those changes. The leading causes of failure of new initiatives are lack of top management support and absence of buy-in on the part of employees.

Management must believe that a particular initiative will make the organization better and must demonstrate its support in that belief, both ideologically and financially, to ensure the success of the initiative. Employee buy-in and support only occur when top management commitment is evident. Communication and training can aid in this process, but only unequivocal management commitment ensures success.

Supply Chain Management

The term *supply chain management* (SCM) was first used in the early 1980s. In 2005, the Council of Supply Chain Management Professionals (2016) agreed on the following definition of SCM:

Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies.

This definition makes apparent that SCM is a broad discipline, encompassing activities outside as well as inside an organization.

SCM has its roots in systems thinking. **Systems thinking** is based on the idea that everything affects everything else. The need for systems thinking comes from the notion that optimizing one part of a system is possible, and even likely, if the whole system is suboptimal. A current example of a suboptimal system in healthcare can be seen in one purchasing avenue for prescription drugs. In

systems thinking

A view of reality that emphasizes the relationships and interactions of each part of the system to all of the other parts.

the United States, the customer can optimize his drug purchases (minimize cost) by purchasing drugs from pharmacies located in foreign countries (e.g., Canada, Mexico). Often, these drugs are manufactured in the United States. Although the customer has minimized costs, the total supply chain has incurred additional costs, as with the extra transportation that takes place shipping drugs to Canada or another foreign country and then back to the United States.

SCM became increasingly important to manufacturing organizations in the late 1990s, driven by the need to decrease costs in response to competitive pressures and enabled by technological advances. As manufacturing became more automated, labor costs as a percentage of total costs decreased, and the percentage of material and supply costs increased; this trend continues today. Consequently, fewer opportunities are available for reducing the cost of goods through decreasing labor and more opportunities are associated with managing the supply chain. Additionally, advances in information technology allow firms to collect and analyze the information needed to be increasingly efficient in managing their supply chains.

Indeed, SCM was significantly enabled by technology, beginning with the inventory management systems of the 1970s—including materials requirements planning—followed by the enterprise resource planning systems of the 1990s. As industry moved to increasingly sophisticated technological systems for managing the flow of information and goods, its ability to collect and respond to information about the entire supply chain expanded and firms could now actively manage their supply chains.

SCM is becoming increasingly important in healthcare as well, with its growing focus on reducing costs and the need to reduce those costs through the development of efficient and effective supply chains.

Big Data and Analytics

Business has always embraced computing technologies as they become available and reliable. For example, in a 2001 *Economist* article, the magazine looks back at the first use of computers in business:

The Lyons Electronic Office (LEO), was built by Lyons, a British catering company. On November 17th 1951, it ran a program to evaluate the costs, prices and margins for that week's output of bread, cakes and pies, and ran the same program each week thereafter. In February 1954 LEO took on the weekly calculation of the company's payroll, prompting an article in these pages [referring to *Economist* (1954)].

Other computers had been used to run one-off calculations for businesses, and many firms used mechanical or electrical calculators. But LEO was the first dedicated business machine to operate on the “stored program” principle, meaning that it could be quickly reconfigured to perform different tasks by loading a new program.

Between 1950 and 1970, business use of computers was essentially confined to databases and computing machines that were physically located in the business enterprise and that only operated on the organization's owned data. In the 1970s, the personal computer was created, which allowed individuals in business to conduct their own analysis using a desktop machine. The year 1991 saw the first public access to the World Wide Web, expediting analysts' access to data from their own companies or wherever they chose. In 1997, Google launched its search engine and the term *big data* began to appear.

Big data is typically characterized by the so-called three Vs (Marr 2015):

- *Volume*. Data sets were becoming huge—in 2008, the world's computers processed 9.57 trillion gigabytes of data.
- *Variety*. Many types of data are now being stored (e.g., text, video, clinical equipment outputs).
- *Velocity*. The data enter computer databases at an increasing rate of speed.

In 2005, Hadoop, an open source data framework developed to process big data, was widely deployed (Bappalige 2014). Hadoop software allowed very large clusters of multiple computers to work as one, thus providing the computing power necessary to analyze immense data sets. In 2014, mobile internet usage (e.g., via tablets and smartphones) surpassed desktop usage, and the connection of many devices (e.g., thermostats, lights, refrigerators, pacemakers) to the internet continues to increase (Marr 2015).

Cloud computing and the emergence of artificial intelligence algorithms has further increased the power of big data and biomedical devices. Both will continue to drive significant innovation in the future.

As these technologies have come online, opportunities for increasingly sophisticated analysis emerged. Many of these new and powerful tools are described throughout the remainder of this book.

Conclusion

Service organizations in general, and healthcare organizations in particular, have lagged in their adoption of process improvement philosophies, techniques, and tools of operations management, but they no longer have this option. Hospitals, health systems, and other healthcare delivery organizations face increasing pressures from consumers, industry, and government to provide their services in an efficient and effective manner, and they must adopt these philosophies to remain competitive.

In healthcare today, organizations such as the Institute for Healthcare Improvement and AHRQ are leading the way in the development and

dissemination of tools, techniques, and programs aimed at improving the quality, safety, efficiency, and effectiveness of the US healthcare system.

Discussion Questions

1. What is the difference between data, information, knowledge, understanding, and wisdom? Give specific examples of each in your own organization.
2. How has operations management changed since its early days as scientific management?
3. What are the major factors leading to increased interest in the use of operations management tools and techniques in the healthcare sector?
4. Why has ISO 9000 certification become important to healthcare organizations?
5. Research those organizations that have won the Baldrige Award in the healthcare category. What factors led to their success in winning the award?
6. What are some of the reasons for the success of Six Sigma?
7. What are some of the reasons for the success of Lean?
8. Compare and contrast ISO 9000, the Baldrige criteria, and Six Sigma.



On the web at
ache.org/books/OpsManagement4

(More information on each of these programs is available on the book's companion website.) Which would you find most appropriate to your organization? Why?

9. How are Lean initiatives similar to total quality management and Six Sigma initiatives? How are they different?
10. Why is supply chain management increasing in importance for healthcare organizations?
11. What are some new opportunities for the use of big data and analytics in healthcare?

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EVIDENCE-BASED MEDICINE AND VALUE PURCHASING

Operations Management in Action

The federally funded Patient-Centered Outcomes Research Institute (PCORI) conducts studies to evaluate the evidence for many common medical diagnostic and treatment approaches. It funds research that offers patients and caregivers the information they need to make important healthcare decisions.

An example of a PCORI study is the very common procedure to manage diabetes: daily home blood sugar testing for type 2 diabetes patients who do not need insulin (PCORI 2020). These individuals need to keep the amount of glucose (sugar) in their blood at a healthy level. Many patients check their blood sugar at home each day. Patients place a drop of blood from their fingertip onto a test strip, then insert the strip into a home glucose meter, which measures the sugar level at that moment. People who use insulin check their blood sugar often so that they know how much insulin to take. But what about type 2 diabetes patients who do not use insulin?

A study by PCORI found that these patients don't benefit from daily self-testing. This study confirmed and expanded earlier research.

OVERVIEW

The science of medicine progressed rapidly through the latter half of the twentieth century, with advances in pharmaceuticals, surgical techniques, and laboratory and imaging technology promoting the rapid subspecialization of medicine itself. This “age of miracles” improved health and lengthened life spans.

In the mid-1960s, the federal government began the Medicare and Medicaid programs. This new source of funding fueled the explosive growth and expansion of the US healthcare delivery system. However, in this vastly expanded care environment, many new tools and clinical approaches that had little scientific merit were initiated alongside those with great promise. As these clinical approaches were used broadly, they became community standards. Meanwhile, many simple yet highly effective tools and techniques either fell out of favor or were not used consistently.

In response to these trends, a number of clinicians began the movement that has become known as evidence-based medicine (EBM). Delivering care using EBM is known as value-based care and is the foundation for many payment systems today. As defined earlier, EBM is the conscientious and judicious use of the best current evidence in making decisions about the care of individual patients. Wide-scale application of EBM was slow until the introduction of the electronic health record, which also facilitated adoption of value payment systems. In almost all cases, the broad application of EBM not only improves clinical outcomes for patients but also reduces systemic costs.

This chapter reviews

- the history, current status, and future of EBM;
- public reporting;
- pay for performance and payment reform; and
- value purchasing, including Medicare's Hospital Value-Based Purchasing program.

(continued)

Study participants who checked their blood sugar each day for a year had the same A1c (a measure of blood sugar) and quality of life as people who didn't test daily. "Even participants who tested daily and received text messages about their results had about the same A1c and quality of life as those who didn't test daily" (PCORI 2020). The application of this evidence-based study will help improve the quality of life for these diabetes patients and reduce healthcare costs.

OVERVIEW (*continued*)

EBM is explored in depth, followed by an examination of how payers use its principles to encourage clinicians to use it.

The operations tools presented in other chapters of this book are introduced in terms of how they are linked to achieving EBM goals. The chapter concludes with an illustration of the chartering of a project team to improve implementation of EBM at Vincent Valley Hospital and Health System (VVH).

Evidence-Based Medicine

The expansion of clinical knowledge has three major phases. First, basic research is undertaken in the lab and with animal models. Second, carefully controlled clinical trials are conducted to demonstrate the efficacy of a diagnostic or treatment methodology that emerges from the preliminary research. Third, the successful or promising clinical trial results are translated to clinical practice. The implementation of successful project management (chapter 6) is key to the translation of clinical knowledge into the ongoing operations of a healthcare delivery system.

Clinical guidelines are now well accepted in practice. They are maintained by a variety of healthcare organizations (e.g., the National Institutes of Health) and by professional societies. For example, this is a guideline from the American Academy of Family Practice (2020):

Management of Acute Pain from Non-Low Back, Musculoskeletal Injuries in Adults Key Recommendations

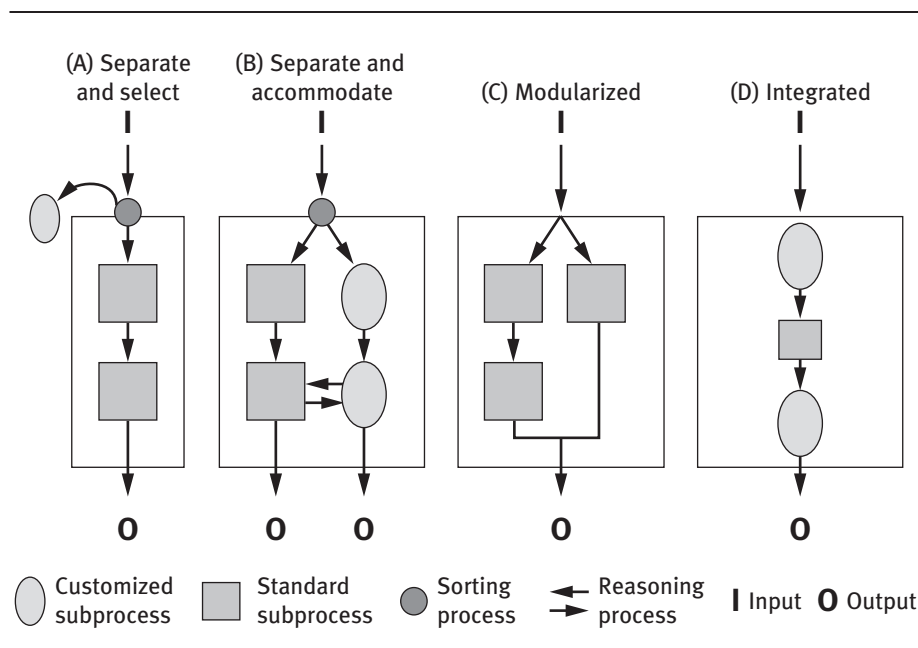
- Topical NSAIDs, with or without menthol gel, should be used as first line therapy for adults with acute pain from non-low back, musculoskeletal injuries.
- Oral NSAIDs and acetaminophen may be considered as options for pharmacologic treatment for adults with acute pain from non-low back, musculoskeletal injuries. Non-pharmacologic options for patients include specific acupressure or transcutaneous electrical nerve stimulation (TENS).

- Opioids, including tramadol, should not be used as first line treatments for adults with acute pain from non-low back musculoskeletal injuries. Severity of the injury and patient intolerance of other treatments, and potential harms should be considered before initiating treatment with opioids.

Standard and Custom Patient Care

One historical criticism of EBM is that all patients are unique and EBM is “cookbook” medicine that only applies to a few patients. EBM proponents counter this argument with simple examples of well-accepted and effective clinical practices that are inconsistently followed. A more productive view of the mix of art and science in medicine is provided by Bohmer (2005), who suggests that all healthcare is a blend of custom and standard care. Exhibit 3.1 shows the four currently used models that blend these two approaches.

Model A (separate and select) provides an initial sorting by patients themselves. Those with standard problems are treated with standard care using EBM guidelines. Examples of this type of system are specialty hospitals for laser eye surgery and walk-in clinics operating in pharmacies and retail outlets. Patients who do not fit the provider’s homogeneous clinical conditions are referred to other providers who can deliver customized care (Bohmer 2005).



Source: Bohmer (2005). Used with permission.

Model B (separate and accommodate) combines the two methods inside one provider organization. Duke University Health System, for example, has developed standard protocols for its cardiac patients. Patients are initially sorted, and those who can be treated with the standard protocols are cared for by nurse practitioners using a standard care model. Cardiologists care for the remainder using custom care. However, on every fourth visit to the nurse practitioner, the cardiologist and nurse practitioner review the patient's case together to ensure that standard care is still the best treatment approach (Bohmer 2005).

Model C (modularized) is used when the clinician moves from the role of care provider to that of architect of care design for the patient. In this case, a number of standard processes are assembled to treat the patient. The Andrews Air Force Base clinic uses this system to treat hypertension patients. "After an initial evaluation, treatment may include weight control, diet modification, drug therapy, stress control, and ongoing surveillance. Each component may be provided by a separate professional and sometimes a separate organization. What makes the care uniquely suited to each patient is the combination of components" (Bohmer 2005, 326).

Model D (integrated) combines standard care and custom care in a single organization. In contrast to Model B, each patient receives a mix of both custom and standard care as determined by her condition. Intermountain Healthcare (IHC) employs this model through the use of 62 standard care processes available as protocols in its electronic health record (EHR). These processes cover "care of over 90 percent of patients admitted in IHC hospitals" (Bohmer 2005, 326). Clinicians are encouraged to override elements in these protocols when it is in the best interest of the patient. All of these overrides are collected and analyzed, and changes are made to the protocol, which is an effective method to continuously improve clinical care.

All of the tools and techniques of operations improvement included in the remainder of this book can be used to make standard care processes operate effectively and efficiently.

prevention quality indicator (PQI)

A set of measures that can be used with hospital discharge data to identify patients whose hospitalizations or complications might have been avoided with the use of evidence-based ambulatory care.

EBM and Cost Reduction

EBM has the potential to not only improve clinical outcomes but also decrease total cost in the US healthcare system. Potentially preventable hospitalizations, which might be avoided with high-quality outpatient treatment and disease management, provide just one significant opportunity for financial savings.

The Agency for Healthcare Research and Quality (AHRQ 2020) developed a set of **prevention quality indicators (PQIs)** to assist providers in reducing the number of potentially preventable hospitalizations for chronic and acute conditions throughout the United States. A patient who

is admitted to a hospital and has a PQI code is an individual whose hospitalization or other severe complication is potentially preventable when good, evidence-based outpatient care is delivered. In addition, PQIs can serve the following purposes:

- Can be used to identify potential healthcare quality problem areas that might need further investigation, as well as for comparative public reporting, trending, and pay-for-performance initiatives.
- Can provide a check on primary care access or outpatient services in a community by using patient data found in a typical hospital discharge abstract or data set.
- Can help public health agencies, state data organizations, healthcare systems, and others interested in improving healthcare quality in their communities (AHRQ 2020).

Chronic Disease Management

One of the most expensive aspects of all healthcare systems is the care of patients with chronic disease (e.g., diabetes, chronic obstructive pulmonary disease, congestive heart failure). Much of the variation in the outcomes of this care can be attributed to providers' and patients' lack of adherence to EBM.

Fortunately, many investigators now look beyond determining which clinical interventions provide good results (e.g., the use of statins) to identifying those systems of care that produce superior results. (Chapter 9 provides more details and examples of the use of business process improvements to achieve high-quality care.)

The Chronic Care Model

Dr. Edward Wagner of the MacColl Center for Health Care Innovation, a leader in the improvement of chronic care, has developed one of the most widely accepted models for chronic disease management (Wagner et al. 2001). The first important element of Wagner's chronic care model (CCM) is population-based outreach, which ensures that all patients in need of chronic disease management receive it. Next, treatment plans are created that are sensitive to each patient's preferences. The most current evidence-based medicine is employed, and this process is aided by clinical information systems with built-in decision support. The patient is encouraged to change risky behaviors and improve the management of his health.

The clinical visit itself differs in the Wagner model to allow more time for interaction between the physician and patients with complicated clinical issues. Visits for routine or specialized matters are handled by other healthcare professionals (e.g., nurses, pharmacists, dietitians, lay health workers). Close

follow-up, supported by clinical information system registries and patient reminders, is also characteristic of effective chronic disease management (Wagner et al. 2001).

The CCM has now been widely deployed and updated. The Institute for Healthcare Improvement (IHI) has developed a model for instituting changes in the approach to chronic illnesses, healthcare settings, and target populations. These changes include (IHI 2021):

Self-Management Support

- Train providers and other key staff on how to help patients with self-management goals
- Use self-management tools that are based on evidence of effectiveness
- Use group visits to support self-management
- Set and document self-management goals collaboratively with patients
- Follow up and monitor self-management goals

Delivery System Design

- Use planned interactions to support evidence-based care
- Ensure regular follow-up by the care team
- Define roles and distribute tasks among team members

Decision Support

- Embed evidence-based guidelines into daily clinical practice
- Integrate specialist expertise and primary care
- Use proven provider education methods
- Share evidence-based guidelines and information with patients to encourage their participation

Health Information Systems

- Share information with patients and providers to coordinate care
- Provide timely reminders for providers and patients

Organizational Leadership

- Senior leaders visit the clinical teams and speak about improvement efforts in all-staff meetings
- Participate in writing the aims and goals of the initiative and provide guidance for the clinical team
- Make monthly updates to the community
- Present local morbidity/mortality data to the Board of Directors to make a compelling case for the need to change current practice

Community Support

- Encourage patients to participate in effective community programs
- Form partnerships with community organizations to support and develop interventions that fill gaps in needed services

EBM and Comparative Effectiveness Research

The source of evidence for EBM has long been medical research that is published in respected and refereed journals. However, these studies usually are initiated by a single investigator's interest, and thus the efficacy of many common clinical approaches has never been adequately tested. The medical research community has held historical and understandable biases toward developing technologies that are designed to address intractable diseases and mysterious diagnostic challenges. Many aspects of routine healthcare have therefore never been sufficiently evaluated.

To address this problem, the Affordable Care Act (ACA) and the American Recovery and Reinvestment Act contained significant policy direction for the establishment and funding of a nonprofit corporation, the Patient-Centered Outcomes Research Institute (PCORI). ACA Section 6301 states that the mission of PCORI is

to assist patients, clinicians, purchasers, and policy-makers in making informed health decisions by advancing the quality and relevance of evidence concerning the manner in which diseases, disorders, and other health conditions can effectively and appropriately be prevented, diagnosed, treated, monitored, and managed through research and evidence synthesis that considers variations in patient subpopulations, and the dissemination of research findings with respect to the relative health outcomes, clinical effectiveness, and appropriateness of the medical treatments, and services.

PCORI's focus is on the application of EBM to specific healthcare technologies and treatments to ascertain which, among alternative therapies for a given medical condition, produce the best clinical outcomes. This specific focus is known as comparative effectiveness research. PCORI's (2017) Clinical Effectiveness and Decision Science program has three priorities:

1. Accelerating patient-centered outcomes research and methodological research
2. Assessment of prevention, diagnosis, and treatment options
3. Communication and dissemination research

Tools to Expand the Use of Evidence-Based Medicine

Organizations that are outside the healthcare delivery system itself, such as payers and government, have used the increased acceptance of EBM as the basis for new programs designed to encourage its implementation. These programs, referred to as **value purchasing**, feature public reporting of clinical results and pay-for-performance elements to help third-party payers determine the value delivered by healthcare providers.

value purchasing

A system using payment as a means to reward providers who publicly report results and achieve high levels of clinical care. Also known as *value-based purchasing*.

public reporting

A statement of healthcare quality made by hospitals, long-term care facilities, and clinics. May also include patient satisfaction and provider charges.

risk adjustment

Raising or lowering fees paid to providers on the basis of factors that may increase medical costs, such as age, sex, or illness.

Public Reporting

Although strongly resisted by clinicians for many years, **public reporting** has come of age. The Centers for Medicare & Medicaid Services (CMS) now report the performance of hospitals, long-term care facilities, home health services, and dialysis facilities online at Medicare Care Compare (www.medicare.gov/care-compare/). Many private health insurance plans also report performance and the prices charged by providers in their networks to assist their plan members, particularly those with consumer-directed health insurance products, in choosing how and from whom they receive treatment or preventive care.

As with any growing field, a number of issues surround public reporting. The first and most prominent is **risk adjustment**. Most providers feel their patients are “sicker” than average and that contemporary risk adjustment systems do not adequately account for this factor in reimbursement. Patient compliance is another challenging aspect of public reporting. If a doctor follows EBM guidelines for diagnosis and treatment but the patient does not take her medication, for example, the public reporting mechanism may trigger an unwarranted poor grade.

Pay for Performance and Value Purchasing

Another logical tool to expand the use of EBM is the financing system. Many buyers of healthcare are installing pay-for-performance systems to encourage providers to deliver EBM care.

Pay-for-Performance Methods

In general, pay-for-performance systems add payments to the amount that would otherwise be reimbursed to a provider. To obtain these additional payments, the provider must demonstrate that he is delivering care that meets clinical EBM goals. These clinical measures can be either process or outcome measures.

Although many providers prefer to be measured on outcomes, this approach is difficult to use, as some outcomes need to be measured over many

years. In addition, some providers have a small number of patients in a particular clinical group, so outcome results can vary dramatically. Therefore, process measures backed by extensive EBM literature are used to assess performance in the treatment of many conditions. For example, a patient with diabetes whose blood pressure is maintained in a normal range tends to experience fewer complications than one whose blood pressure is uncontrolled. Blood pressure can be measured and reported at every visit, whereas complications occur infrequently.

In a study sponsored by the National Quality Forum, Schneider, Hussey, and Schnyer (2011) surveyed the breadth of payment reform methods and found nearly 100 implemented and proposed payment reform programs. They then classified these methods into 11 payment models. Many of these models are included in the ACA, and the goals for these methodologies are illustrated in exhibit 3.2. Exhibit 3.3 lists and describes each model, and chapter 14 examines how organizations can apply the operations management tools contained throughout this book to succeed financially with any of these payment models.

Value-Based Purchasing¹

The ACA called for establishment of a value purchasing program on the basis of much of the research, practical experience, and analysis in both public reporting and pay for performance described in the previous section. Value purchasing applications, as alternatives to the traditional fee-for-service (FFS) reimbursement scheme, are accelerating, and the majority of financing systems for health services in the United States likely will move completely from FFS to value purchasing.

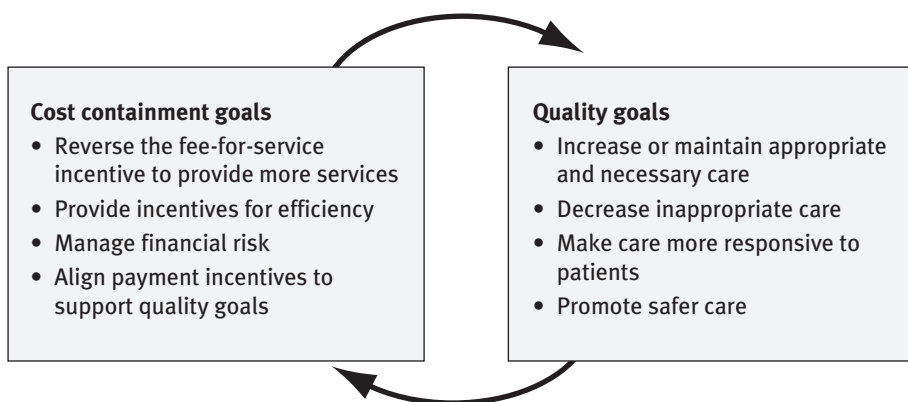


EXHIBIT 3.2
General
Payment Reform
Model

Source: Schneider, Hussey, and Schnyer (2011).

EXHIBIT 3.3
Payment Reform
Model Details

Model	Description
1. Global payment	A single per-member per-month payment is made for services delivered to a patient, with payment adjustments based on measured performance and patient risk.
2. ACO shared savings program	Groups of providers (known as accountable care organizations [ACOs]) that voluntarily assume responsibility for the care of a population of patients share payer savings if they meet quality and cost performance benchmarks.
3. Medical home payments	A physician practice or other provider is eligible to receive additional payment if medical home criteria for primary care are met. Payment may include calculations based on quality and cost performance using a value purchasing mechanism.
4. Bundled payment	A single bundled payment, which may include multiple providers in multiple care settings, is made for services delivered during an episode of care related to a medical condition or procedure.
5. Payment for coordination	Payments are made to providers furnishing care coordination services that integrate care between providers.
6. Hospital value purchasing	Hospitals receive differential payments for meeting or missing performance benchmarks. These benchmarks may be clinical, operational, or financial, or a combination of measures.
7. Payment adjustment for readmissions	Payments to hospitals are adjusted based on the rate of potentially avoidable readmissions.
8. Payment adjustment for hospital-acquired conditions	Hospitals with high rates of hospital-acquired conditions are subject to a payment penalty, or treatment of hospital-acquired conditions or serious reportable events is not reimbursed.
9. Physician value purchasing	Physicians receive differential payments for meeting or missing performance benchmarks.

Source: Schneider, Hussey, and Schnyer (2011), as revised and updated by authors.

Moving from FFS to Value

A study funded by the Commonwealth Fund of New York (Blanchfield et al. 2020) examined the transition of many healthcare organizations from volume (FFS) to value-based payments (accountable care organizations or

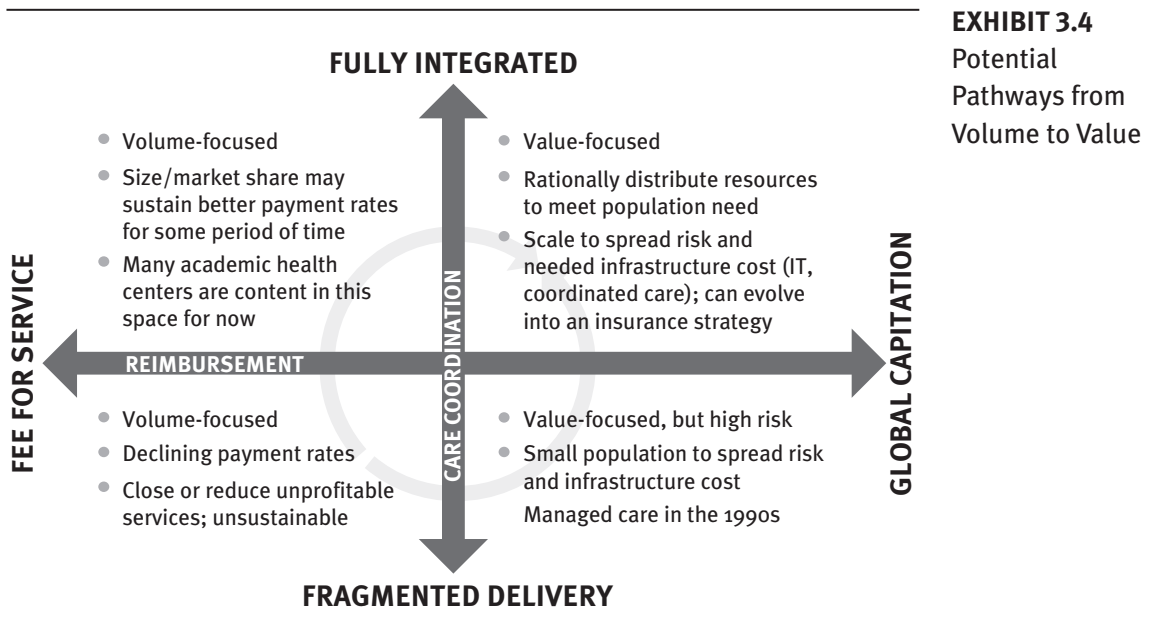
capitation). This transition is difficult for most organizations as their financial health has been built on the foundations of creating optimal revenue from the volume of services delivered. A rapid movement to a value-based system will create poor financial results during the transition period unless it is carefully executed.

The study found that successful organizations shared these traits:

- An organizational history of success with financial risk
- A willingness to move to models that have value (clinical outcomes, patient satisfaction) as the primary goal of the organization
- Regional connections to other organizations that were also successful
- Synergies with other organizational activities (e.g., the ability to alleviate strained clinical capacity in some areas and to attract new community physicians)
- Significant investments in EHRs and data warehouses

They also identified potential pathways for organizations to move from volume to value (exhibit 3.4).

Most organizations start in the lower left corner and move to the upper right over time. Although organizations can remain on the left-hand side of



Source: Blanchfield et al. (2020).

the diagram, their financial results and market share likely will diminish over time because of the increasing use of value payment systems.

Medicare Value Purchasing

Medicare has been a leader in value purchasing with its Hospital Value-Based Purchasing (VBP) Program. According to CMS (2021):

The Hospital VBP Program encourages hospitals to improve the quality, efficiency, patient experience and safety of care that Medicare beneficiaries receive during acute care inpatient stays by:

- Eliminating or reducing adverse events (healthcare errors resulting in patient harm).
- Adopting evidence-based care standards and protocols in order to obtain the best outcomes for Medicare patients.
- Incentivizing hospitals to improve patient experience.
- Increasing the transparency of care quality for consumers, clinicians, and others.
- Recognizing hospitals that provide high-quality care at a lower cost to Medicare.

It rewards hospitals based on quality provided to Medicare patients through the following methods:

- Withholds participating hospitals' Medicare payments by a percentage specified by law (2%).
- Uses the estimated total amount of those reductions to fund value-based incentive payments to hospitals based on their performance in the program.
- Applies the net result of the reduction and the incentive as a claim-by-claim adjustment factor to the base operating Medicare severity diagnosis-related group (MS-DRG) payment amount for Medicare fee-for-service claims in the fiscal year associated with the performance period (CMS 2021).

And the measures used to score each hospital's quality performance include:

- Mortality and complications
- Healthcare-associated infections
- Patient safety
- Patient experience
- Efficiency and cost reduction (CMS 2021)

CMS Oncology Care Model

The CMS Innovation Center (2021) is also pursuing value-based models for specific disease groups:

The Oncology Care Model . . . aims to provide higher quality, more highly coordinated oncology care at the same or lower cost to Medicare. Under the Oncology Care Model (OCM), physician practices have entered into payment arrangements that include financial and performance accountability for episodes of care surrounding chemotherapy administration to cancer patients. The Centers for Medicare and Medicaid Services (CMS) is also partnering with commercial payers in the model. The practices participating in OCM have committed to providing enhanced services to Medicare beneficiaries such as care coordination, navigation, and national treatment guidelines for care. . . .

OCM incorporates a two-part payment system for participating practices, creating incentives to improve the quality of care and furnish enhanced services for beneficiaries who undergo chemotherapy treatment for a cancer diagnosis. The two forms of payment include a per-beneficiary Monthly Enhanced Oncology Services (MEOS) payment for the duration of the episode and the potential for a performance-based payment for episodes of chemotherapy care. The \$160 MEOS payment assists participating practices in effectively managing and coordinating care for oncology patients during episodes of care, while the potential for performance-based payment incentivizes practices to lower the total cost of care and improve care for beneficiaries during treatment episodes.

Implications for Operations Management

One clear advantage of FFS was its clean lines of accountability for services—if you provided the service, you got paid. Value purchasing breaks this link as, in many cases, the service provider does not get paid directly. Hence, improved operational structures need to be built to accommodate these payment systems.

Strategy Execution

The value purchasing environment leads to growth in the number of quality improvement projects required to respond to the new incentive opportunities. A useful management strategy is the blended balanced scorecard–strategy mapping approach developed by Kaplan and Norton (2001). This method converts general strategies (e.g., reduce readmission rates) into specific projects (e.g., acquire predictive analytics capability), which are then connected in a strategy map. Each project establishes metrics that then can be displayed as a scorecard. This disciplined execution method is used by many large organizations both inside and outside healthcare. The balanced scorecard methodology is outlined in detail in chapter 5.

Improved Modeling and Analytics

The new environment requires more sophisticated systems of analysis than in the past. The EHR is a significant advancement in helping an organization understand its care patterns and patient outcome (see chapter 4.)

Although traditional accounting systems were adequate for the FFS environment, much more detailed costing systems are now needed, such as activity-based accounting. Patient behavior models were historically built on groups (e.g., men aged 65 or older) but now must be built with individual predictive modeling capabilities. Modeling and analytics tools can be used to finely align delivery system resources with patient needs. Analytics is addressed in chapter 8, and activity-based accounting is covered in chapter 14.

Clinical Decision Support

One development in the use of guidelines is the spread of clinical decision support systems, which are now becoming a standard part of EHRs. As a clinician accesses a specific patient's medical record, the automated system provides advice on recommended treatments and needed follow-up (see the Operations Management in Action section at the beginning of this chapter).

Clinical Decisions Support for Improved Quality and Cost Reductions

In a survey article on clinical decision support systems (CDSS), Sutton and colleagues (2020) identified a number of areas of healthcare delivery that can be improved with these additions to EHRs:

Studies have shown CDSS can increase adherence to clinical guidelines. This is significant because traditional clinical guidelines and care pathways have been shown to be difficult to implement in practice with low clinician adherence [*sic*]. The assumption that practitioners will read, internalize, and implement new guidelines has not held true. However, the rules implicitly encoded in guidelines can be literally encoded into CDSS. Such CDSS can take a variety of forms, from standardized order sets for a targeted case, alerts to a specific protocol for the patients it pertains to, reminders for testing, etc. Furthermore, CDSS can assist with managing patients on research/treatment protocols, tracking and placing orders, follow-up for referrals, as well as ensuring preventative care.

CDSS can also alert clinicians to reach out to patients who have not followed management plans, or are due for follow-up, and help identify patients eligible for research based on specific criteria. A CDSS designed and implemented at Cleveland Clinic provides a point-of-care alert to physicians when a patient's record matches clinical trial criteria. The alert prompts the user to complete a form which establishes

eligibility and consent-to-contact, forwards the patient's chart to the study coordinator, and prints a clinical trial patient information sheet. . . .

CDSS can be cost-effective for health systems, through clinical interventions, decreasing inpatient length-of-stay, CPOE [computerized provider order entry]-integrated systems suggesting cheaper medication alternatives, or reducing test duplication. A CPOE-rule was implemented in a pediatric cardiovascular intensive care unit . . . that limited the scheduling of blood count, chemistry and coagulation panels to a 24-h interval. This reduced laboratory resource utilization with a projected cost savings of \$717,538 per year, without increasing length of stay . . . or mortality.

CDSS can notify the user of cheaper alternatives to drugs, or conditions that insurance companies will cover. In Germany, many inpatients are switched to drugs on hospital drug formularies. After finding that 1 in 5 substitutions were incorrect, Heidelberg hospital developed a drug-switch algorithm and integrated it into their existing CPOE system. The CDSS could switch 91.6% of 202 medication consultations automatically, with no errors, increasing safety, reducing workload and reducing cost for providers.

In addition to clinical and cost management improvement, CDSS can also assist by improving administrative functions, diagnostic support, and patient-facing decision support (e.g., the ability to connect with data in EHRs) (Sutton et al. 2020).

The Future of Evidence-Based Medicine and Value Purchasing

The current FFS system is not sustainable, as it creates wastes in the US health-care system as delineated in chapter 1: failure of care coordination and delivery and the use of low-value care.

The combination of the increasing availability of evidence-based guidelines and their incorporation into value-based payment systems provides hope for a more financially sustainable system of care that also might encourage continued increases in clinical quality and patient engagement. The remainder of this book provides many of the operational tools and techniques that can be used to achieve this end.

Vincent Valley Hospital and Health System and Pay for Performance

The leaders of VVH feel they have a number of opportunities to succeed with the Medicare Hospital VBP program. They begin by creating a project team

to improve the care of patients with pneumonia. The specific measures the team targets for improvement are those delineated in the VBP:

- Pneumonia patients assessed and given pneumococcal vaccination
- Pneumonia patients whose initial emergency department blood culture was performed prior to the administration of the first hospital dose of antibiotics
- Pneumonia patients given smoking cessation advice and counseling
- Pneumonia patients given initial antibiotic(s) within six hours of arrival
- Pneumonia patients given the most appropriate initial antibiotic(s)
- Pneumonia patients assessed and given influenza vaccination

The operations management tools and approaches detailed in this book were used to improve performance for each of these measures, culminating in chapter 15, which describes how VVH accomplishes this goal.

Conclusion

The use of evidence-based medicine to develop systems of care is becoming well accepted by most clinicians. Clinical results are being made transparent and easily accessible to the general public. Payers are implementing systems that reward value, and providers are installing clinical decision support systems to help in their practices. The effective use of EBM identifies high-performance healthcare organizations, and its widespread use is a key to the provision of high-quality, cost-effective care throughout the world.

Discussion Questions

1. In addition to those mentioned in the chapter, what are some examples of a care delivery setting offering a mix of standard and custom care?
2. Access the CMS Hospital Care Compare website and review three local hospitals' quality scores. At which hospital would you choose to receive care, and why? Which hospital would you choose for your parents or your children? Did your answers differ? Why or why not?
3. Review the 11 payment reform methodologies (exhibit 3.3) and rank them on two scales: ability to improve quality and ability to reduce healthcare inflation. Provide a rationale for your ranking.
4. What are three strategies to maximize pay-for-performance revenue?

Note

1. Portions of this section were adapted from McLaughlin (2015) with permission from the American College of Healthcare Executives.

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USE OF TECHNOLOGY IN HEALTHCARE DELIVERY

Operations Management in Action

The move to digitize patient records is a global phenomenon, with countries at different stages of implementation and facing unique challenges. Such initiatives not only face technological barriers but also require a cultural transformation on the part of patients and providers. For example, AORTA, the Netherlands' digital platform for exchanging patient information among providers, was launched in 2011. The platform had to delete a majority of its patient records when patient opt-in was made a prerequisite in 2016 for holding patient records. Despite this setback, more than 90 percent of providers now use AORTA, and its cost and care delivery benefits have been documented (Cornet 2017). Similarly, the rollout of MHR, Australia's electronic health record (EHR) system, has enabled nationwide access to patient records, including prescriptions and medication history. This system layers on top of providers' existing EHR systems and creates summaries from the information housed therein. Although not all providers and patient information are currently compatible with MHR, this system and its demonstrated benefits are set to improve.

With the COVID-19 pandemic accelerating the move toward digitization and e-health, this technology-driven transformation of healthcare will continue in the coming years.

OVERVIEW

Digitization and integration of digital patient records, and caregiver access to these records, has multiple benefits, including reduced costs, improved quality of care, adherence to protocols, and better patient experience. However, setting up an interoperating and secure electronic health record infrastructure is challenging at both the technological and user levels. This chapter discusses the trends toward digitizing medical records and their benefits and challenges. The following major topics are covered:

- Types of information flows
- Health information technology (HIT) solutions
- HIT architecture
- Impact of HIT on healthcare operations
- Adoption and assimilation of HIT
- Challenges with HIT use

Health Information Technology

Health information technology (HIT) collectively refers to software solutions used in the healthcare sector. Used for managing information flows in an organization, HIT significantly influences organizational processes. Reports show HIT adoption and assimilation to be a costly and time-consuming process for hospitals, with

cost estimates for a new EHR system—a type of HIT—exceeding \$600 million for large hospital networks (Barlas 2011). In addition to the start-up costs of HIT adoption, these systems often require training, change management, and adaptation to fit work routines, all of which have direct and indirect costs. The indirect costs result from disruptions and adaptations of existing work routines, which may harm productivity and increase errors. Once appropriately integrated, however, HIT has multiple documented advantages, including fewer errors and improved productivity, that can reduce operating expenses while improving quality of patient care (Chaudhry et al. 2006; Mangalmurti, Murtagh, and Mello 2010; Sharma et al. 2016).

Recognizing the long-term benefits of HITs (especially EHRs) in improving care delivery and reducing costs, the US Congress passed the Health Information Technology for Economic and Clinical Health (HITECH) Act in 2009 to incentivize hospitals' adoption of HITs. This legislation provided \$25.9 billion to hospitals to ease the cost burden of adopting and using HITs. Government policy initiatives and industry trends have accelerated the adoption of technology in the healthcare sector, with EHR-associated expenditures increasing at an annual rate of 5.4 percent and projected to reach \$19.9 billion by 2024 (Jercich 2020). Rising expenditure has accelerated adoption: at acute care hospitals, EHR use rose from about 15 percent of facilities in 2008 to more than 95 percent in 2017, and at physicians' offices from 40 percent to more than 85 percent (<https://dashboard.healthit.gov>). Such increased emphasis on HITs in healthcare settings makes it useful to explore their benefits, challenges in adoption, and impact on existing processes.

Information Flows and Types of HIT

Healthcare settings primarily deal with two different types of information flow—administrative and clinical—and rely on different HITs to manage them. Administrative information flow involves operational data created as a result of a hospital's administrative processes. Examples include data from human resources, billing, procurement, or inventory. Administrative data is primarily organization specific, usually managed by a particular department, and either entirely housed within the organization or shared with a limited number of vendors. These characteristics reduce how much interoperability administrative data requires within and across an organization. Additionally, given that many other sectors feature business processes that generate similar administrative data, software solutions handling this type of data are more mature, with customized versions of the same solution in use across industries.

Clinical information deals with patient medical records, covering their profile, medical history, diagnosis, and treatment. Given that patients may seek

care across multiple hospital departments (e.g., a patient admitted in Cardiology may require lab tests and the care of other entities, such as primary care or other hospitals or specialties), getting a complete picture of the patient imposes high requirements of interoperability on clinical data. Moreover, because of the nature of the care delivery process, clinical data is generated, updated, and accessed by multiple caregivers across organizations, as well as by patients through portals. This creates numerous access and update points for clinical data, which requires higher standards for security and accountability. Further, the Health Insurance Portability and Accountability Act (HIPAA) imposes stringent privacy and security requirements to protect this data, which makes the issue of multiple access points more challenging. Given the healthcare industry's requirements for HIPAA compliance, interoperability, accountability, and adjustments for care delivery workflows, software solutions managing clinical data are more industry specific than for administrative data.

HITs are categorized into administrative and clinical based on the type of information flow they handle. Examples of a hospital's administrative HIT needs include accounting and financial management systems. By contrast, clinical HITs deal with data generated during patient care. Examples include imaging devices such as a computed tomography (CT) machine, and more complex systems like electronic medication administration records (eMARs), which are used for medication tracking and management with the goal of reducing medication errors through increased transparency and accountability. Clinical HITs can be further classified into basic clinical and augmented clinical HITs depending on their primary functionality and users (Sharma et al. 2016). Basic clinical HITs primarily deal with patient data collected via manual entry or generated through diagnostics and testing. The previously mentioned CT machine would be an example of a basic clinical HIT. Another would be an order entry system, which facilitates patient data entry by caregivers from electronic devices within a hospital. These types of HIT are not new to hospital settings and have been used extensively as stand-alone systems for patient data acquisition through diagnostics, testing, and data entry. Further, these systems are primarily used by technicians and caregiving assistants; nurses' and physicians' interactions with them are limited.

Augmented clinical HITs, on the other hand, combine data collected by basic clinical HITs to generate integrated patient records, and they provide advanced functionality built on this integrated data to help physicians and nurses with clinical decision making. They add functions such as data visualization, reporting, decision support, and analytics. Examples of augmented clinical HIT are clinical decision support systems, which make recommendations on care and clinical decisions to physicians using insights from predictive analytics on historical patient data and research, and the aforementioned eMARs. These HITs are more advanced and expensive than basic clinical HITs, and

they are also a relatively new addition to the healthcare environment, which has witnessed increased adoption of systems like EHRs, themselves a type of augmented clinical HIT.

Exhibit 4.1 shows the association among different types of HITs with the corresponding information flows. Administrative HITs manage the flow of administrative data with inputs on clinical episodes of care for billing purposes. Clinical data is housed in a central repository, which is updated by basic clinical HITs and used for higher-order functions like reporting and decision support by augmented clinical HITs. Patient scans are stored in a picture archiving and communication system because of their different storage format.

Impact of HITs

HITs improve workflow efficiency and employee productivity through faster and more effective information processing. Hence, the value of HITs increases as an organization's volume and complexity of information-processing needs increase. Further, research has argued that the benefits of HITs are enhanced with the addition of stand-alone technologies and better integration of HITs into users' work routines (Boyer 1999; Meredith 1987). As a result of these factors, organizations realize disparate benefits from HITs depending on their size, integration of their HIT infrastructure, and assimilation into caregiver work routines. However, on average, research has documented positive benefits of HITs on different aspects of hospital operations, as this section describes.

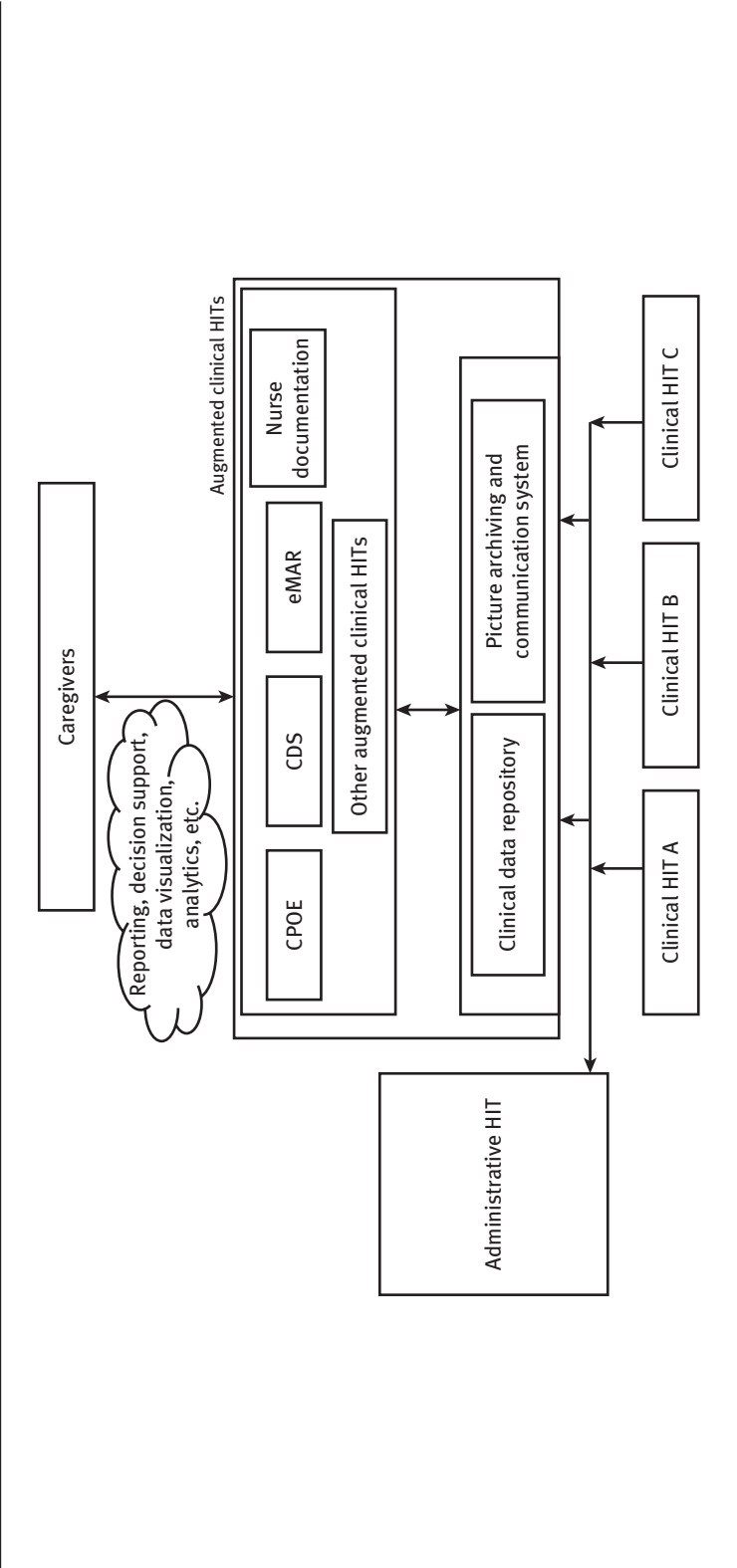
Impact on Process Quality

Process quality is measured as the degree of adherence to predefined standards and protocols. HITs can affect process quality through several mechanisms. First, HITs can enable faster patient-data access, diagnosis, and treatment identification, resulting in better compliance with customized standards applicable to a patient's medical condition (Bates and Gawande 2003). HITs also promote standardization of routines by codifying protocols and process steps directly into HIT systems. At the same time, these systems can use program logic to generate a customized checklist of protocols for patients given their condition. Further, these systems can ensure better compliance to care delivery standards and protocols during the patient's hospital stay through better monitoring of progress and improved accountability, owing to the ability of HIT to track any shortfalls to specific caregivers. These factors suggest a positive association between HITs and process quality.

Impact on Cost

Cost is a measure of expenses associated with adoption and use of HITs. As discussed earlier, adoption of HITs is an expensive endeavor for hospitals; as

EXHIBIT 4.1
HIT System Architecture Demonstrating Clinical and Administrative Information Flows



Note: CDS = clinical decision support; CPOE = computerized physician order entry; eMAR = electronic medication administration record; HIT = health information technology.

mentioned, new EHR systems can cost hundreds of millions of dollars (Barlas 2011). Once adopted, users of HITs need to undergo an adaptation process often requiring training, change management, software upgrades, and workflow modifications. As an example, software patches or upgrades, commonly used to deploy software changes, can cost between 1 percent and 5 percent of the contract value of the software for a minor upgrade, and 10 percent to 49 percent for a major upgrade (Katalus 2012). However, once assimilated, HITs can greatly improve hospital efficiencies through standardizing procedures and policies across various hospital entities, better information flow, increased responsiveness, and reduced rework (Das and Teng 1998; Li and Collier 2000).

Impact on Patient Experience

Patient experience captures their quality assessment of the care delivery process and their interactions with caregivers. With the move of healthcare facilities toward patient-centered care, patient experience has become an important metric. Experiences are captured using the HCAHPS (Hospital Consumer Assessment of Healthcare Providers and Systems) survey, which is now part of the Centers for Medicare & Medicaid Services Value-Based Purchasing reimbursement program. Higher levels of patient experience have been associated with reduced readmissions and improved quality of life after discharge (Boulding et al. 2011; Senot et al. 2015).

HIT use can have a competing effect on patient satisfaction. On the positive side, rich interactions between patients and caregivers can allow hospitals to capture patients' individual concerns and integrate them into their clinical decisions. HITs can facilitate such richer interactions by providing faster access to information and improved responsiveness. However, new HIT users need to adapt to the system, during which care delivery workflows may be in a state of flux as caregivers acclimatize to their new technology-mediated routines. Such situations have been shown to reduce quality of patient experience (Ford et al. 2009; Jha et al. 2009). This situation has been prevalent in healthcare settings because of an emphasis on adoption of augmented clinical HITs post HITECH Act. Augmented clinical HITs are primarily used by caregivers and have a bigger impact on care delivery routines than other HITs.

Impact on Clinical Quality

Clinical quality refers to clinical outcomes of care delivery, including, but not limited to, metrics such as readmissions and mortality. HITs have the potential to improve clinical quality directly and indirectly through improvements in care delivery processes. Basic clinical HITs primarily deal with patient data collection, either through manual entry or data generated through diagnostics and testing. Hence, hospitals with a higher intensity of basic clinical HITs should realize improvements in clinical quality through faster diagnosis and, in turn, a better-directed treatment protocol. Augmented clinical HITs, by contrast, enable faster

access to medical records, better reporting, decision support, and standardized care delivery protocols, all of which should improve clinical quality. Research also largely supports the benefits of a technology-mediated healthcare delivery environment. Appari et al. (2012) shows that technology use is associated with better medication adherence; Gardner, Boyer, and Gray (2015) and Sharma et al. (2016) support an association between technology use and better process quality-of-care measures; and Sharma, Queenan, and Ozturk (2019) report an association between technology use and fewer medical malpractice lawsuits.

However, recent evidence has shown that a technology-mediated environment increases HIT-related errors. Data from Quantros Analytics estimates safety incidents attributed to technology use in healthcare at 3,769 in 2018, a significant increase from near zero incidents in 2007 (Fry and Schulte 2019). These errors can take the form of missed medication, incomplete or inaccurate medical records, missed communication between stakeholders in the care delivery process, and inaccurate decision support. HIT errors can have a significant impact on care delivery, as evident from the case of Annette Monachelli, who died of a brain aneurysm that was never tested for because the test her physician entered in the clinic's software system was never transmitted to the lab (Fry and Schulte 2019).

Adoption and Assimilation of HITs

Adoption of HITs

Technology adoption is a strategic hospital initiative that involves multiple decisions, including the sourcing strategy (single vs. multi-sourcing), the timing of adoption (early vs. late adopters), and the rollout speed of the technology. Such critical decisions affect assimilation of HIT into hospital routines and potentially can influence rates of HIT-associated errors. Further, their impact can vary with available hospital resources and the maturity of the vendor's technology.

From a sourcing perspective, hospitals can source different HITs from one vendor (single sourcing) or choose the best-in-breed products available for each technology (multi-sourcing). A hospital's chosen sourcing strategy can influence interoperability, which is especially critical for HITs requiring high volumes of data exchange, like augmented clinical technologies. Specifically, a single-sourcing strategy will streamline data transfer among augmented clinical technologies, potentially reducing costs associated with interface design and reducing data-access or transmission errors. This strategy, however, can result in solutions that may restrict the functionality of certain modules. A multi-sourcing strategy, on the other hand, results in higher functionality for each module but may increase integration and data transmission challenges.

Another HIT decision hospitals face is the timing of adoption (i.e., early vs. late compared to competitors). Early adopters can gain a competitive

advantage from the successful adoption of HITs because of better clinical quality, and can achieve cost efficiencies resulting from better integration and coordination of care. At the same time, these hospitals face a steeper learning curve because of a lack of best practices associated with such adoptions. By contrast, late adopters can benefit from the assimilation and use experiences of early adopters, availability of more mature HIT solutions, and established best practices to reduce disruptions during the technology adoption process, all of which may reduce associated errors.

Finally, hospitals need to decide the rollout speed of HITs. A faster rollout benefits hospitals in terms of quicker realization of care delivery improvements. Yet this can place a bigger burden on the primary users of these HITs (i.e., caregivers), who need to go through an accelerated adaptation process to learn to use these technologies on the shortened rollout time frame.

Assimilation of HITs

Because technologies are designed to facilitate users with their work routines, adopting new technologies often requires extensive training, change management, and adaptations to both the technology and existing work routines. Although new technologies are customized to fit organizational work routines before rollout, their use often reveals unforeseen issues (Dutton and Thomas 1985; Rosenberg 1982). This requires adaptations to the existing work routines and the technology, a process called technology adaptation. This process is recursive, often requiring multiple mutual adaptations in the technology and its associated work routines (Leonard 2011). Adaptations in technology may require changes in programmatic assumptions, logic, user interfaces, and so forth, which are implemented through software patches. The workflow adaptation may require changes in interactions between users, or between users and customers; standardization; and increased reliance on technology for information and decision support. Hence, adaptations to HIT require close collaboration between the users and developers of the technology.

Challenges with HIT Use

Technology is rapidly transforming healthcare delivery. Although the healthcare sector has witnessed increased adoption and use of HITs after the HITECH Act, their use has also introduced operational challenges, which we discuss next.

Interoperability

One of the key benefits of EHR systems (as noted, a subset of augmented clinical HITs) is interoperability of data. Interoperability implies that patient data housed in one EHR system can be digitally transmitted to other systems within and among hospitals in real time. Interoperability can support real-time

alerts, access to more comprehensive patient records, and smart engagement with patients, together serving as a basis for delivering patient-centered care. However, even with increased adoption and use of EHRs, interoperability (especially among hospitals) remains elusive. One key issue preventing interoperability is the lack of a universal medical identification, which makes identifying patients among hospitals a probabilistic matching exercise. Additionally, even though industry standards for data standards exist, such as the Fast Healthcare Interoperability Resource protocol, they are not used consistently among hospitals. A mix of new and legacy systems in hospital settings also compounds such issues. These concerns should decline over time as the healthcare HIT infrastructure matures. Additionally, use of cloud-based EHRs or those based on the blockchain protocol (i.e., decentralized distributed electronic ledgers that are synchronized and stored in multiple different geographical locations; see chapter 15) could help resolve concerns around interoperability.

Data Security

Digitization of existing patient records has moved their information online. New patient data is collected through multiple disparate channels, ranging from manual entry at multiple locations within hospitals, to automatic collection and transmission between medical devices using the Internet of Things. Multiple entry and access points for patient data, along with central storage of such data in EHR systems, has increased data privacy and security challenges. These vulnerabilities have increased data breaches and ransomware attacks on hospital networks. Such breaches and attacks, potentially resulting in identity theft and financial harm, are not only harmful for patients, but can be detrimental to hospital operations as well. As an example, consider the University of Vermont Health Network cyberattack in 2020, which infected 5,000 computers and lasted more than 40 days. The healthcare system had to furlough 300 workers as a result of this cyberattack, which cost the hospital more than \$63 million (Dryda 2022). Data security concerns can be reduced through better access control, data encryption, and patch management. Decentralized databases, similar to ones used in blockchain designs, could also improve data security.

User Interfaces

Caregivers face a steep learning curve when using new HITs. This acclimatization effort is compounded by high caregiver workload and poorly designed user interfaces for HITs. These interfaces have been documented to have nonintuitive designs and present too much data. User experience problems often increase caregiver workloads and technology-related medical errors. We anticipate these issues will resolve over time as HITs mature; engaging caregivers in interface design can help speed this process.

Conclusion

Technology has the potential to transform healthcare delivery through streamlining existing operations, improving productivity and care delivery outcomes, and inspiring new business models. Although technology use is documented to have a positive impact on healthcare operations, hospitals need to carefully plan their HIT procurement and rollout strategies in order to reduce assimilation and adaptation challenges. Additionally, hospital management needs to be cognizant of and prepared for new challenges associated with a technology-mediated care delivery environment, including data security, interoperability, and data privacy.

Discussion Questions

1. MedRec is a blockchain-based EHR solution (<https://medrec.media.mit.edu/>) designed to overcome some of the limitations of current EHR systems. Read through the MedRec documentation and compare it with current EHR solutions on aspects like interoperability, data security, and data ownership. A blockchain solution requires consensus among different participating organizations on data structures, data security, and validation protocols. Do you foresee any challenges with implementation of a blockchain-based solution?
2. With increased use of technology in healthcare settings, medical errors attributed to technology have emerged as a new category of medical errors. What are some of the drivers behind such errors and what operational decisions can hospitals take to avoid them?
3. The user interfaces of HITs are often unintuitive with too much information. What is your experience with the HITs that you have used? What recommendations will you make to improve their user interfaces?
4. New HIT rollout is often accompanied with changes in existing workflows, which may cause disruptions. What has your experience been in this regard? Do you have any recommendations to improve the rollout of HITs to reduce such disruptions?

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SETTING GOALS AND EXECUTING STRATEGY

STRATEGY AND THE BALANCED SCORECARD

Operations Management
in Action

The Bridgeport Hospital in Connecticut was a successful 425-bed institution staffed with more than 550 active physicians. However, it was facing financial pressures and felt the use of a balanced scorecard could help them achieve their patient care and financial goals. Their vision included four perspectives:

- Organizational health
- Quality and process improvement
- Volume and market share growth
- Financial health

For each of these perspectives they developed a set of initiatives that were linked and scored. Many initiatives were team based and ranged from large projects to “seven daily” commitments such as “I will introduce myself to patients 100 percent of the time,” “I will be sensitive to and aware of cultural diversity,” and, “I will keep patients and families informed” (BSC Designer 2018).

After one year, the hospital was able to:

- lower turnover rates,
- exceed their volume goals in targeted areas such as cardiovascular surgery,

OVERVIEW

Most healthcare organizations have good strategic plans; what frequently fails is their execution. This chapter demonstrates how the balanced scorecard can be an effective tool to consistently move strategy to execution. First, we examine traditional management systems and explore their failures. Next, we review the theory behind the balanced scorecard and strategy mapping and explain the tools’ application to healthcare organizations. Practical steps to implement and maintain a balanced scorecard system are provided, and detailed examples from Vincent Valley Hospital and Health System demonstrate the application of these tools. The companion website to this book contains templates and explanatory videos that can be used for student exercises or to implement a balanced scorecard in a healthcare organization. In addition, a case study on the website includes data that can be used to develop a realistic dashboard.



On the web at ache.org/books/OpsManagement4

This chapter gives readers a basic understanding of balanced scorecards that enables them to

- explain how a balanced scorecard can be used to move strategy to action,
- explain how to monitor strategy from the four stakeholder perspectives,
- identify key initiatives to achieve a strategic objective,
- develop a strategy map that links relevant initiatives,
- identify and measure leading and lagging indicators for each initiative,
- understand the use of business intelligence tools to extract data for scorecards, and
- demonstrate the connection of value purchasing metrics to strategy and execution.

- increase patient satisfaction and customer preference,
- stay below budgeted levels of staffing,
- reduce supply chain costs by \$750,000, and
- improve financial performance for the whole organization (BSC Designer 2020).

Moving Strategy to Execution

The Challenge of Execution

Environmental causes that are commonly cited for the failure to execute in healthcare organizations include intense financial pressures, complex operating structures, and cultures with multistakeholder leadership that resists change. New and redefined relationships among healthcare providers—particularly physicians, hospitals, and health plans—are accompanied by a rapid growth in medical treatment knowledge and technology. Increased public scrutiny of how healthcare is delivered is leading to an associated rise of consumer-directed healthcare. The Affordable Care Act (ACA) is also altering strategy significantly.

No matter how significant these external factors are, however, most organizations founder on internal factors. Outram (2014) identifies a number of internal issues that prevent effective strategy execution in industry at large:

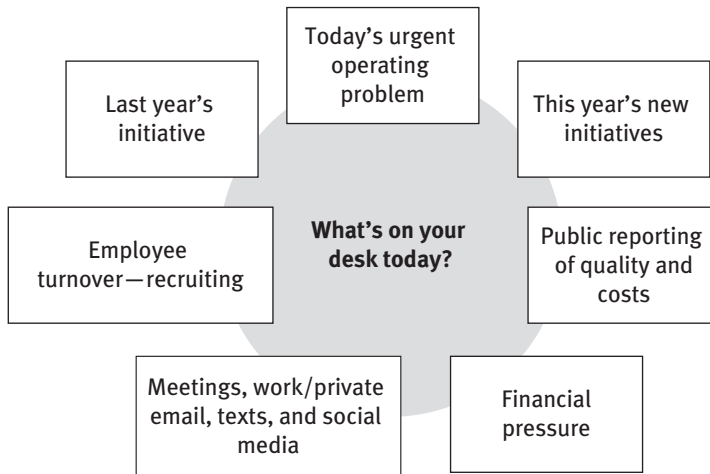
- The leadership team does not understand the strategy.
- The leadership team is overconfident.
- The organization is incapable of moving with speed and pace.
- The organization focuses on short-term goals.
- The strategy is too diffuse—it has too many goals.
- The communication of strategy to the entire organization is poor.
- The strategy is not linked to organizational mission.
- Organizational leaders lack accountability.

These factors also plague healthcare organizations. To gain competitive advantage from its operations, an organization needs an efficient system to move its strategies forward. The management systems of the past are poor tools for today's challenging environment.

The day-to-day world of a current healthcare leader is intense (exhibit 5.1). Because of ever-present communication technologies (smartphones, email, texts, blogs, social networks), managers float in a sea of inputs and daily barriers.

Healthcare leaders often focus on urgent issues rather than strategy execution. And although organizations can develop effective project managers

EXHIBIT 5.1
The Complex
World of Today's
Healthcare
Leader



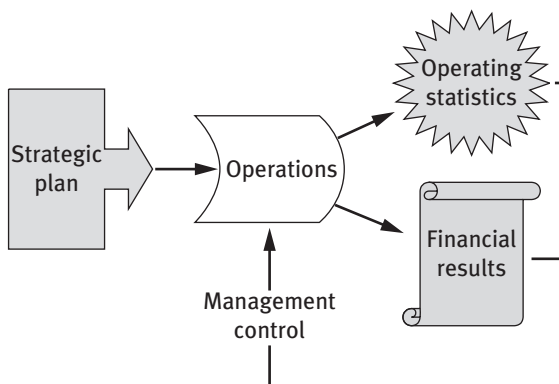
(as discussed in chapter 6), they fail to compete successfully if they do not place the undertaken projects in a broader system of strategy implementation. The **balanced scorecard** provides a framework and sophisticated mechanisms to move from strategy to execution.

Why Do Today's Management Tools Fail?

Historically, most organizations have been managed with three primary tools: strategic plans, operational reports, and financial reports. Exhibit 5.2 shows the relationships among these tools. In this traditional system, the first step is to create a strategic plan, which is usually updated annually. Next, a budget

balanced scorecard
A system of strategy links and reporting mechanisms that supports effective strategy execution.

EXHIBIT 5.2
The Traditional
Theory of
Management



and operations or project plan is created. The operations plan is sometimes referred to as the tactical plan; it provides a detailed level of task descriptions with timelines and expected outcomes. The organization's performance is monitored by senior management through the financial and operational reports. Finally, if deviations from expected performance are encountered, managers take corrective action.

Although theoretically easy to grasp, this management system frequently fails for a number of reasons. Organizations are awash in operating data, and they make no effort to identify key metrics. The strategic plans, financial reports, and operational reports are all created by different departments, and each report is reviewed in different time frames, often by different managers. Finally, none of the reports connect with the others.

These are the root causes of poor execution. If strategies are not linked to action items, operations do not change, nor do the financial results. In addition, strategic plans frequently are not linked to departmental or individual goals and, therefore, simply reside on a shelf in the executive suite.

Many strategic plans contain a logic hole, meaning they lack an explanation of how accomplishing a strategic objective provides a specific financial or operational outcome. Consider the following example:

- Strategic objective: to increase the use of evidence-based medicine (EBM)
- Expected outcome: increased patient satisfaction

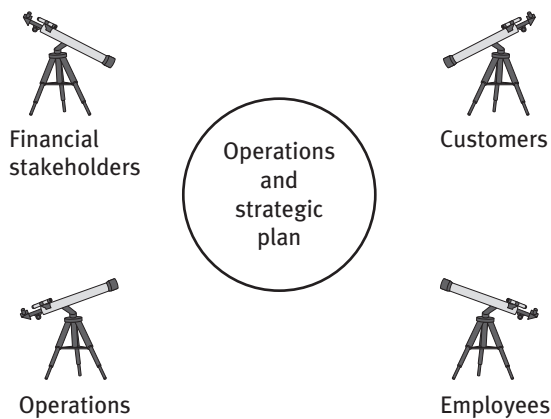
Although this proposition may seem reasonable on the surface, the logic behind connecting the use of EBM to patient satisfaction is unclear. In fact, patient satisfaction may decrease if providers constantly counsel patients on personal lifestyle issues (e.g., "Will you stop smoking?" "You need to lose weight"); the providers are meeting EBM guidelines, but their patients might see these efforts as bullying or offensive behavior.

The time frame of strategy execution also tends to be problematic. Financial reports are generally timely and accurate but only reflect the current reporting period. A review of these reports does not encourage the long-term strategic allocation of resources (e.g., a major capital expenditure) that may require multiple-year investments. A positive current-month financial outcome is likely the outcome of an action that occurred many months in the past. The cumulative result of these timing problems is poor execution, leading to poor outcomes.

Balance

The key element of the balanced scorecard is, of course, balance. An organization can be viewed from many perspectives; to allow a standardized approach,

EXHIBIT 5.3
The Four
Perspectives in
the Balanced
Scorecard



the balanced scorecard methodology uses four common perspectives from which an organization examines its operations (exhibit 5.3):

1. Financial stakeholders
2. Customers
3. Internal process and innovation (operations)
4. Employee learning and growth

Because an organization is viewed from each perspective, different measures of performance are important. Every perspective in a complete balanced scorecard contains a set of objectives, metrics, targets, and actions. Each measure in each perspective must be linked to the organization's overall strategy.

The indicators that characterize performance in each of the four perspectives must be both leading (predicting the future) and lagging (reporting on performance today). Indicators must also be obtained from both inside the organization and the external environment.

Although many think of the balanced scorecard as a reporting technique, its true power lies in its ability to link strategy to action. Balanced scorecard practitioners develop strategy maps that connect projects and actions to outcomes in a series of road map-type graphics. These maps display the "theory of the company" and can be evaluated and fine-tuned as strategies are implemented.

The Balanced Scorecard as Part of a Strategic Management System

Although it does not substitute for a complete strategic management system, the balanced scorecard is a key component in such a system and an effective tool

for moving an organization's strategy and vision into action. The development of a balanced scorecard leads to the clarification of strategy, and it communicates and links strategic measures throughout an organization. Organizational leaders can plan projects, set targets, and align strategic initiatives during the creation of the balanced scorecard. If used properly, the balanced scorecard can also enhance strategic feedback and learning.

Elements of the Balanced Scorecard System

A complete balanced scorecard system has the following elements, which are explained in detail in the subsequent sections:

- Organizational mission and vision, and their relationship to strategy
- Perspectives
 - Financial
 - Customer
 - Internal business process
 - Learning and growing
- Strategic alignment—linking balanced scorecard measures to strategy
- Strategy maps
- Implementation of the balanced scorecard, including processes for identifying targets, resources, initiatives, and budgets
- Feedback and the strategic learning process—making sure the balanced scorecard works

Mission and Vision

The balanced scorecard system presupposes that an organization has an effective mission, vision, and strategy in place. For example, the mission of Vincent Valley Hospital and Health System (VVH) is “to provide high-quality, cost-effective healthcare to our community.” Its vision is, “Within five years, we will be financially sound and will be considered the place to receive high-quality care by the majority of the residents of our community.” To accomplish this vision, VVH has identified five specific strategies:

1. Recruit five new primary care physicians.
2. Expand the VVH accountable care organization.
3. Increase the volume of obstetric care.
4. Renegotiate health plan contracts to include performance incentives for improved chronic disease management.
5. Improve emergency department (ED) operations and patient satisfaction.

The VVH example is used throughout this chapter to demonstrate the use of the balanced scorecard. The two strategies examined in depth are increasing the volume of obstetric care and improving ED operations and patient satisfaction.

With an effective strategic plan in place, the next step is to evaluate the plan's implementation as viewed from each of the four perspectives (financial, customer, internal business process, and learning and growing). Placing a perspective at the top of a balanced scorecard strategy map means that results in this perspective include the final outcomes desired by an organization. In most organizations, the financial view is the topmost perspective. Therefore, the initiatives undertaken in the other three perspectives should result in positive financial performance for the organization.

"No margin, no mission" is still a valid assessment for nonprofit health-care organizations. They need operating margins to provide financial stability and capital. However, some organizations prefer to position the customer (patient) as the top perspective. In that case, the initiatives undertaken in the other three perspectives are intended to result in positive patient outcomes. (Modifications to the classic balanced scorecard are discussed at the end of this chapter.)

Perspectives

Financial Perspective

Viewed from the financial perspective, the customer, operational, and learning and growing perspectives and their associated initiatives should lead to outstanding financial performance. Although the focus of this book is not directly on healthcare finance, some general strategies should always be under consideration by a hospital or health system.

If the organization is in a growth mode, its financial focus should be placed on increasing revenue to accommodate this growth. If it is operating in a relatively stable environment, the organization may choose to emphasize profitability. If the organization is stable and profitable, the focus can shift to investment—in both physical assets and human capital. Another major strategy in the financial domain is the diversification of revenues and expenditures to minimize financial risk. Exhibit 5.4 lists many common metrics used to measure performance from the financial perspective.

Customer Perspective and Market Segmentation

The second perspective is to view an organization's operations from the customer's point of view. In most healthcare operations, the customer is the patient. Integrated health organizations, however, may operate insurance programs and health plans; some of their customers, then, are employers or the government.

EXHIBIT 5.4

Metrics of
Performance
from the
Financial
Perspective

- Percentage of budget—revenue
- Percentage of budget—expense
- Days in accounts receivable
- Days of cash on hand
- Collection rate
- Return on assets
- Expense per relative value unit
- Cost per surgical case
- Case-mix index
- Payer mix
- Growth, revenue, expense, and profit—product line
- Growth, revenue, expense, and profit—department
- Growth of revenue from value purchasing payments
- Growth in members and profitability of accountable care organization
- Growth, revenue, and cost per adjusted patient day
- Growth, revenue, and cost per physician full-time equivalent
- Price competitiveness on selected services
- Profitability of accountable care organizations or capitated operations
- Profitability of value purchasing contracts
- Research grant revenue

Health insurance exchanges are a new vehicle to connect insurance companies directly with customers. Many hospitals and clinics also consider their community at large to be the customer. Finally, the physician is seen as the customer in many hospital organizations.

Once the general customers are identified, a helpful step is to segment them into smaller groups and determine the **value proposition** that will be delivered to each. Examples of market segments are patients with chronic illnesses (e.g., diabetes, congestive heart failure); patients seeking obstetric care, sports medicine services, cancer care, or emergency care; Medicaid patients; small employers; and referring primary care physicians.

value proposition

A marketing term summarizing the relative cost, features, and quality of a service or good.

Customer Measures

Once market segments have been determined, a number of traditional measures of marketplace performance may be applied, the most prominent being market share. Customers should be individually tracked and measured in terms of retention and acquisition, because retaining an existing customer is always easier than attracting a new one. Customer satisfaction and profitability are also useful measures. Exhibit 5.5 displays a number of common customer metrics.

Customers: The Value Proposition

Organizations create value to retain current customers and attract new ones. Each market segment may require products to have different attributes to

EXHIBIT 5.5
Metrics of
Performance
from the
Customer
Perspective

-
- Patient care volumes
 - By service, type, and physician
 - Turnover (new patients and those exiting the system)
 - Physician
 - Referral and admission rates
 - Satisfaction
 - Availability of resources (e.g., operating suite time)
 - Market share by product line
 - Clinical measures
 - Readmission rates
 - Complication rates
 - Compliance with evidence-based guidelines
 - Medical errors
 - Customer service and engagement
 - Patient satisfaction
 - Patient use of their electronic health record
 - Waiting time
 - Cleanliness, ambience
 - Ease of navigation
 - Parking
 - Billing complaints
 - Reputation
 - Price comparisons relative to competitors
-

maximize that segment's particular value proposition. For example, the organization may seek to be a price leader for outpatient imaging, as some patients will pay for this service via a healthcare savings account. For another segment—emergency services, for example—speed of delivery may be critical. The personal relationship of provider to patient may be important in primary care but not as important in anesthesiology.

Image and reputation are particularly strong influences in consumer behavior and can be competitive advantages for specialty healthcare services. Taking care to understand the value proposition in an organization can lead to the development of effective metrics and strategy maps in the balanced scorecard system.

Vincent Valley Hospital and Health System's Value Proposition

VVH has developed a value proposition for its obstetric services. Its market segment is pregnant women aged 18–35. VVH believes the product attributes for this market should be

- quick access to care;
- warm and welcoming facilities;

- customer interactions characterized by strong and personal relationships with nurses, midwives, and doctors; and
- an image of high-quality care that is supported by an excellent system for referrals and air transport for high-risk deliveries.

VVH has determined the following metrics to measure each attribute:

- The time from arrival to care in the obstetric suite
- A patient survey of facility attributes
- A patient survey of satisfaction with staff
- The percentage of high-risk newborns referred and transported, and the clinical outcomes of these patients

The main value proposition for emergency care has been identified as reduced waiting time. Following internal studies, competitive benchmarking, and patient focus groups, VVH has determined that its goal is to have fewer than 10 percent of its ED patients wait more than 30 minutes for care.

Internal Business Process Perspective

The third perspective in the balanced scorecard is internal business processes or operations—the primary focus of this book. The internal business process perspective has three major components: innovation, ongoing process improvement, and post-sale service.

Innovation

Any well-functioning healthcare organization has in place a purposeful innovation process. However, many hospitals and health systems today do not, and they can only be characterized as reactionary. They simply respond to—rather than anticipate—new reimbursement rules, government mandates, or technologies introduced through the medical staff. Bringing thoughtful innovation into the life cycle is one of the most pressing challenges contemporary organizations face.

The first step in an organized innovation process is to identify a potential market segment. Then, two primary questions must be answered: (1) What benefits will customers value in tomorrow's market? (2) How can the organization innovate to deliver those benefits? Once these questions have been researched and answered, related products can be created.

Quality function deployment (chapter 9) can be a useful tool for new product or service development. If a new service is on the clinical leading edge, it may require additional research and testing. A more mainstream service calls for competitor research and review of the clinical literature. The principles of project management (chapter 6) should be used throughout this process until

the new service is operational and stable. The process of innovation and design thinking is explored in more depth in chapter 6.

Standard innovation measures used in many industries outside healthcare include percentage of total sales resulting from new products and proprietary products, number of new product introductions per year, time to develop new products, and time to break even.

Healthcare operations tend toward stability (bordering on being rigid), and, therefore, a major challenge is simply ensuring that all clinical staff use the latest and most effective diagnostic and treatment methodologies. However, with the passage of the ACA, those organizations with a well-functioning product development process have a clear competitive advantage.

Ongoing Process Improvement

The case for process improvement and operations excellence is made throughout this book. The project management system (chapter 6) and the tools and methodologies contained in parts III and IV are key to these activities. The strategic effect of process improvement and maintaining gains is discussed in chapter 15.

Post-sale Service

The final aspect of the operations perspective is the post-sales area, an element that is poorly executed in most healthcare delivery organizations. Sadly, the most common post-sale contact with a patient may be an undecipherable or incorrect bill.

Good post-service systems provide patients with follow-up information on the service they received. Patients with chronic diseases should be contacted periodically with reminders on diet, medication use, and the need to schedule follow-up visits. An outstanding post-sale system also finds opportunities for improvement in the service as well as possible innovations for the future. Open-ended survey questions such as “From your perspective, how could our organization improve?” or “How else can we serve your healthcare needs?” can point to opportunities for improvement and innovation. Exhibit 5.6 lists common metrics used to measure operational performance.

External Operational Metrics Today and into the Future

We pause in our discussion of the elements of the strategic plan to revisit value purchasing, specifically in terms of its influence on the business process perspective. Value-based care purchasing (or value-based purchasing, as it is often referred to) emphasizes meeting external goals and benchmarks. This emphasis on measuring a wide range of quality metrics complicates strategy maps.

The Centers for Medicare & Medicaid Services (CMS) implemented the Merit-Based Incentive Payment System (MIPS) for physician compensation

EXHIBIT 5.6

Metrics of
Performance
from the
Operational
Perspective

- Average length of stay—case-mix adjusted
- Full-time equivalent (FTE)/adjusted patient day
- FTE/diagnosis-related group
- FTE/relative value unit
- FTE/clinic visit
- Waiting time inside clinical systems
- Access time to appointments
- Percentage of value-added time
- Utilization of resources (e.g., operating room, imaging suite)
- Patients leaving emergency department without being seen
- Operating room cancellations
- Admitting process performance
- Billing system performance
- Medication errors
- Nosocomial infections
- Measures from external agencies such as The Joint Commission, the National Quality Forum, and the Centers for Medicare & Medicaid Services

in 2019. Because MIPS introduces many new metrics and publicly reported quality measures, organizations might be tempted to develop a strategy that directly links physician payment to MIPS metrics (which may already be happening in some small practices). The MIPS system contains more than 200 metrics (CMS 2020).

The proliferation of metrics might also tempt an organization to develop overly complex scorecards. These data visualizations are not a substitute for a disciplined strategy featuring a strategy map that can be communicated to the entire organization and effectively executed.

Vincent Valley Hospital and Health System Internal Business Processes

VVH is executing four major projects to move its birthing center and ED strategies forward. The birthing center projects include remodeling and redecorating labor and delivery suites, contracting with a regional health system for emergency transport of high-risk deliveries, and introducing predelivery tours of labor and delivery facilities by nursing staff. The ED project is to execute a Lean analysis and *kaizen* event to improve patient flow.

Learning and Growing Perspective

The final perspective from which to view an organization is employee learning and growth. To execute a strategy well, employees must be motivated and have the necessary tools to succeed. Therefore, a high-performing organization makes substantial investments in this aspect of its operations. Kaplan and Norton (1996) identified three critical aspects of learning and growing: employee skills and abilities, necessary information technology (IT), and employee motivation.

Kaizen and Kaizen Events

Kaizen is the Japanese term for “change for the better,” or continuous improvement. Kaizen has become the vehicle by which Lean systems make changes and improve. The philosophy of kaizen involves all employees in making suggestions for improvement, then implementing those suggestions quickly. It arises from the assumptions that everything can be improved and that many small incremental changes result in an enhanced system. A kaizen event, sometimes referred to as a rapid process improvement workshop, is a focused, short-term project aimed at improving a particular process.

Employee Skills and Abilities

Although employees in healthcare usually come to their jobs with general training in their technical field, continuous updating of skills is necessary. Some healthcare organizations are effective in ensuring that clinical skills are updated but neglect training in other vital processes (e.g., purchasing systems, organization-wide strategies). A good measure of the attention paid to this area is the number of classes conducted by the organization (or an outside education vendor) for the staff. Another important measure is the breadth of employee occupations attending these classes. Do all employees—from doctors to housekeepers—attend organization-wide training?

Necessary IT

Most healthcare workers are considered knowledge workers. They primarily use thinking to accomplish the goals of their profession, as opposed to physical labor. The more immediately and conveniently they can obtain information, the more effectively they can perform their jobs. Facilitative IT is one key to this ability.

Process redesign projects frequently use IT as a resource for automation and information retrieval. Measures of automation include the number of employees having easy access to IT systems, the percentage of individual jobs that have an automation component, and the speed of installation of new IT capabilities. The use of data and analytics is explored in depth in chapter 8.

Employee Motivation

A progressive culture and motivated employees are clearly competitive advantages; therefore, the organization must monitor these areas with some frequency. Measures of employee satisfaction include the following:

- Level of involvement in decision making
- Recognition for doing a good job
- Amount of access to information

- Level of encouragement of creativity and initiative
- Support for staff-level functions
- Overall satisfaction with the organization
- Turnover rate
- Absenteeism rate
- Training hours per employee

Data for many of these measures are typically collected through employee surveys.

These three aspects of learning and growing—employee skills, IT, and motivation—all contribute to employee satisfaction. A satisfied employee is productive and tends to remain with the organization. Employee satisfaction, productivity, and loyalty make outstanding organizational performance possible.

Vincent Valley Hospital and Health System Learns and Grows

VVH realizes its employees need new skills to successfully execute some of its projects, so it has engaged training firms to provide classes for all staff. Exhibit 5.7 illustrates this undertaking for improvement.

Strategic Alignment: Linking Measures to Strategy

Once expected objectives and their related measures are determined for each perspective, the initiatives to meet these goals must be developed. An initiative can be a simple action or a large project. Regardless of its scale, each initiative must be logically linked to the desired outcome through a series of cause-and-effect statements. These statements are usually constructed in “if-then” format to tie initiatives together and contribute to the outcome, as with the following examples:

- If the wait time in the ED is decreased, then the patient will be more satisfied.
- If an admitting process is improved through the use of automation, then the final collection rate will improve.
- If an optically scanned wristband is used in conjunction with an electronic health record, then medication errors will decline.
- If a discharge summary is routinely dictated and transmitted to the primary care provider within 24 hours, then the number of readmissions within 30 days will decrease.

Each initiative should have measures associated with it, and every measure selected for a balanced scorecard should be an element in a chain of cause-effect relationships that communicates the organization’s strategy.

Project	Employees Involved	Training
Begin predelivery tours of labor and delivery facilities by nursing staff	Obstetric nursing and support staff	Customer service and sales
Execute a Lean analysis and kaizen event to improve patient flow in the emergency department	Managers and key clinicians in the emergency department	Lean tools (chapter 10)

EXHIBIT 5.7

VVH

Improvement Projects and Associated Training

Outcomes and Performance Drivers

Selecting appropriate measures for each initiative is critical. Measures can be categorized into two basic types of indicators. Outcome indicators, familiar to most managers, are also termed **lagging indicators** because they result from earlier actions. Outcome indicators tend to be generic instead of tightly focused. Healthcare operations examples include profitability, market share, and patient satisfaction. The other type of indicator is a *performance driver*, or **leading indicator**. These indicators predict the future and are specific to an initiative and the organization's strategy. One example of a performance driver is waiting time in the ED. A drop in waiting time should predict an improvement in a related outcome indicator, such as patient satisfaction.

A common pitfall in developing indicators is the use of measures associated with the improvement project rather than with the process improvement. For example, the fact that a project to improve patient flow in a department is 88 percent complete is a less adequate indicator than a measure of the actual change in patient flow, a 12 percent reduction in waiting time. Outcome measures are always preferred, but in some cases they may be difficult or impossible to obtain.

Because the number of balanced scorecard measures should be limited—ideally to fewer than 20—identifying measures that are indicators for a complex process is sometimes useful. For example, a seemingly simple indicator such as time to next appointment for patient scheduling actually tracks many complex processes in an organization.

Strategy Maps

As discussed, a set of initiatives should be linked together by if-then statements to achieve a desired outcome. Both outcome and performance driver indicators should be determined for each initiative. These can be displayed graphically in a **strategy map**, which may be most helpfully organized into

lagging indicator

A performance measurement that assesses the outcome of existing actions.

leading indicator

A performance measurement that predicts the future and is specific to an initiative or organizational strategy. Also called *performance driver*.

strategy map

A set of initiatives that are graphically linked by if-then statements to describe an organization's strategy.

the four perspectives, where learning and growing is positioned at the bottom and financial resides at the top. A general strategy map for any organization includes the following conditional statements:

- If employees have skills, tools, and motivation, then they will improve operations.
- If operations and marketing efforts are improved, then customers will buy more products and services.
- If customers buy more products and services and operations are run efficiently, then the organization's financial performance will improve.

Exhibit 5.8 shows a strategy map in which these general initiatives are indicated.

The strategy map is enhanced if each initiative also contains the strategic objective, measure used, and results that the organization hopes to achieve (targets). Each causal pathway from initiative to initiative needs to be as clear and quantitative as possible.

Vincent Valley Hospital and Health System Strategy Maps

VVH has two major areas of strategic focus—the birthing center and the ED. Exhibit 5.9 displays the strategy map for the birthing center.

EXHIBIT 5.8
General
Strategy Map

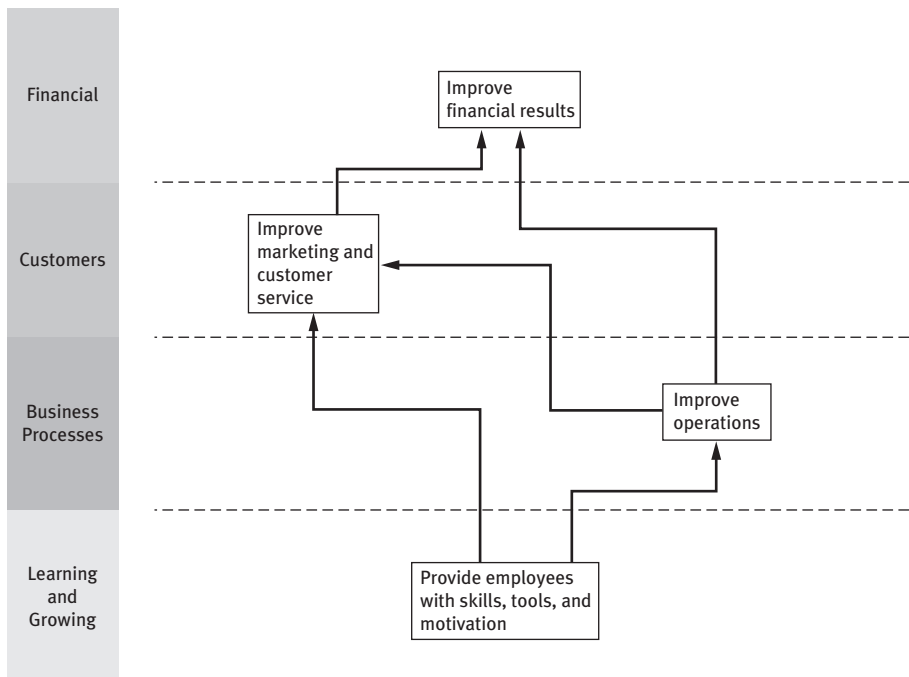
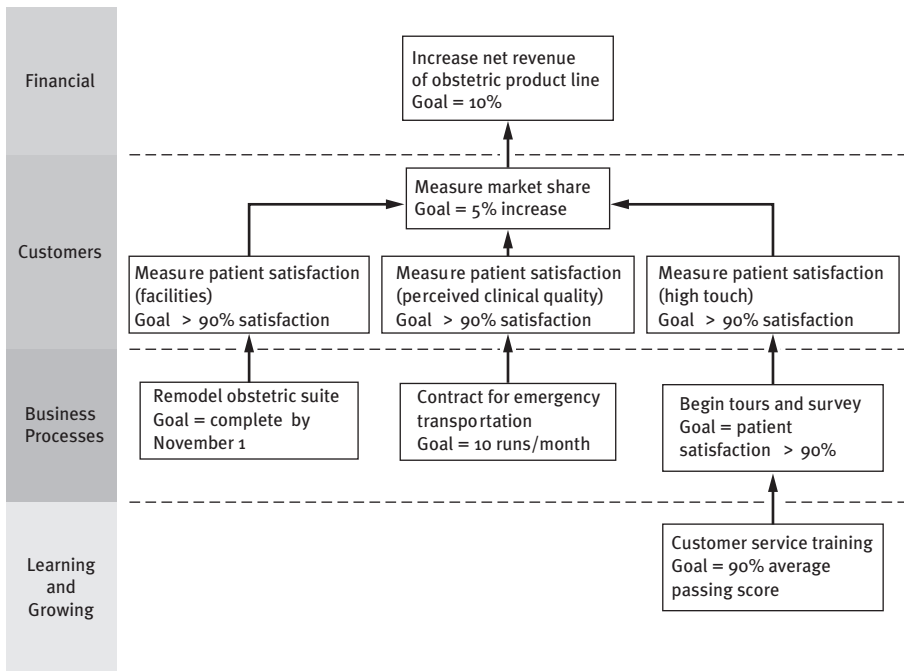


EXHIBIT 5.9
VVH Birthing
Center Strategy
Map



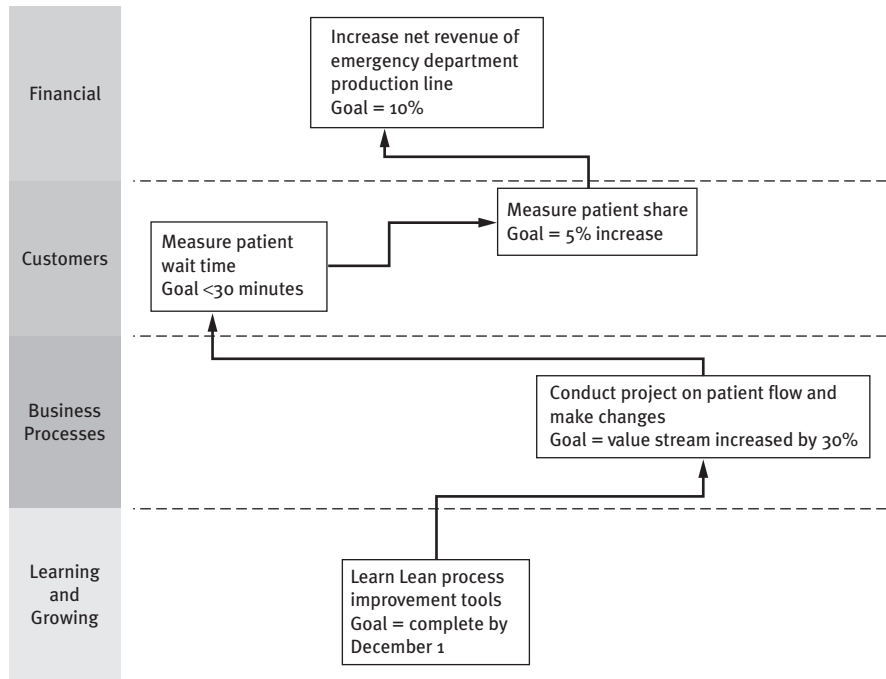
Recall that VVH has decided to execute three major projects in this area. Other initiatives needed for the successful execution of each project are identified on the map. For instance, for nursing staff to successfully lead expectant mothers on tours of labor and delivery suites, the staff must participate in a customer service training program. After the tours begin, the birthing center will measure potential patients' satisfaction to ensure that the tours are being conducted effectively.

After patients deliver their babies in VVH's obstetric unit, they will again be surveyed on their experience, with special questions on the effect of each major project. These leading satisfaction indicators should predict the lagging indicators of increased market share and net revenue.

The second major strategy for VVH is to improve patient flow in the ED. Exhibit 5.10 shows the strategy map for the department.

The first required steps in this strategy are forming a project team (chapter 6) and learning how to use Lean process improvement tools (chapter 10). Then the team can begin analyzing patient flow and implementing changes to improve flow. VVH has set a goal of reducing the amount of non-value-added time by 30 percent. From the time this goal is first met, waiting time for 90 percent of patients should not exceed 30 minutes. A reduced waiting time should result in patients being more satisfied and, hence, a growth in market

EXHIBIT 5.10
VVH Emergency
Department
Strategy Map



share and increased net revenue. Following are more formal cause-and-effect statements:

- If ED staff undertake educational activities to learn project management and Lean, then they can effectively execute a patient flow improvement project.
- If a patient flow project is undertaken and non-value-added time is reduced by 30 percent, then the waiting time for 90 percent of the patients should never exceed 30 minutes.
- If the waiting time for most patients never exceeds 30 minutes, then they will be highly satisfied, and this satisfaction will increase the number of patients and VVH's market share.
- If the ED market share increases, then net revenue will increase.

The book's companion website contains a downloadable strategy map and linked scorecard. It also includes a number of videos that demonstrate how to use and modify these tools for student and practitioner use.



On the web at
ache.org/books/OpsManagement4

Implementation of the Balanced Scorecard

Linking and Communicating

The balanced scorecard can be used at many different levels in an organization. However, departmental scorecards should link to the divisional, and ultimately the corporate, level. Each scorecard should be linked upward and downward. For example, an obstetric initiative to increase revenue from normal childbirths should be linked to the corporate-level objective of overall increased revenue.

Sometimes, specific linkages are difficult to establish between a departmental strategy map and corporate objectives. In these cases, the department head must derive a more general link by stating how a departmental initiative will influence a particular corporate goal. For example, improving the quality of the hospital laboratory testing system generally affects the corporate objective that patients should perceive that the hospital provides the highest level of quality care.

The development and operation of scorecards at each level of an organization require disciplined communication, which can be an incentive for action. Balanced scorecards can also be used to communicate with an organization's external stakeholders. A well-implemented balanced scorecard system is integrated with individual employee goals and the organization's performance management system.

Targets, Resources, Initiatives, and Budgets

As demonstrated in this chapter, a balanced scorecard strategy map consists of a series of linked initiatives, and each initiative should have a quantitative measure and a target. Initiatives can reside in one department, but they are frequently cross-departmental. Many initiatives are projects, and the process for successful project management (chapter 6) should be followed.

A well-implemented balanced scorecard also links carefully to an organization's budget, particularly if initiatives and projects are expected to consume considerable operating or capital resources.

The use of the balanced scorecard does not obviate the need for additional operating statistics. Many other operating and financial measures still must be collected and analyzed. If the performance of any of these measures deviates substantially from its target, a new strategy and initiative may be needed. For example, most healthcare organizations carefully track and monitor their accounts receivable. If this financial measure is within industry norms, it probably will not appear on an organization's balanced scorecard. However, if the accounts receivable balance drifts over time and begins to exceed expectations, a balanced scorecard initiative may be started to address the problem.

Displaying Results

The actual scorecard tracks and communicates the results of each initiative. (Chapter 8 provides several examples of dashboards and other visual displays.) A challenge for most organizations is to collect the data to display in the scorecard. Because the scorecard should include fewer than 20 measures, a simple solution is to assign this responsibility to one individual who develops efficient methods to collect the data and determines effective methods by which to display them. A more robust solution is to develop a data warehouse with associated analysis and reporting tools (see exhibit 5.11).

Does the Balanced Scorecard Work? Feedback and Strategic Learning

Once a balanced scorecard system is created, it must be monitored closely. Management teams should divide their routine meetings into three types: operational reviews, strategy reviews, and strategy testing and adaptation. The operational meeting is held frequently (e.g., weekly) and is designed to respond to short-term problems and promote improvements. The strategy review meeting is held monthly and focuses on monitoring and fine-tuning the existing strategy map. The strategy testing and adaptation meeting should be held at least annually—more frequently if the business environment is changing rapidly. These meetings are designed to improve or transform the existing strategy, develop new initiatives and revise maps, and authorize needed expenditures.

The explicit purpose of the balanced scorecard is to ensure the successful execution of an organization's strategy. But what if it does not achieve the desired results? Two possible causes can be at play.

The first, most obvious, problem is that an initiative itself is not achieving its targeted results. For example, the ED's patient flow project may not be able to decrease non-value-added time by 30 percent. In that case, the hospital may need to add an initiative, such as engaging a consultant. This measure must be carefully monitored and frequently posted on the scorecard.

The second, more complex, problem occurs when the successful execution of an initiative does not lead to achievement of the next linked target. For example, although waiting times in the ED decrease, the department does not gain market share. The first step in solving this problem is to reconsider the cause-and-effect relationships.

An organization should review its results and strategy map at least quarterly and revise its strategy annually, usually as part of the budgeting process.

Modifications of the Classic Balanced Scorecard

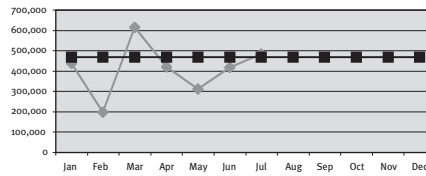
The balanced scorecard has been modified by many healthcare organizations, most commonly by placing the customer or patient at the top of the strategy map (exhibit 5.12). Finance then becomes a means to achieve superior patient outcomes and satisfaction.

EXHIBIT 5.11

Balanced Scorecard Template

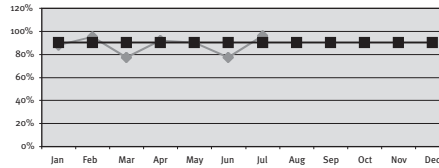
Net revenue

YTD	
Actual	2,877,842
Goal	3,266,667



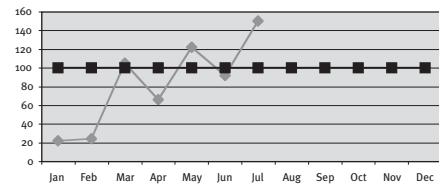
Patient satisfaction

YTD	
Actual	88%
Goal	90%



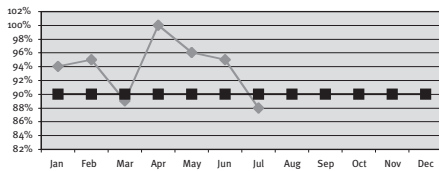
Increase in admissions

YTD	
Actual	83
Goal	100



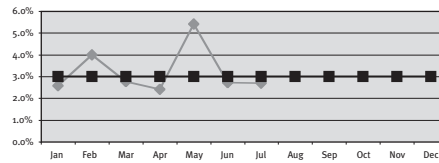
Customer service training tests

YTD	
Actual	94%
Goal	90%



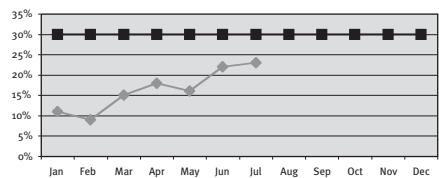
Profit

YTD	
Actual	3.2%
Goal	3.0%



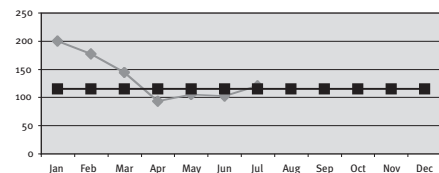
FT admission (%)

YTD	
Actual	16%
Goal	30%



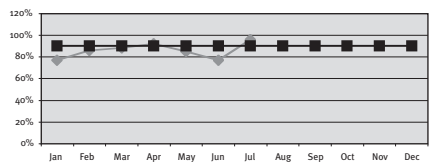
Cost/unit

YTD	
Actual	134
Goal	115



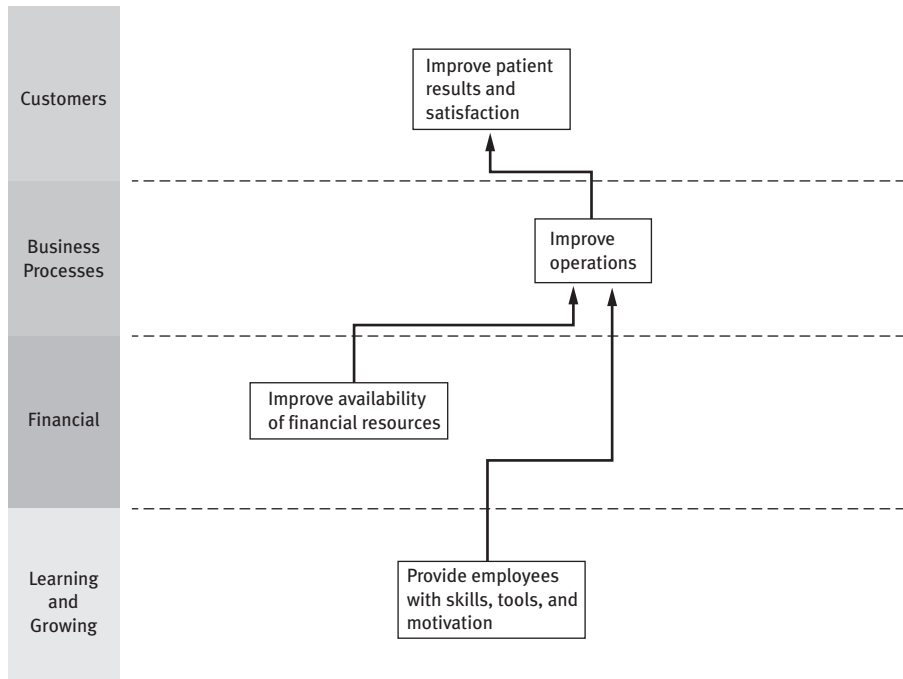
Six Sigma training tests

YTD	
Actual	86%
Goal	90%



Note: Download this scorecard from the book's companion website at ache.org/books/OpsManagement4. FT = full time; YTD = year to date.

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EXHIBIT 5.12**Inverted
General
Strategy Map****Implementation Issues**

Two common challenges arise when implementing balanced scorecards: (1) determination and development of metrics, and (2) initiative prioritization.

The balanced scorecard is a quantitative tool and, as such, requires data systems that generate timely information for inclusion. Each initiative on a strategy map should have quantitative measures that represent an even mix of leading and lagging indicators. Each initiative should have a target as well. However, setting targets is an art: Too timid a goal does not move the organization forward, and too aggressive a goal is discouraging for staff.

A number of sources should be used to construct targets. They include internal company operating data, executive interviews, internal and external strategic assessments, customer research, industry averages, and benchmarking data. Targets can be incremental on the basis of current operating results (e.g., increase productivity in a nursing unit by 10 percent in the next 12 months), or they can be “stretch goals,” which are possible to achieve but require extraordinary effort (e.g., improve compliance with evidence-based guidelines for 98 percent of patients with diabetes). Including too many measures and initiatives renders a scorecard confusing; therefore, even the most sophisticated organizations limit their measures to 20 or fewer.

Achieving perfect alignment with a balanced scorecard's goals for all of an organization's initiatives is difficult. However, the closer the alignment, the more likely the organization's strategic objectives will be achieved.

Conclusion

This text is about how to get things done. The balanced scorecard with strategy mapping provides a powerful tool toward that end because it

- links strategy to action in the form of initiatives;
- provides a comprehensive communication tool inside and outside an organization; and
- is quantitatively based, providing a vehicle for ongoing strategy analysis and improvement.

Discussion Questions

1. What other indicators might be used in each of the four perspectives for public health agencies? For health plans?
2. If you were to add a perspective to the four discussed in the chapter, what would it be? Draw a strategy map of a healthcare delivery organization and include this perspective.
3. How do you manage the other operations of an organization—that is, those that do not appear on a strategy map or balanced scorecard?
4. How would a department link its balanced scorecard to the corporate scorecard?
5. What methods could be used to involve the customer or patient in identifying the key elements of the balanced scorecard?

Exercises

1. View the videos at the companion website for this book, and download the PowerPoint strategy map provided. Develop a strategy map and balanced scorecard for a primary care dental clinic. Conduct internet research to determine the challenges facing primary care dentistry, and develop a strategy map for success in this environment.

On the web at  ache.org/books/OpsManagement4

Make sure the strategy map includes at least eight initiatives and that they touch on the four perspectives. Include targets, and be sure the metrics are a mix of leading and lagging indicators. Develop a plan to periodically review your map to ascertain its effectiveness.

2. Download the data for this chapter provided on the companion website, and develop a dashboard in Excel to identify readmissions that occur within 30 days of discharge. A number of initiatives are described on the website to minimize readmissions. Conduct additional internet research and construct a strategy map to improve this readmission rate.

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PROJECT MANAGEMENT

Operations Management in Action

The examples in the Operations Management in Action sections throughout this book generally demonstrate the *effective* use of the principles of operations management. However, professionals can also learn from failures. One of the most visible, and nearly catastrophic, failures in healthcare operations management was in the implementation of the Affordable Care Act's health insurance exchanges by the US federal government.

Although most of the operational issues with the exchanges have now been corrected, at the outset of the implementation, many of the principles of good project management were not employed. Following is a list of poor or inadequate approaches compiled by an experienced governmental project manager that demonstrate the absence of good operations management (adapted from Thomson 2013).

Unrealistic requirements. This is the first time anybody has ever tried to develop a single website where diverse users could (1) establish an online identity, (2) review hundreds of health-insurance options, (3) enroll in a specific plan, and (4) determine eligibility for federal subsidies—all in real time.

OVERVIEW

Everyone manages projects, whether painting a bedroom at home or adding a 100-bed wing to a hospital. This chapter provides grounding in the science of project management. The major topics covered include

- selecting and chartering projects;
- using stakeholder analysis to set project requirements;
- developing a work breakdown structure and schedule;
- using Microsoft Project to develop project plans and monitor cost, schedule, and earned value;
- managing project communications, change control, and risk; and
- creating and leading project teams.

After reading this chapter and completing the associated exercises, readers should be able to

- create a project charter with a detailed plan for costs, schedule, scope, and performance;
- monitor the progress of a project, make changes as required, communicate to stakeholders, and manage risks; and
- develop the skills to successfully lead a project team.

If virtually everyone has had experience managing projects, why devote a chapter in a healthcare operations book to the topic? The answer lies in the question. Although everyone has life experiences in project management, few healthcare professionals take the time to understand and practice the science and discipline of project management. The ability to successfully move a project forward while meeting time and budget goals is a distinguishing characteristic of a high-quality, highly competitive healthcare organization.

Effective project management provides an opportunity for progressive healthcare organizations to quickly develop new clinical

(continued)

Technical complexity. As often occurs with poorly planned defense projects, unrealistic requirements for HealthCare.gov resulted in an extraordinarily complicated system that is difficult to maintain. There are just too many moving pieces.

Integration responsibility. Despite weak internal information technology (IT) capabilities, the Centers for Medicare & Medicaid Services (CMS) decided it would take charge of integrating all the parts in HealthCare.gov, and testing the end product to ensure functionality. The results show why the military almost always

hires outside companies to serve as lead integrator. The final resolution of the problems of HealthCare.gov was led by an outside consultant.

Fragmented authority. There seems to have been a great deal of infighting at CMS over how the website would operate and what the user experience would feel like. With three different parts of the bureaucracy contending for control—the IT shop, the policy shop, and the communications shop—key decisions were often delayed, guidance to contractors was inconsistent, and nobody was truly in charge.

Loose metrics. Perhaps the most important factor in keeping complex projects on track is for managers to use rigorous, unambiguous performance metrics in measuring progress. Absence of reliable metrics helps explain why federal officials didn't realize until late in the game that HealthCare.gov might not be ready for prime time.

OVERVIEW (*continued*)

services, fix major operating problems, reduce expenses, and provide new consumer-directed products to their patients.

Project management as a formalized management methodology came of age in the period 1958–1979. New management science mathematical tools, such as program evaluation and review technique (PERT) and the critical path method (introduced in chapter 2 and discussed later in this chapter), were developed. In addition, the rapid development of computer systems, such as the minicomputer, made the use of these tools accessible to project managers (Azzopardi 2016).

Project management as a discipline continued to develop over time, culminating in the establishment of the Project Management Institute (PMI) in 1969 (www.PMI.org). As of 2021, PMI has more than 650,000 members (PMI 2021a) and publishes the *Project Management Body of Knowledge (PMBOK)* (PMI 2021b), which details best practices for successful project management.

Much as evidence-based medicine delineates the most effective methods to care for specific clinical conditions, *PMBOK* provides science-based, field-tested guidelines for successful project management. This chapter is based on *PMBOK* principles as applied to healthcare. Healthcare professionals who spend much of their time leading projects should consider using resources available through PMI; for some, PMP certification may be appropriate.

Inadequate testing. Despite repeated warnings from contractors that more testing of system components was needed, CMS was determined to see the site go live on its planned debut date of October 1.

Aggressive schedules. You wouldn't think that standing up a website after literally years of planning might entail overly aggressive schedules, but in the case of HealthCare.gov the disorganized bureaucracy took so long to make design choices that the back end of the project was way too hurried for comfort.

Administrative blindness. CMS may not have had good management practices or metrics for identifying problems, but that doesn't mean it didn't get plenty of warnings about potential problems with HealthCare.gov. Outside consultants and contractors on the project repeatedly warned government officials about functional difficulties with some features of the site, lack of adequate testing, poor protection of sensitive information, and the like.

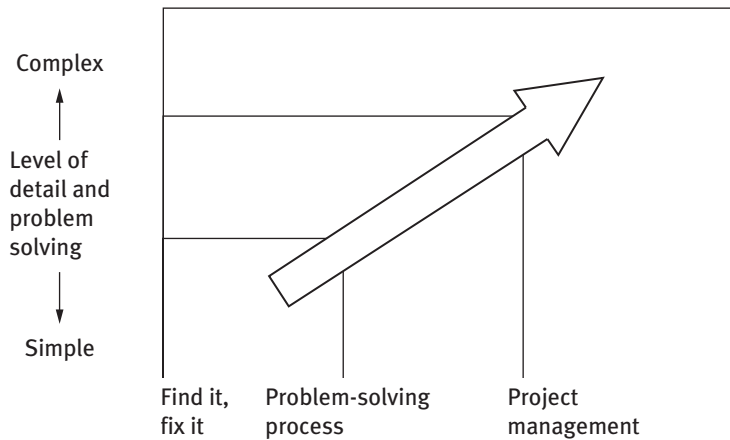
Definition of a Project

A project is a one-time set of activities that culminates in a desired outcome. Therefore, activities that occur repeatedly—for example, making appointments for patients in a clinic—are not projects. However, the installation of new software to upgrade appointment-making capability is a project, as is a major process improvement effort to reduce telephone hold time for patients.

Slack (2005) provides a useful tool for determining the need for formal project management (exhibit 6.1). Operational issues arise frequently; if they are simple, they can be fixed immediately by operations staff. More difficult problems can be addressed by using the tools detailed in chapter 7. However, projects that are complex and have high organizational value need the discipline of formal project management. Many of the strategic initiatives on an organization's balanced scorecard should use the project management methodology.

A well-managed project includes

- a specified scope of work,
- expected outcomes and performance levels,
- a budget,
- a detailed work breakdown tied to a schedule,
- a formal change procedure,
- a communications plan,
- a plan to deal with risk,
- a project conclusion process, and
- a plan for redeployment of staff.

EXHIBIT 6.1**When to
Use Project
Management**

Source: Slack (2005). Used with permission.

Many high-performing organizations also have a formal, executive-level chartering process for projects and a project management office to monitor enterprise-wide project activities. Some healthcare organizations (e.g., health plans) may have a substantial share of their operating resources invested in projects at any one time.

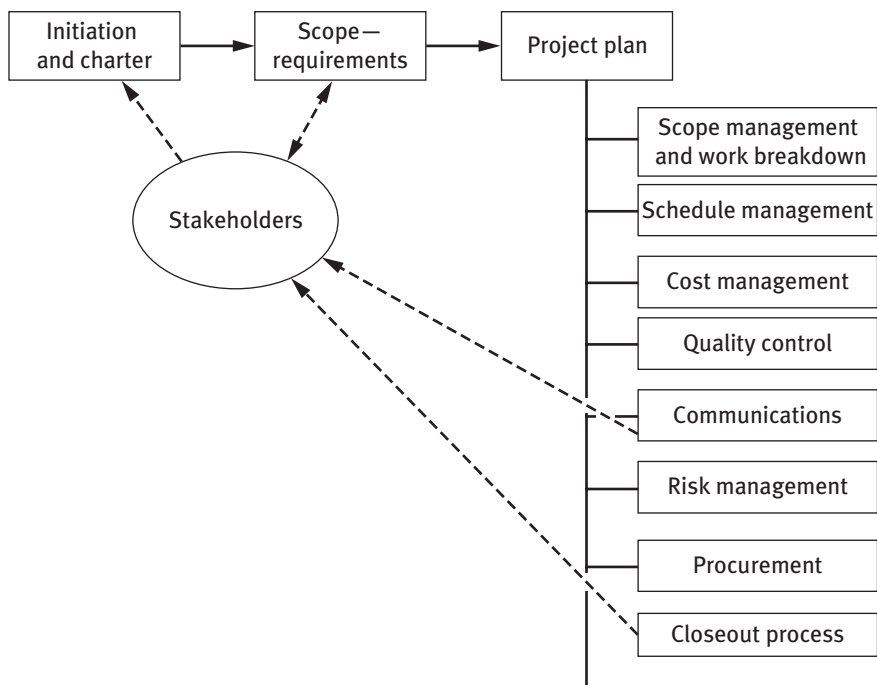
For effective execution of a project, PMI recommends that three elements be in place. A *project charter* begins the project and addresses stakeholder needs. A *project scope statement* identifies the project outcomes, timelines, and budget in detail. Finally, a *project plan* is developed and includes scope management, work breakdown, schedule management, cost management, quality control, staffing management, communications, risk management, procurement, and the closeout process. Exhibit 6.2 displays the relationships among these elements.

Project Selection and Chartering

Project Selection

Most organizations have many projects vying for attention, funding, and senior executive support. The annual budget and strategic planning processes serve as useful vehicles for prioritizing projects in many organizations. The balanced scorecard (chapter 5) helps guide the identification of worthwhile strategic projects. Other external forces (e.g., new Medicare rules) or clinical innovations (e.g., new imaging technologies), however, conspire to present an organization's

EXHIBIT 6.2
Complete
Project
Management
Process



leadership with a list of projects too long for successful implementation. When selection dilemmas present themselves, consider using a quantitative approach, such as the example provided in exhibit 6.3. In this case, each possible project is scored on six measures, including the four balanced scorecard perspectives with a predetermined weighting.

To use this tool, each potential project should be scored by a senior planning group on the following factors: how well it fits into the organization’s strategy, its financial benefit, how it affects quality, its operational impact, key personnel requirements, and the costs and time required for the project itself. A scale of 1 (low) to 10 (high) is usually used. Each criterion is also weighted; the scores are multiplied by their weight for each criterion and summed over all of the criteria. In exhibit 6.3, project B has a higher total score because of its importance to the organization’s strategy. Such a ranking methodology helps organizations avoid committing resources to projects that may have a powerful internal champion but do not advance the organization’s overall strategy. This matrix can be modified with other categories and weights in accordance with an organization’s current needs.

EXHIBIT 6.3
Project
Management
Matrix

Measures	Possible Points	Project A	Project B
Strategy alignment	5	3	5
Financial impact	10	4	8
Quality and productivity impact	5	2	3
Customers/patients impact	7	4	4
Staff availability and training	2	2	1
Probability of success (time, cost)	3	3	1
Total	32	18	22

Project Charter

Once a project is identified for implementation, it needs to be chartered. “The project charter is [a] document issued by the project initiator or sponsor that formally authorizes the existence of a project and provides the project manager with the authority to apply organizational resources to project activities” (PMI 2021b). A project initiator, or sponsor external to the project, issues the charter and signs it to authorize the start of the project.

Four factors tend to constrain the execution of a project charter: time, cost, scope, and performance. A successful project has a scope that specifies the resulting performance level, how much time it will take to complete, and its budgeted cost. A change in any one of these factors affects the other three, as expressed mathematically in the following equation:

$$\text{Scope} = f(\text{Time, Cost, Performance}),$$

where f is the function of the four factors in a project. Similarly,

$$\text{Time} = f(\text{Cost, Scope, Performance}),$$

and so on.

Exhibit 6.4 demonstrates these relationships graphically. Here, the area of the triangle is a measure of the scope of the project. The length of each side of the triangle indicates the amount of time, amount of money, or level of performance needed to complete the project. Because each side of the triangle is connected, changing any of these parameters affects the others. Exhibit 6.5 shows this same project with an increase in required performance

$$\text{Cost} = f(\text{Performance}, \text{Time}, \text{Scope})$$

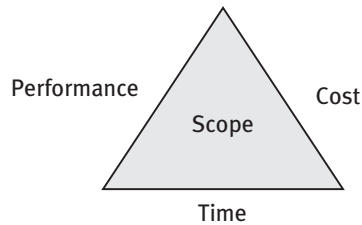


EXHIBIT 6.4
Relationship of
Project Scope
to Performance
Level, Time,
and Cost

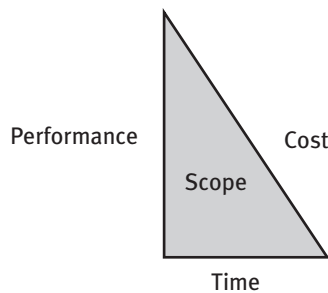


EXHIBIT 6.5
Project with
Increased
Performance
Requirement
and Shortened
Schedule

level and shortened timelines. With the same scope, this “new” project will incur additional costs.

Although determining the exact relationship among all four factors is difficult, the successful project manager understands this general relationship well and communicates it to project sponsors. A useful analogy is the balloon: If you push hard on one part of it, a different part bulges out. The classic project management dilemma is an increase in scope without additional time or funding (sometimes termed *scope creep*). Many project failures are directly attributable to ignoring this unyielding formula.

Stakeholder Identification and Dialogue

The first step in developing a project charter is to identify the **stakeholders**—in general, anyone who has an investment in the outcome of the project. Key stakeholders on a project include the project manager; customers; users; project team members; any contracted organizations involved; the project sponsor; those who can influence the project; and the project management office, if one exists in the organization.

The project manager is the individual held accountable for the project’s success and, therefore, represents the core of the stakeholder group. The customer or user of the service or product is an important stakeholder who

stakeholder
Anyone who has a vested interest in the outcome of a project, including, but not limited to, employees, customers, users, partner organizations, project sponsors, and the project manager.

influences and helps determine the performance of the final product. Even if project team members serve on the project in a limited part-time role, the success of the project reflects on them; therefore, they become stakeholders as well. A common contracting relationship in healthcare involves large IT installations provided through an outside vendor, which also is included as a project stakeholder. A project should always have a sponsor with enough executive-level influence to clear roadblocks as the project progresses; hence, such individuals need to be included in the stakeholder group. A project may be aided or hindered by many individuals or organizations that are not directly part of it; a global systems analysis should be performed (the system as depicted in exhibit 1.2, chapter 1) to identify which of these should be included as stakeholders.

Once stakeholders have been identified, they need to be interviewed by the project manager to develop the project charter. If an important stakeholder is not available, the project manager should interview someone who represents the stakeholder's interests. At this point, differentiating between the needs and the wants of stakeholders is important. Adequate detail must be gathered in this process to construct the project charter.

When the project team is organized, it need not include all stakeholders, but the team should be vigilant in attempting to meet all stakeholder needs. The project team should also be cognizant of the culture of the organization, sometimes defined as "how things get done around here." Projects that challenge an organization's culture encounter frequent difficulties.

Feasibility Analysis

An important activity in developing the project charter is determining the project's feasibility. Feasibility analysis is the review of all the elements of a project that are judged by the project's sponsor to be acceptable, leading to its approval. Because the project already should have undergone an initial prioritization review by the senior management team, the link to the organization's strategy likely has already been made. To reinforce that linkage, it should be documented in the feasibility analysis. The operational and technical feasibility should also be examined. For example, a new clinical project that requires the construction of new facilities may be impeded in its execution because its timing is contingent on completion of the new buildings.

An initial schedule should be created as part of the feasibility analysis to avoid committing to a requested completion date that is impossible to meet. Finally, both financial benefit and marketplace demand should be considered here. Conducting a financial feasibility analysis is beyond the scope of this text; consult Reiter and Song (2021) to view numerous examples of financial analysis.

All elements of the feasibility analysis should be included in the project charter document, which is described next.

Project Charter Document

The project charter authorizes the project and serves as an executive summary. A formal charter document should be constructed with the following elements:

- Project mission statement
- Project purpose or justification and connection to strategic goals
- High-level requirements that satisfy customers, sponsors, and other stakeholders
- Assigned project manager and authority level
- Summary milestones
- Stakeholder influences
- Functional organizations and their expected level of participation
- Organizational, environmental, and external assumptions and constraints
- Financial business case, budget, and return on investment
- Project sponsor with approval signature

A project charter template is provided on the companion website to this book. The initial description of the project scope is found in the Requirements, Milestones, and Financial sections of the template.

On the web at 
ache.org/books/OpsManagement4

A project charter can be illustrated with an example from Vincent Valley Hospital and Health System (VVH). The hospital operates an oncology clinic, Riverview Clinic, in the south suburban area of Bakersville. Recently, the three largest health plans in the area instituted value purchasing programs to encourage the use of precision medicine in the care of patients with cancer. Precision medicine focuses on identifying which therapeutic approaches will be effective for which patients on the basis of genetic, environmental, and lifestyle factors. For cancer care, pharmacogenomics—the study of how genes affect a person’s response to particular drugs—is a key element of precision medicine. This therapeutic approach combines pharmacology (the science of drugs) and genomics (the study of genes and their functions) to develop effective, safe medications and doses tailored to variations in a person’s genes (Lister Hill 2016).

The health plans will pay the clinic bonuses if Riverview achieves specific levels of performance in the use of precision medicine. The value purchasing system is being initiated because precision medicine has been shown to provide better results for the patient and to reduce the health plans’ costs over the course of treatment (Plöthner et al. 2016). Riverview Clinic staff have decided to embark on a project to increase their use of precision medicine; their project charter is displayed in exhibit 6.6.

EXHIBIT 6.6**Project
Charter for
VVH Precision
Medicine
Project****Project Mission Statement**

This project for Vincent Valley Hospital and Health System (VVH) will increase the level of use of precision medicine—pharmacogenomic drugs—to improve outcomes, lower the long-term costs of care to our patients, and increase reimbursements to the clinic.

Project Purpose and Justification

Health plans in Bakersville have begun to provide additional funding to clinics that meet pharmacogenomic use guidelines. Although a number of conditions are covered by these new payment systems, VVH leadership feels that pharmacogenomic drug use should be the first project executed because it is likely to be accomplished in a reasonable time frame with the maximum financial benefit to our patients and the clinic. Once this project has been executed, the clinic will move on to more complex clinical conditions.

The project team will be able to incorporate what it has learned about some of the barriers to success and methods to succeed in value purchasing. This project is a part of the larger VVH strategic initiative of maximizing reimbursement.

High-Level Requirements

Once completed, a new prescribing process will

- continue to meet patients' clinical needs and provide high-quality care and
- increase pharmacogenomic drug use by 4 percent from baseline within six months.

Assigned Project Manager and Authority Level

Sally Humphries, RN, will be the project manager. Sally has authority to make changes in budget, time, scope, and performance by up to 10 percent. Any larger change requires approval from the clinic operating board.

Summary Milestones

- The project will commence on January 1.
- A system to identify approved pharmacogenomic drugs will be available on February 15.
- The system will go live on March 15.

Stakeholder Influences

The following stakeholders will influence the project:

- *Clinicians* will strive to provide the best care for their patients.
- *Patients* will need to understand the benefits of this new system.
- *Clinic staff* will need training and support tools.
- *Health plans* should be a partner in this project as part of the supply chain.
- *Pharmaceutical firms* should provide clinical information on the efficacy of certain pharmacogenomic drugs.

(continued)

Functional Organizations and Their Participation

- Clinic management staff will lead.
- Compcare (electronic health record vendor) will perform software modifications.
- VVH information technology (IT) department will support.
- VVH main pharmacy department will support.

Organizational, Environmental, and External Assumptions and Constraints

- Success depends on appropriate substitution of pharmacogenomics for more traditional therapeutic approaches.
- Patients need to understand the benefits of this change.
- Health plans need to continue to fund this project over a number of years.
- IT modifications need to be approved rapidly by the VVH central IT department.

Financial Business Case—Return on Investment

The project budget is \$161,000 for personnel. Software modifications are included in the master VVH contract and, therefore, have no direct cost impact on this project. If the 4 percent increase in pharmacogenomic drug use is achieved, the two-year revenue increase should be approximately \$175,000.

Project Sponsor with Approval Signature

Dr. Jim Anderson, Clinic President

James Anderson, MD

EXHIBIT 6.6

Project
Charter for
VVH Precision
Medicine
Project
*(continued from
previous page)*

Project Scope and Work Breakdown

Once a project has been chartered, the detailed work of planning can begin.

Tools

At this point, the project manager should consider acquiring two important tools. The first is the lowest of low tech, the humble three-ring binder. All projects need a continuous record of progress reports, team meetings, approved changes, and so on. A complex project requires many binders, and they will prove invaluable to the project manager. The classic organization of the binders is by date, so the first pages should be the project charter. Of course, if the organization has an effective imaging and document management system, this can substitute for the binders.

The second tool is project management software. Although many options are available, the market leader is Microsoft Project, which is used for the

examples throughout the remainder of the chapter. Microsoft Project is part of the Microsoft Office suite and may already be on many computers in the organization. If not, a demonstration copy can be downloaded from Microsoft.



On the web at
ache.org/books/OpsManagement4

The companion website for this book provides additional explanation related to the use of Project, along with detailed illustrations of the software's use for the Riverview Clinic precision medicine drug project.

Project management software is not essential for small projects, but it is helpful and almost required for any project that lasts longer than six months and involves a large team of individuals. Although the Riverview Clinic pharmacogenomic drug project is relatively small, Project software is used to manage it to provide an illustration of the program's applicability.

Scope

The project scope determines what activities fall within the parameters of a project—a good scope document is specific about these boundaries. The starting point for developing the detailed scope document is the project charter. To provide the level of detail needed for this document, the project manager revisits many of the same stakeholders who contributed to the charter to acquire specific inputs and requirements. A simple methodology is to interview stakeholders and ask them to list the three most important outcomes of the project, which can be combined into project objectives. The objectives must be specific, achievable, measurable, and comprehensible to stakeholders. In addition, they should be stated in terms of time-limited “deliverables.” For example, the objective “Improve the quality of care to patients with diabetes” is a poor one, whereas “Improve the rate of foot examinations for patients with diabetes by 25 percent in one year” is much better because it states a specific, measurable goal that makes sense to stakeholders and is likely achievable.

The scope document also provides detailed requirements and descriptions of expected outcomes, and it often specifies what types of outcomes are *not* being sought. For example, the Riverview Clinic project scope document might state that the project does not include the use of pharmacogenomic drugs that are still undergoing clinical trials.

The types of deliverables should be specified in the project scope as well, such as implementation of a new process, installation of a new piece of equipment, or presentation of a report. The organization of the project's personnel is also clarified in the scope document. It names the project manager and team members and defines their relationships in terms of their roles in the overall organization.

An initial evaluation of potential risks to the project should be presented in the scope document. As with other details, the schedule length and milestones should be more detailed in the scope statement than in the charter. As

discussed in the next section, the final schedule is developed on the basis of the work breakdown structure. Finally, the scope document should include methods for monitoring progress and making changes where necessary, including the formal approvals required.

The individual assigned to create the project scope document must avoid expanding the scope of the project beyond its original intent: “While we are at it, we might as well ____.” These add-ons, sometimes called “gold plating,” tend to be some of the most dangerous occurrences in the world of project management because they can result in projects going over budget, not being completed on time, and not meeting performance goals.

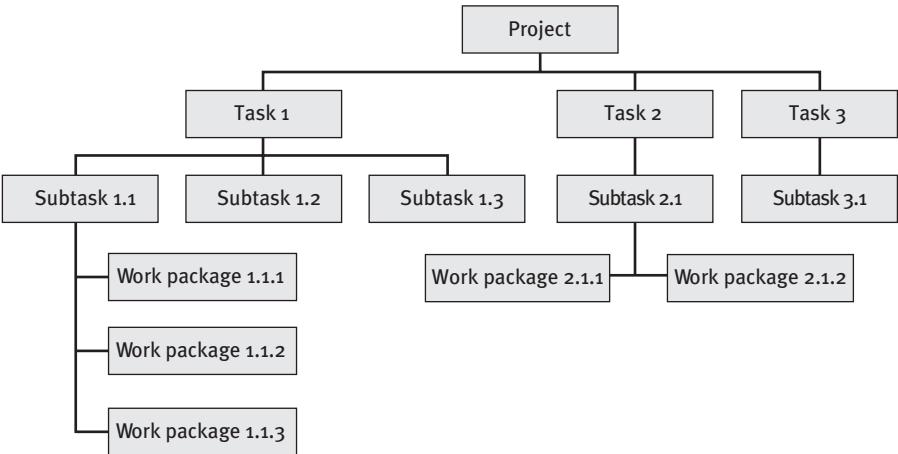
Work Breakdown Structure

The second major component of the scope document is the **work breakdown structure (WBS)**, considered the engine of the project because it determines how the project’s goals are to be achieved. The WBS lists the tasks that need to be accomplished, including an estimate of the resources required (e.g., staff time, services, equipment). For complex projects, the WBS is a hierarchy of major tasks, subtasks, and work packages (subdivisions of the work contained in a subtask). Exhibit 6.7 demonstrates this framework graphically.

The size of each task should be planned carefully. A task should not be so small that its monitoring consumes a disproportionate share of the task itself. Similarly, an overly large task cannot be effectively monitored and should be divided into subtasks and then work packages. The task should be described in enough detail that the individual responsible, the cost, and the duration can be identified.

work breakdown structure (WBS)
A list of the tasks that need to be accomplished, their relationship to each other, and the resources required for a project to meet its goals.

EXHIBIT 6.7
General Format for WBS



Note: This type of diagram can be generated in Microsoft Word and other Microsoft Office products by using the commands Insert → Smart Art → Hierarchy. WBS = work breakdown structure.

A reasonable guideline in terms of duration is that a task should be one to three weeks in length to be effectively monitored. Some tasks are particularly critical to the success of the project. These tasks should be identified as *milestones*. The completion of milestones provides a convenient shorthand method to communicate overall project progress to stakeholders.

The WBS can be developed by the project team itself or with the help of outside experts who have executed similar projects. At this point in the project, the WBS is the best estimate of how the project will be executed. Of course, WBSs are almost always inaccurate in some way, so the formal control and change procedures described in this section are essential to successful project management.

After the WBS has been constructed, the resources required and estimated time for each element must be refined. Estimating the time a task will require is an art and is best exercised by a team of individuals. Any previous experiences and data can be helpful in this phase. One group process that has proved useful is the program evaluation and review technique (PERT) for time estimation. Team members individually estimate the time a task will take at its best, worst, and most likely progression. After averaging the team's responses for each of the times, the final PERT time estimate is computed as

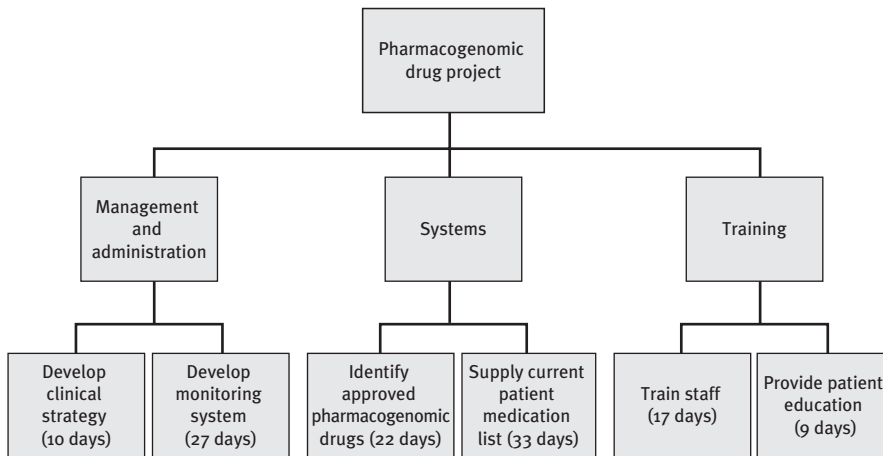
$$\text{Estimated task time} = \frac{\text{Best} + (4 \times \text{Most likely}) + \text{Worst}}{6}$$

After a number of meetings, the Riverview Clinic team has determined that the pharmacogenomic drug project includes three major tasks, each with two subtasks, that need to be accomplished to meet the goals of the project. The subtasks are as follows:

- Develop a clinical strategy that maintains quality care with the increased use of pharmacogenomics.
- Develop a system to inform clinicians of approved pharmacogenomics.
- Update systems to ensure that timely patient medication lists are available to clinicians.
- Develop and deploy a staff education plan.
- Develop a system to monitor performance.
- Develop and begin to distribute patient education materials.

The WBS for Riverview Clinic's project is displayed in exhibit 6.8. The actions listed in the bottom tier represent the higher-level tasks for this project. For a project of this scope to proceed effectively, many more subtasks, perhaps

EXHIBIT 6.8
WBS for
Riverview
Pharmaco-
genomic Drug
Project



Note: WBS = work breakdown structure.

50 to 100, are generally required; we are limiting this example to higher-level tasks to illustrate the principles of project management.

It is important to note that the time estimate for each task is the total time needed to accomplish a task, not the calendar time it will take—a three-day task can be accomplished in three days by one person or in one day by three people.

The next step is to determine what resources are needed to accomplish these tasks. Riverview Clinic has decided that this project will be accomplished by four existing employees and the purchase of consulting time from VVH's IT supplier. The individuals involved are

- Tom Simpson, clinic administrator;
- Dr. Betsey Thompson, oncologist;
- Sally Humphries, RN, nursing supervisor;
- Cindy Tang, billing manager; and
- Bill Onku, IT vendor support consultant.

The Project software provides a convenient window in which to document these individuals' participation and their cost per hour. The program also provides higher levels of detail, such as the hours an individual can devote to the project and actual calendar days that they are available. When asking clinicians to contribute to a project, the project manager should consider the revenue per hour generated by these individuals, as opposed to their salaries

EXHIBIT 6.9
Resources for
the Riverview
Clinic Pharma-
cogenomic Drug
Project

	Resource Name	Type	Material	Initials	Group	Max.	Std. Rate	Out. Rate	Cost/Use	Accrue	Base	Code
1	Dr. Betsey Thompson	Work		D		100%	\$90.00/hr	\$0.00/hr	\$0.00	Prorated	Standard	
2	Sally Humphries RH	Work		S		100%	\$60.00/hr	\$0.00/hr	\$0.00	Prorated	Standard	
3	Tom Simpson	Work		T		100%	\$75.00/hr	\$0.00/hr	\$0.00	Prorated	Standard	
4	Cindy Tang	Work		C		100%	\$40.00/hr	\$0.00/hr	\$0.00	Prorated	Standard	
5	Bill Onku	Work		B		100%	\$130.00/hr	\$0.00/hr	\$0.00	Prorated	Standard	

and benefits, because most organizations lose this revenue if the clinician has a busy practice. Exhibit 6.9 shows the Project window for the Riverview Clinic staff who will work on the pharmacogenomic drug project.

RASIC

A chart delineating all project team members’ roles for each task in a project. The acronym comes from the members’ roles: responsible, approval, support, informed, consult.

Team members should be clear about their accountability for each task. A functional responsibility chart, such as the **RASIC** framework (which stands for *responsible, approval, support, informed, and consult*) is helpful; the Riverview project RASIC is displayed in exhibit 6.10. The RASIC diagram is a matrix of team members and tasks from the WBS. For each task, one individual is responsible (R) for ensuring that the task is completed. Other team members may need to approve (A) the completion of the task. Additional team members may work on the task as well, so they are considered support (S). Assigning

EXHIBIT 6.10
RASIC for the
Riverview
Pharma-
cogenomic Drug
Project

WBS Task	Clinic Board of Directors	Lead MD Betsey Thompson	Adminis- trator Tom Simpson	Project Manager Sally Humphries	Billing Lead Cindy Tang	IT Lead Bill Onku
Develop clinical strategy	A	R	C	C	I	I
System to identify approved pharmacogenomics	A	R	S	R	S	
Updated medication lists	R	I	S	I	S	
Patient education	A	S	S	R	I	I
Staff education	A	R	C	S	I	
Monitoring system	A	C	R	C	S	C

Note: R = responsible; A = approval; S = support; I = inform; C = consult. WBS = work breakdown structure.

to a team member the obligation to inform (I) other members helps a team communicate effectively. Finally, some team members need to be consulted (C) as a task is implemented.

Scheduling

Network Diagrams and Gantt Charts

Because the WBS does not specify a sequence of activities, the next step is to schedule each task to complete the total project. First, the logical order of the tasks must be determined. For example, the Riverview Clinic project team has determined that the system to identify appropriate pharmacogenomic drugs must be developed before the training of staff and education of patients can begin. Other constraints must also be considered in the schedule, including required start or completion dates and resource availability.

Two tools are used to visually display the schedule. The first is a **network diagram** that connects each task in precedence order. This is essentially a process map (chapter 7) in which the process is performed only once; the main difference is that network diagrams do not display paths that return to the beginning (as happens frequently in process maps). A practical way to develop an initial network diagram is to place each task on a sticky note and arrange, and rearrange, the notes on a set of flip charts until they meet the logical and date-imposed constraints. The tasks can then be entered into a project management software system.

Exhibit 6.11 is the network diagram developed by the team for the Riverview Clinic pharmacogenomic drug project. This schedule can be entered into Project to generate a similar diagram. Another common scheduling tool is the Gantt chart, which lists each task on the left side of the page with a bar indicating the start and end times. The **Gantt chart** for the Riverview Clinic

network diagram
A scheduling tool that connects tasks in order of precedence.

Gantt chart
A scheduling tool that lists project tasks, with bars indicating start and end dates for each task.

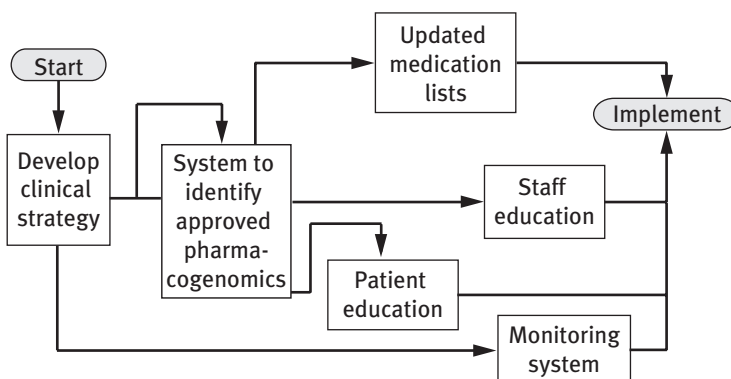
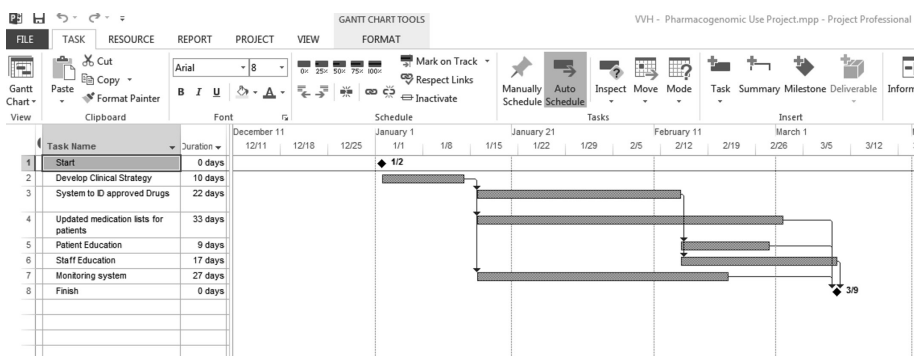


EXHIBIT 6.11
Network Diagram for Riverview Pharmacogenomic Drug Project

EXHIBIT 6.12

Riverview Pharmacogenomic Drug Project Gantt Chart

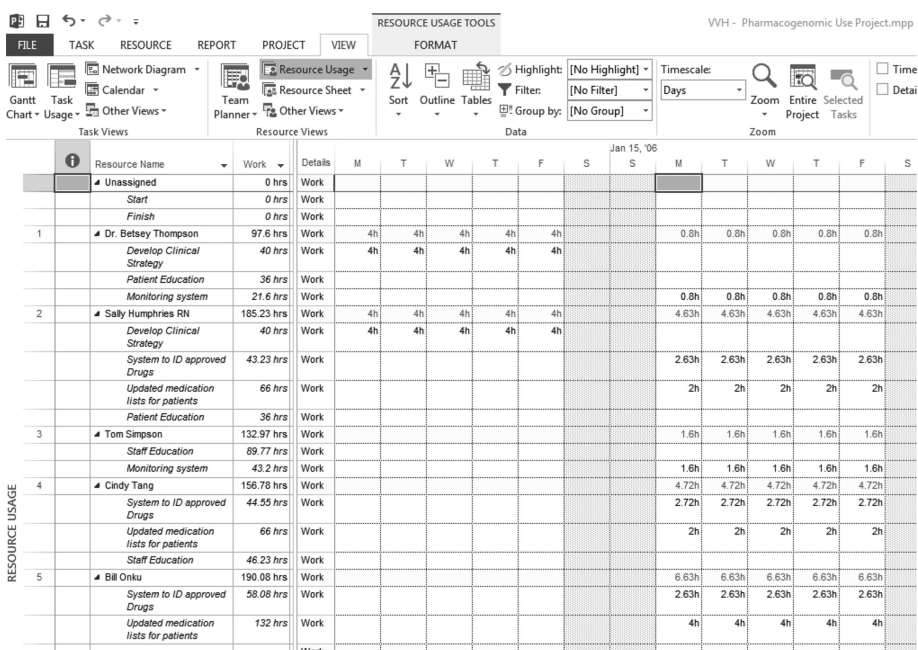


project, generated by Project, is shown in exhibit 6.12. Each bar indicates the duration of the task, and the small arrows connecting the bars indicate the predecessor–successor relationship of the tasks.

The next step is to assign resources to each task. Exhibit 6.13 shows how the resources are assigned for each day in the project. Care must be taken when assigning resources, as no person works 100 percent of the time. If any single individual is allocated at more than 80 percent in any period, the schedule may need to be adjusted to reduce this allocation. Adjusting the schedule to accommodate this constraint is known as “resource leveling.”

EXHIBIT 6.13

Riverview Pharmacogenomic Drug Project Tasks with Resources Assigned



A final review of this initial schedule is undertaken to assess how many tasks are being performed in parallel (simultaneously). A project with few parallel tasks takes longer to complete than does one with more total tasks of which many are parallel. Another consideration may be date constraints. Examples include a task that cannot begin until a certain date because of staff availability and a task that must be completed by a certain date to meet an externally imposed deadline (e.g., new Medicare billing policy). The Project software provides tools to set these constraints in the schedule.

Slack and the Critical Path

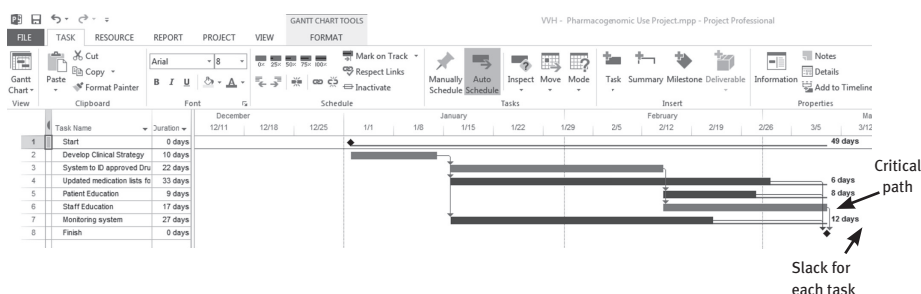
To optimize a schedule, the project manager must pay attention to slack in the schedule and to the critical path. A task that takes three days but does not need to be completed for five days is said to have two days of slack. The critical path is the longest sequence of tasks with no slack, or the shortest possible completion time of the project.

Slack is determined by the early finish and late finish dates. The *early finish date* is the earliest date that a task could possibly be completed, as determined by the early finish dates of predecessor tasks. The *late finish date* is the latest date that a task can be completed without delaying the finish of the project; it is based on the late start and late finish dates of successor tasks. The difference between early finish and late finish dates equals the amount of slack. For critical path tasks (which have no slack), the early finish and late finish dates are identical. Tasks with slack can start later based on the amount of slack they have available. In other words, if (1) a task takes three days, (2) the early finish date is day 18 (based on its predecessors), and (3) the late finish date is day 30 (based on its successors), the slack for this task is 12 days; this task could start as late as day 27 without affecting the completion date of the project. The critical path, which determines the duration of a project, is the connected course through a project of critical tasks.

Calculating slack and the critical path can be complex and time-consuming. Fortunately, Project performs these functions automatically. However, in some cases (e.g., a basic clinical research project), estimating the duration of tasks is difficult. If a project includes many tasks with high variability in their expected durations, the PERT estimating system should be used. Note that, although PERT employs probabilistic task times to estimate slack and critical paths and is good for time estimation prior to the start of the project, the critical path method is better suited for project management once a project has begun. Having a range of start dates for a task is not particularly useful—what is really important is knowing when a task should have started and whether the project is ahead of or behind schedule.

Although Project provides a PERT scheduling function, the use of PERT is infrequent in healthcare and beyond the scope of this book. Exhibit 6.14

EXHIBIT 6.14
Gantt Chart
for Riverview
Clinic Pharma-
cogenomic
Drug Project
with Slack and
Critical Path
Calculated



displays a Gantt chart for the Riverview Clinic pharmacogenomics project, with slack and critical path calculated.

Schedule Compression

Say the president of Riverview Clinic has been notified by one health plan that if the Riverview pharmacogenomic drug project is implemented by March 1, the clinic will receive a \$20,000 bonus. He asks the project manager to consider speeding up, or “crashing,” the project.

The term *project crashing* has negative associations, as the thought of a computer crashing stirs up dire images. However, a crashed project is simply one that has had its schedule compressed. Schedule compression of a project requires reducing the length of the critical path and can be achieved by using any of the following techniques (PMI 2021b):

- Shortening the duration of work on a task on the critical path
- Changing a task constraint to allow for more scheduling flexibility
- Breaking a critical task into smaller tasks that can be worked on simultaneously by different resources
- Revising task dependencies to allow more scheduling flexibility
- Performing tasks in parallel as opposed to a linear sequence (fast-tracking)
- Setting lead time between dependent tasks where applicable
- Scheduling overtime
- Bringing in additional staff
- Paying for expedited delivery of needed supplies
- Assigning additional resources to work on critical path tasks
- Lowering performance goals (not recommended without strong stakeholder agreement)

The scope, time, duration, and performance relationships need to be considered in a crashed project. A crashed project has a high risk of costing

more than the original schedule predicted, so the formal change procedure, discussed in the next section, should be used.

Project Control

Project management would be straightforward if every project's schedule and costs occurred according to the initial project plan. However, because this is almost never the case, an effective project monitoring and change control system must be in place throughout the life of a project.

Monitoring Progress

The first important monitoring element is a system to measure schedule completion, cost, and expected performance against the initial plan. Microsoft Project provides a number of tools to assist the project manager in this area. After the plan's initial scope document, WBS, staffing, and budget have been determined, they are saved as the "baseline plan." Any changes during the project can be compared to this baseline.

On a disciplined time basis (e.g., once per week), the project manager needs to receive a progress report from each task manager—the individual designated as responsible on the RASIC chart (see exhibit 6.10 and the companion website for examples)—regarding schedule completion and cost.

On the web at
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Change Control

The project manager should hold a status meeting at least once a month, and preferably more frequently. At this meeting, the project team should review the actual status of the project in terms of task completion, expenses, personnel utilization, and progress toward expected project outcomes. The majority of time spent in these meetings should be devoted to problem solving, not reporting.

Once deviations are detected, their source and causes must be determined by the team. For major or complex deviations, diagnostic tools such as fishbone diagrams (chapter 7) can be used. Three courses of action are now available: Ignore the deviation if it is small, take corrective action to remedy the problem, or modify the plan by using the formal change procedure developed in the project charter and scope document.

One major cause of deviations is an event that occurs outside the project. The environment constantly changes during a project's execution, and modifications of the project's scope or performance level may be necessary. For example, the application of a new clinical breakthrough may take priority over projects that improve support systems, or a competitor may initiate a new service that requires a response.

A formal change mechanism is a key tool used by high-performing project managers. Resistance to communicating a schedule or cost problem to project sponsors and stakeholders is part of human nature. However, the consequences of this inaction can be significant, if not fatal, to large projects. The change process forces all parties involved in a project to subject themselves to disciplined analysis of options and creates disincentives for scope creep. Changes to the initial plan should be documented in writing and formally approved by the project sponsor as appropriate. They should then be added to the project records (three-ring binders or equivalent).

The Riverview Clinic project charter (and subsequent scope document) states that changes in plan that constitute less than 10 percent of the total affected resource can be made by project manager Sally Humphries. Therefore, she is authorized to adjust the schedule by up to 4.9 days, the cost by up to \$6,100, and the performance goal by 0.4 percent. For deviations greater than these amounts, Sally needs the clinic board to review and sign off on the adjustment. The companion website contains project change documentation and a sign-off template.



On the web at
ache.org/books/OpsManagement4

Communications

A formal communications plan should be developed as part of scope creation. Communications to internal and external stakeholders are critical to the success of a project. Many types of communications media can be used, from simple oral briefings to emails to formal reports. One approach used by many organizations today is to establish a web-based intranet that contains detailed information on the project, combined with a periodical email update sent to stakeholders with a summary progress report and links back to the intranet site for more detailed information. A sophisticated communications plan is fine-tuned to meet stakeholder needs and interests and communicates only those issues of interest to each stakeholder. As part of the communications strategy, feedback from stakeholders should always be solicited, as changes in the project plan may affect one or more stakeholders in ways unknown to the project manager.

The project update communications should contain information gathered from quantitative reports. At a minimum, these communications should provide progress against baseline on schedule, cost, scope, and expected performance. Any changes to project baseline or the approval process should be noted, as should those issues that need resolution or are being resolved. The expected completion date is always of interest to all stakeholders and should be a prominent part of any project plan communication.

Risk Management

Comprehensive prospective **risk management** is another element of successful projects. A risk is an event that, if realized, causes the project to experience a

risk management
Within a project, the identification of possible events that, if realized, will affect the execution of the project and a plan to mitigate these events.

substantial deviation from the planned schedule, cost, scope, or performance. Like many other aspects of project management, developing a risk management plan at the beginning of a project—and updating it continuously as the project progresses—takes discipline.

The most direct way to develop a risk management plan is to begin with the WBS. Each task in the WBS should be assessed for risks, both known and unknown. Risks can occur for each task in its performance, duration, or cost. If a project includes 50 tasks, it has 150 potential risks.

A number of techniques can be used to identify risks; the most straightforward is a brainstorming exercise by the project team. (Some of the tools found in chapter 7, such as mind mapping, root-cause analysis, and force field analysis, can also be used in risk assessment.) Another useful technique is to interview stakeholders to identify risks to the project as viewed from their perspective. The organization's strategic plan is also a resource, especially if it contains a *strengths, weaknesses, opportunities, and threats analysis* (frequently referred to as a SWOT analysis). The weaknesses and threats sections may contain clues as to potential risks to a project task.

Once risks have been identified for each task in the WBS, the project team should assign a risk probability to each. Those risks with the highest probability, or likelihood, of occurring during the project should be analyzed in depth and a risk management strategy devised. The failure mode and effects analysis method (chapter 7) can also be used for a more rigorous risk analysis.

For tasks that are critical to project execution or that carry high risk, a quantitative analysis can be conducted. Assuming that data can be collected for similar tasks in multiple circumstances, probability distributions can be created and used for simulation and modeling. An example of the applicability of this technique is in remodeling space in an older building. If an organization were to review a number of recent remodeling projects, it might determine that the average cost per square foot of remodeled space is \$200 with a normal distribution (think bell curve; distribution is discussed in more detail later in the book). This information may be used as the basis of a Monte Carlo simulation or as part of a decision tree (chapter 7). The results of these simulations provide the project manager with quantitative boundaries on the possible risks associated with the task and project and are useful in constructing mitigation strategies.

Tasks with the following characteristics may be high risk and thus should be considered carefully:

- Long duration
- Highly variable estimates of duration
- Dependence on external organizations
- Requirement of a unique resource (e.g., a physician who is on call)
- Likely to be affected by external government or payer policies

The management strategy for each identified risk should have three components. First, risk avoidance initiatives should be identified. Avoiding an adverse event is always preferable to dealing with its consequences. An example of a risk avoidance strategy is to provide mentoring to a young team member who has responsibility for key tasks in the project plan.

mitigation plan
A set of tasks intended to reduce or eliminate the effect of risk in a project.

The second element of the risk management strategy is to develop a **mitigation plan**. One example of a mitigation response is to bring additional people and financial resources to a task. Another is to call on the project sponsor to help break an organizational logjam.

Third, a project team may decide to transfer the risk to an insurance entity. This strategy is common in construction projects through the use of bonding for contractors.

All identified risks and their management plans should be outlined in a *risk register*, a listing of each task, identified risks, and prevention and mitigation plans. This register should be updated throughout the life of the project.

The Riverview Clinic project team has identified three serious risks, which are listed in exhibit 6.15 with their mitigation plans.

Quality Management, Procurement, the Project Management Office, and Project Closure

Quality Management

The majority of the focus in this chapter has been on managing the scope, cost, and schedule of a project. The performance, or quality, of an operational project is the fourth key element in successful project management. In general, quality can be defined as meeting specified performance levels with minimal variation and waste.

EXHIBIT 6.15
Risk Mitigation
Plan for the
Riverview
Clinic Pharma-
cogenomic Drug
Project

Risk	Mitigation Plan
Pharmacogenomic drug use is not as effective as traditional methods.	Assistance will be sought from • VVH hospital pharmacy • Pharmaceutical firms • Health plans
Computer systems do not work.	• IT vendor has specialists on call who will be flown to Riverview Clinic. • Assistance will be sought from VVH IT department.
Software modifications are more expensive than budgeted.	• Contingency funding has been earmarked in clinic budget.

The fundamental tools for accomplishing these goals are described in chapters 7 and 9. More advanced techniques for reducing variation in outcomes can be found in chapter 9 (Quality), and chapter 10 discusses tools for waste reduction (Lean).

Throughout the life of a project, the project team should monitor the expected quality of the final product. Individual tasks that are part of a quality management function within a project should be created in the WBS. For example, one task in the Riverview Clinic pharmacogenomics project is to develop a monitoring system. This system will not only track the use of pharmacogenomic drugs but also ascertain whether their use results in any negative clinical effects.

Procurement

Many projects depend on outside vendors and contractors, so a procurement system integrated with the organization's project management system is essential. The organization's purchasing or procurement department can be helpful in this process as well. Procurement staff have developed templates for many of the processes described in the following paragraphs. They also have knowledge of the latest legal constraints an organization may face. However, the most useful attribute of the procurement department may be the frequency with which it executes the purchasing cycle. By performing this task frequently, its staff have developed expertise in the process and are aware of common pitfalls to avoid.

Contracting

Once an organization has decided to contract with a vendor for a portion of a project, three basic types of contracting are available. The *fixed-price contract* is an agreement that features a lump sum payment for the performance of specified tasks. Fixed-price contracts sometimes contain incentives for early delivery.

Cost-reimbursement contracts call for payment to be made to the vendor on the basis of the vendor's direct and indirect costs of delivering the service for a specified task. Clearly documenting in advance how the vendor will calculate its costs is important.

The most open-ended type of contract is known as a *time-and-materials contract*. Here, the task itself may be difficult to define, and the contractor is reimbursed for her actual time, materials, and overhead. A time-and-materials contract is commonly used for remodeling an older building, where the contractor is not certain of what she will find in the walls. Great caution and monitoring are needed when an organization uses this type of contracting.

Any contract should contain a **statement of work (SOW)**. The SOW contains a detailed scope statement, including WBS, for the work to be

statement of work (SOW)

A detailed set of tasks, expected outcomes, dates, and costs of a project undertaken by an external contractor.

performed by the contractor. It also includes expected quantity and quality levels, performance data, task durations, work locations, and other details used to monitor the work of the contractor.

Selecting a Vendor

Once a preliminary SOW has been developed, the organization solicits proposals and selects a vendor. A useful first step is to issue a *request for information (RFI)* to as many possible vendors as the project team can identify. The RFIs generate responses from vendors about their products and experience with similar organizations. On the basis of these responses, the number of feasible vendors can be reduced to a manageable set for consideration.

A more formal *request for proposal (RFP)* can then be issued to the remaining vendors under consideration for the task. The RFP asks for a detailed proposal, or bid. The following criteria should be applied in the process of reviewing RFPs and awarding the contract:

- Does the vendor clearly understand the organization's requirements?
- What is the vendor's total cost estimate for completing the task?
- Does the vendor have the capability and correct technical approach to deliver the requested service?
- Does the vendor have a management approach to monitor successful execution of the SOW?
- Can the vendor provide maintenance or meet future requirements and changes?
- Does the vendor provide references from clients that are similar to the contracting organization?
- Does the vendor assert intellectual or proprietary property rights in the products it supplies?

Project Management Office

Many types of organizations outside the healthcare industry (e.g., architecture, consulting) are primarily project oriented. Such organizations often have a centralized project management office (PMO) to oversee the work of their staff. Because healthcare delivery organizations are primarily operational, the majority do not use this structure.

However, departments in large hospitals and clinics, such as IT and quality, have begun to use a centralized project office approach. In addition, some organizations have designated and trained project leaders in Six Sigma or Lean techniques. These project leaders are assigned from a central PMO.

PMOs provide a single structure through which to monitor progress on all projects in an organization and reallocate resources as needed when

projects encounter problems. They also serve as a resource for the training and development of project managers. PMOs support the project manager in many ways, including but not limited to the following (PMI 2021b):

- Managing shared resources across all projects administered by the PMO
- Identifying and developing project management methodology, best practices, and standards
- Coaching, mentoring, training, and oversight
- Developing and managing project policies, procedures, templates, and other shared documentation
- Monitoring compliance with project management standards, policies, procedures, and templates via project audits
- Coordinating communications across all projects

Another useful function of a PMO is that it maintains an information system that can provide reports to project stakeholders and senior management. The contents of this information system may include the following:

- Progress reports on individual projects (schedule, cost, performance)
- Risk management (tasks with high risks and their current status)
- Performance failures and remediation steps
- A log of lessons learned

Project Closure

A successful project should have an organized closure process, which includes a formal stakeholder presentation and approval process. In addition, the project sponsor should sign off at project completion to signify that performance levels have been achieved and all deliverables have been received. During the closeout process, special attention should be paid to project staff, who will be interested in knowing their next assignment. A disciplined handoff of staff from one project to the next allows successful completion of the closure process.

All documents related to the project should be indexed and stored. This process can be helpful if outside vendors have participated in the project and a contract dispute arises in the future. Historical documents can also provide a good starting point for the next version of a project.

The project team should conduct a final session to identify lessons learned—good and bad—in the execution of the project. These lessons should be included in the project documentation and shared with other project managers in the organization.

Agile Project Management

In some situations, knowledge of the tasks necessary for project success is not available as the project is chartered and scheduled. In these cases, agile project management often works better than other methods. Agile project management is *adaptive*, in contrast to the *predictive* style of formal project management.

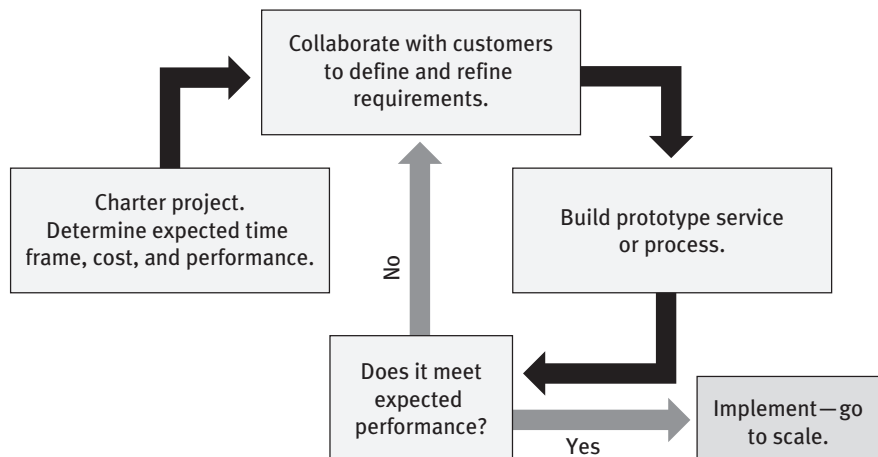
Characteristics of agile project management include the following:

- Customer satisfaction is achieved by rapid, continuous delivery of services or new processes.
- Newly prototyped services or processes are delivered frequently (weekly rather than monthly).
- The effectiveness and ease of use of these prototypes are the principal measures of progress.
- The project team can easily incorporate late changes.
- The project team and customer interact informally and frequently.
- The project team and customer are co-located.
- The project team is cross-functional across the organization.
- Continuous attention is given to technical excellence and good design in the new services or processes.
- The project team regularly adapts to changing circumstances.

Exhibit 6.16 illustrates agile project management.

Agile project management is best used for “mysteries,” to which there are no known answers (e.g., finding the best treatment for an emerging disease),

EXHIBIT 6.16
Agile Project
Management



as opposed to “puzzles,” to which the solution is known but complex (e.g., building a new clinic).

The Project Manager and Project Team

The project manager’s role is pivotal to the success of any project, as he must select, develop, and nurture high-functioning team members, among other critical activities. The project manager’s skills also include running effective meetings and facilitating optimal dialogue during these meetings.

Team Skills

A project manager can take on multiple roles in a project. In many smaller healthcare projects, the project manager is the person who actually accomplishes several of the project tasks. In larger or more complex projects, the project manager’s job is solely to lead and manage the individuals performing the tasks. Slack (2005) provides a useful matrix to determine what role a project manager should assume in projects of varying sizes (exhibit 6.17).

Team Structure and Authority

Team members may be selected and the project structure determined by the project manager, but in many cases they are outlined by the project sponsor and other members of senior management. Formally documenting the team makeup and how team members are assigned in the project charter and scope is important in clarifying team roles for both team members and project stakeholders.

A number of key issues must be addressed as the project team is formed. The most important is the project manager’s level of authority to make decisions. Can the project manager commit resources, or must he ask senior managers or department heads each time a new resource is needed? Is the budget controlled by the project manager, or does a central financial authority control it? Is administrative support available to the team, or do the project team members need to perform these tasks themselves?

Variable	Small Project	Medium Project	Large Project
Effort range	40–400 hours	400–2,400 hours	2,400+ hours
Duration	1 week–3 months	3–6 months	6 months–2 years
Project leader role	“Doer” with some help	Manage and “do some”	Manage

EXHIBIT 6.17
Project
Manager’s Role
Based on Effort
and Duration of
a Project

Source: Slack (2005). Used with permission.

Finally, care should be taken to avoid overscheduling team members. All members must have the availability to work on the project as expected.

Team Meetings

A weekly or biweekly project team meeting is highly recommended to keep a project on schedule. At this meeting, the project's progress can be monitored and discussed and actions initiated to resolve deviations and problems.

All good team meetings include a comprehensive agenda and a complete set of minutes. Minutes should be action oriented (e.g., "The schedule slippage for task 17 will be resolved by assigning additional resources from the temporary pool"). In addition, the individual accountable for following through on the issue should be identified. If the meeting's deliberations and actions are confidential, everyone on the team should be aware of the policy and adhere to it uniformly.

The decision-making process should be clear and understood by all team members. In some situations, all major decisions are made by the project manager. In others, team members may have veto power if they represent a major department that is expected to commit resources. Some major decisions may require review and approval by individuals external to the project team. The use of data and analytical techniques is strongly encouraged as part of the decision-making process.

Team members need to take responsibility for the success of the team. They can demonstrate this acceptance by following through on commitments, contributing to discussions, actively listening, and giving and being receptive to feedback. Everyone on a team should feel that she has a voice, and the project manager needs to lead the meeting in such a way as to balance the "air time" among team members. This approach requires occasionally interrupting—politely and artfully—the wordy team member and summarizing her point; it also means calling on the silent team member to solicit input.

At the end of a meeting, one useful activity is to evaluate the meeting itself. The project manager and team can spend a few minutes reviewing questions such as the following:

- Did we accomplish our purpose?
- Did we take steps to maintain our gains?
- Did we document actions, results, and ideas?
- Did we work together successfully?
- Did we share our results with others?
- Did we recognize everyone's contribution and celebrate our achievements?

Leadership Skills

Although this book is not primarily concerned with leadership, clearly the project manager must be able to lead a project forward. Effective project leadership requires the following skills:

- The ability to think critically using complex information
- The strategic capability to take a long-term view of the organization
- The ability to gain and maintain a systems view of the organization and its environment (discussed in chapter 1)
- The ability to create and lead change
- The capacity to understand oneself to permit positive interactions, conflict resolution, and effective communication
- The ability to mentor and develop employees into high-performing team members
- The ability to develop a performance-based culture

Additional resources on leadership can be found by searching the American College of Healthcare Executives website (www.ache.org/search).

Conclusion

This chapter provides a basic introduction to the science and discipline of project management. The field is finding a home in healthcare IT departments and has a history in construction projects. Successful healthcare organizations of the future will use this rigorous methodology to make significant changes and improvements throughout their operations.

Discussion Questions

1. Who should be included as members of the project team, key stakeholders, and project sponsors for a clinical project in a physician's office? In a hospital? Support your choices.
2. Identify five common risks in healthcare clinical projects, and develop contingency responses for each.

Exercises

1. Download the project charter and project schedule from the companion website, and perform the following activities:
 - a. Complete the missing portions of the charter.

On the web at
ache.org/books/OpsManagement4 

- b. Develop a risk assessment and mitigation plan.
 - c. Add tasks to the schedule for those areas that require more specificity.
 - d. Apply resources to each task, determine the critical path, and devise a method to crash the project to reduce its total duration by 20 percent.
2. Review the Institute for Healthcare Improvement website, and select one of the quality improvement projects described. Although you will not know all the details of the organization that executed this project, create a charter document for your chosen project.
3. For the project identified in exercise 2, create a feasible WBS and project schedule. Enter the schedule into Microsoft Project.

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PERFORMANCE IMPROVEMENT TOOLS, TECHNIQUES, AND PROGRAMS

TOOLS FOR PROBLEM SOLVING AND DECISION MAKING

Operations Management in Action

Approximately 1 million patients fall in US hospitals each year (Parasol Medical 2021). Data from the UK National Health Service show that of patients who fall, more than 30 percent sustain an injury, which often leads to longer patient stays and imposes greater costs on hospital systems (Morris and O’Riordan 2017). According to the Centers for Disease Control and Prevention (2020), the annual costs associated with falls in the US healthcare system exceed \$50 billion, of which more than \$754 million is associated with fatal falls.

Several studies have shown that the reason a patient falls is simply because the environment is unsafe. For example, having electrical cords and other items in the environment that present tripping hazards substantially increases fall risk. To help avoid injuries and control costs, the Agency for Healthcare Research and Quality (AHRQ) has developed a toolkit for preventing falls in hospitals (AHRQ 2013). The AHRQ toolkit provides healthcare workers

with the diagnostic and solution-oriented tools to lower the risk of falling. At least 20 percent to 30 percent of all falls could be prevented using the problem-solving tools (Morris and O’Riordan 2017). The reduction of falls could potentially result in annualized savings for healthcare systems of more than \$10 billion.

OVERVIEW

This chapter introduces the basic tools associated with problem solving and decision making. Much of the work of healthcare professionals is just that—making decisions and solving problems—and in an ever-changing landscape, that work must be accomplished well and quickly. A structured approach can enable problem solving and decision making that is efficient and effective.

Major topics in this chapter include the following:

- The decision-making process, with a focus on framing the problem or issue
- Mapping techniques, including mind mapping, process mapping, activity mapping, and service blueprinting
- Problem identification tools, including root-cause analysis, failure mode and effects analysis, and the theory of constraints
- Analytical tools, such as optimization using linear programming and decision analysis
- Force field analysis to address implementation issues

This chapter helps readers gain a basic understanding of different problem-solving tools and techniques, enabling them to

- frame questions or problems,
- analyze a problem and various solutions to it, and
- implement one or more of those solutions.

The tools and techniques outlined in this chapter should provide a basis for tackling difficult, complicated problems.

Decision-Making Framework

A structured, rational approach to problem solving and decision making includes the following steps:

1. Identify and frame the issue or problem.
2. Generate or determine possible courses of action, and evaluate those alternatives.
3. Choose and implement the best solution or alternative.
4. Review and reflect on the previous steps and outcomes.

Decision Traps: The Ten Barriers to Brilliant Decision-Making and How to Overcome Them (Russo and Schoemaker 1989) outlines these steps (exhibit 7.1) and the barriers encountered in decision making (exhibit 7.2).

EXHIBIT 7.1 Decision Elements and Activities

Framing	Structuring the question. This means defining what must be decided and determining in a preliminary way what criteria would cause you to prefer one option over another. In framing, good decision makers think about the viewpoint from which they and others will look at the issue and decide which aspects they consider important and which they do not. Thus, they inevitably simplify the world.
Typical amount of time: 5%	
Recommended amount of time: 20%	
Gathering intelligence	Seeking both the knowable facts and the reasonable estimates of “unknowables” that you will need to make the decision. Good decision makers manage intelligence gathering with deliberate effort to avoid such failings as overconfidence in what they currently believe and the tendency to seek information that confirms their biases.
Typical amount of time: 45%	
Recommended amount of time: 35%	
Coming to conclusions	Sound framing and good intelligence don’t guarantee a wise decision. People cannot consistently make good decisions using seat-of-the-pants judgment alone, even with excellent data in front of them. A systematic approach forces you to examine many aspects and often leads to better decisions than hours of unorganized thinking would.
Typical amount of time: 40%	
Recommended amount of time: 25%	
Learning from feedback	Everyone needs to establish a system for learning from the results of past decisions. This usually means keeping track of what you expected would happen, systematically guarding against self-serving explanations, then making sure you review the lessons your feedback has produced the next time a similar decision comes along.
Typical amount of time: 10%	
Recommended amount of time: 20%	

Source: Russo and Schoemaker (1989).

EXHIBIT 7.2

The Ten Barriers to Brilliant Decision Making and the Key Elements into Which They Fall

Framing the Question

Plunging in—Beginning to gather information and reach conclusions without first taking a few minutes to think about the crux of the issue you're facing.

Frame blindness—Setting out to solve the wrong problem because you have created a mental framework for your decision with little thought, which causes you to overlook the best options or lose sight of important objectives.

Lack of frame control—Failing to consciously define the problem in more ways than one or being unduly influenced by the frames of others.

Gathering Intelligence

Overconfidence in your judgment—Failing to correct key factual information because you are too sure of your assumptions and opinions.

Shortsighted shortcuts—Relying inappropriately on “rules of thumb,” such as implicitly trusting the most readily available information or anchoring too much on convenient facts.

Coming to Conclusions

Shooting from the hip—Believing you can keep straight in your head all the information you've discovered, and therefore you “wing it” rather than follow a systematic procedure.

Group failure—Assuming that with many smart people involved, good choices will follow automatically, and therefore you fail to manage the group decision process.

Learning/Failing to Learn from Feedback

Fooling yourself about feedback—Failing to interpret the evidence from past outcomes for what it really says, either because you're protecting your ego or because you are tricked by hindsight.

Not keeping track—Assuming that experience will make its lessons available automatically, and therefore you fail to keep systematic records to track results of your decisions and fail to analyze these results in ways that will reveal their true lessons.

Failure to audit your decision process—You fail to create an organized approach to understanding your own decision making, so you remain constantly exposed to all the aforementioned mistakes.

Source: Russo and Schoemaker (1989).

The plan-do-check-act process for continuous improvement (discussed in depth in chapter 10), the define-measure-analyze-improve-control process of Six Sigma (chapter 9), and process improvement (chapter 11) all follow the same basic steps as presented in this chapter for the decision-making process. The tools and techniques found in this book can be used not only in the process of decision making but also to help gather the right information to make optimal decisions and learn from those decisions. Often, the learning step in the decision-making process is neglected, but it should not be. It is important to evaluate and analyze both the decision made and the process(es) used to reach the decision to ensure learning and enable continuous improvement.

Framing

The frame of a problem or decision encompasses the assumptions, attitudes, and preconceived limits that an individual or a team brings to the analyses. These assumptions can stifle the ability to solve the problem by reducing or eliminating creativity and causing the decision maker(s) to overlook possibilities. Alternatively, these assumptions can aid in problem solving by eliminating wildly improbable paths. That said, they usually hinder a team's ability to find the best solution or even a possible solution.

Millions of dollars and working hours are wasted in finding solutions to the wrong problems. An ill-defined problem or mistaken premise can eliminate promising solutions before they are even considered. People tend to identify convenient problems and find solutions that are familiar to them rather than looking more deeply for problems that are meaningful to solve.

People also have a tendency to want to do something; quick and decisive action is seen as necessary in today's rapidly changing environment. Leaping to the solutions before taking the time to properly frame the problem usually results in suboptimal solutions.

However, framing the problem can be difficult, as it requires an understanding of the issue at hand. If the problem is well understood, the solution is more likely to be obvious; therefore, when framing a problem, it is important to approach it in an expansive way by soliciting many different viewpoints and considering many possible scenarios, causes, and solutions. The tools outlined in this chapter are designed to help with this process.

Mapping Techniques

Mind Mapping

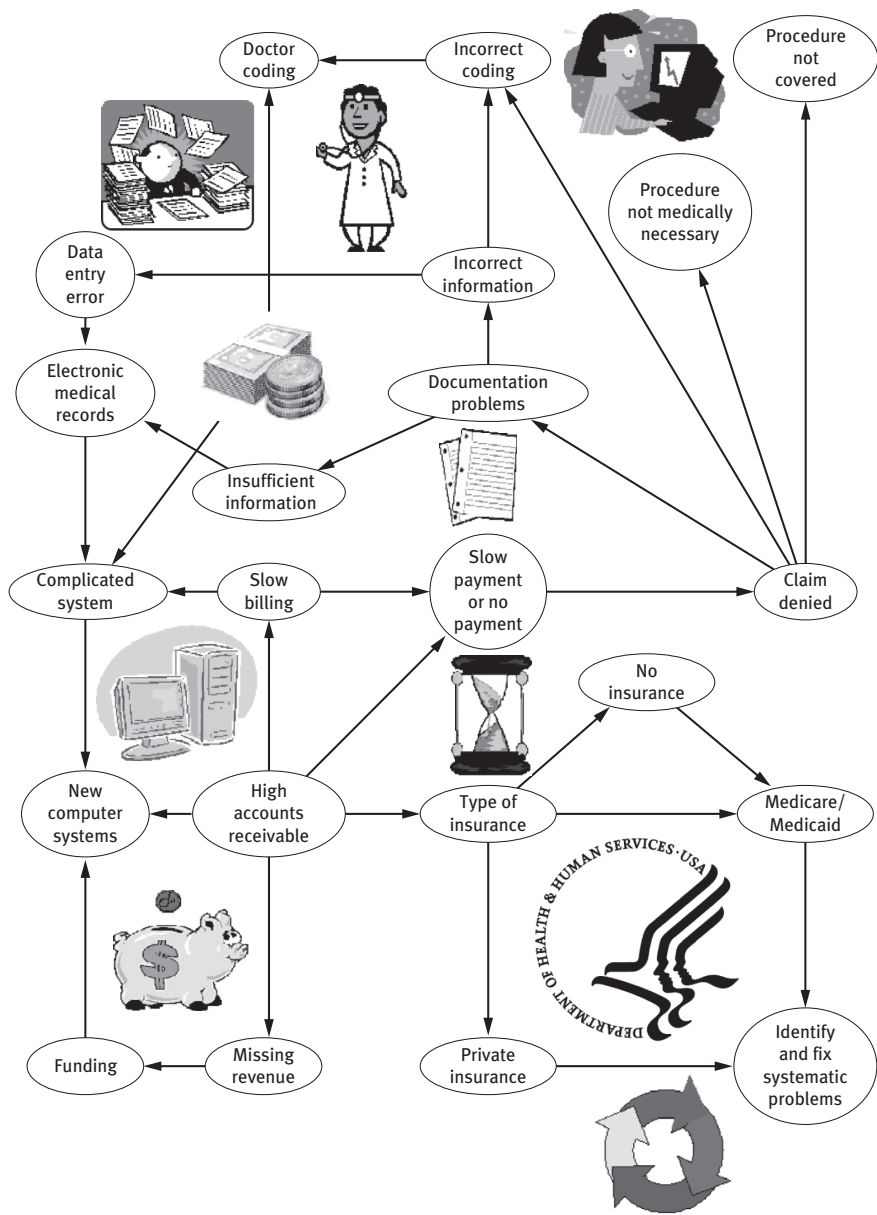
Tony Buzan is credited with developing the mind-mapping technique (Buzan 1991; Buzan and Buzan 1994). **Mind mapping** develops thoughts and ideas in a nonlinear fashion and typically uses pictures or phrases to organize and further develop those thoughts. In this structured brainstorming technique, ideas are organized on a "map" and the connections between them are made explicit. Mind mapping can be an effective technique for problem solving because thinking linearly is not necessary. Making connections that are not obvious or linear can lead to innovative solutions.

Mind mapping starts with the issue to be addressed placed in the center of the map. Ideas on causes, solutions, and so on radiate from the central theme. Questions in the form of who, what, where, why, when, and how are often helpful for problem solving. Exhibit 7.3 illustrates a mind map related to high accounts receivables.

mind mapping

A nonlinear technique used to develop thoughts and ideas by placing pictures or phrases on a map to show logical connections.

EXHIBIT 7.3
Mind Map:
High Accounts
Receivables

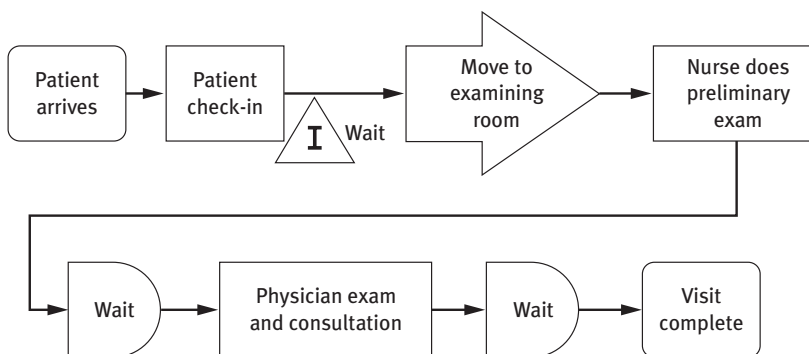
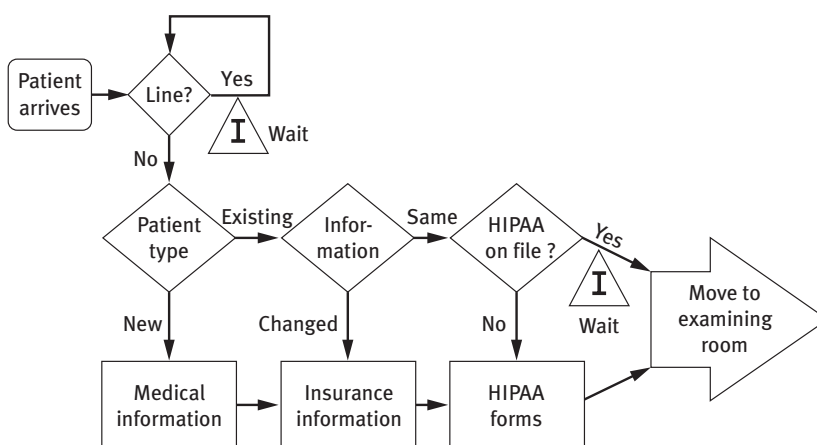


Note: Diagram created in Inspiration by Inspiration Software, Inc.

Process Mapping

A **process map**, or flowchart, is a graphic depiction of a process showing inputs, outputs, and steps in the process. Depending on the purpose of the map, it can be high level or detailed. Exhibit 7.4 shows a high-level process map for Vincent Valley Hospital and Health System’s (VVH’s) Riverview Clinic, and exhibit 7.5 shows a more detailed map of the check-in process at the clinic.

process map
A graphic depiction of a process showing the sequence of events, including tasks, decisions, and other activities from inputs to outputs. A process map is a type of flowchart.

EXHIBIT 7.4**Riverview Clinic
High-Level
Process Map****EXHIBIT 7.5****Riverview
Clinic Detailed
Process Map:
Patient Check-In**

Process maps offer a clear picture of what activities are carried out as part of the process, where they occur, and how they are performed. Typically, process maps are used to understand and optimize a process. The process is commonly charted from the viewpoint of the material, information, or customer being processed (often the patient in healthcare) or the staff member carrying out the work. Process mapping is one of the seven basic quality tools (see the following chart) and an integral part of most improvement initiatives (e.g., Six Sigma, Lean, balanced scorecard, root-cause analysis, failure mode and effects analysis).

Seven Fundamental Quality Tools	
• Check sheet • Pareto diagram • Histogram • Scatter plot	• Process map • Cause-and-effect diagram • Run chart or control chart

The steps for creating a process map or flowchart are as follows:

1. *Assemble and train the team.* The team should consist of people from all areas and levels in the process of interest to ensure that the real process is captured.
2. *Determine the boundaries of the process (where it starts and ends) and the level of detail desired.* The level of detail desired, or needed, depends on the question or problem the team is addressing.
3. *Brainstorm the major process tasks and subtasks.* List them, and then arrange them in order. (Sticky notes are often helpful here.)
4. *Create a formal chart.* Once an initial flowchart has been generated, the chart can be formally drawn using the standard symbols of process mapping (exhibit 7.6). (This formal graphic can be completed most efficiently using software such as Microsoft Visio.) When first developing a flowchart, the important point is to obtain an accurate picture of the process rather than worrying about using the correct symbols.
5. *Make corrections.* The formal flowchart should be checked for accuracy by all relevant personnel. Often, inaccuracies are found in the flowchart and must be corrected in this step.
6. *Determine any need for additional information.* Depending on the purpose of the flowchart, data may need to be collected or information added at this stage. Often, data specifically related to process performance are collected and added to the flowchart.

We discuss these quality tools in much more detail in chapters 8 (Healthcare Analytics) and 9 (Quality Improvement in Healthcare).

Cross-Functional Process Maps

The **cross-functional process map**, or “swim lane” map, is a specialized process map that follows the flow of a process through the various departments of the organization. The swim lanes indicated by the dashed lines between departments show the work being completed by a particular department or individual in the process. The swim lane chart is useful for viewing the number of times an item is handed off between departments and how many times the process is creating duplication and rework.

Exhibit 7.7 is an example of a presurgery holding room (the area where patients are staged, vital signs are taken, consent forms are completed, surgery type is confirmed, etc., just prior to entering surgery) for a Veterans Administration hospital.

Service Blueprinting

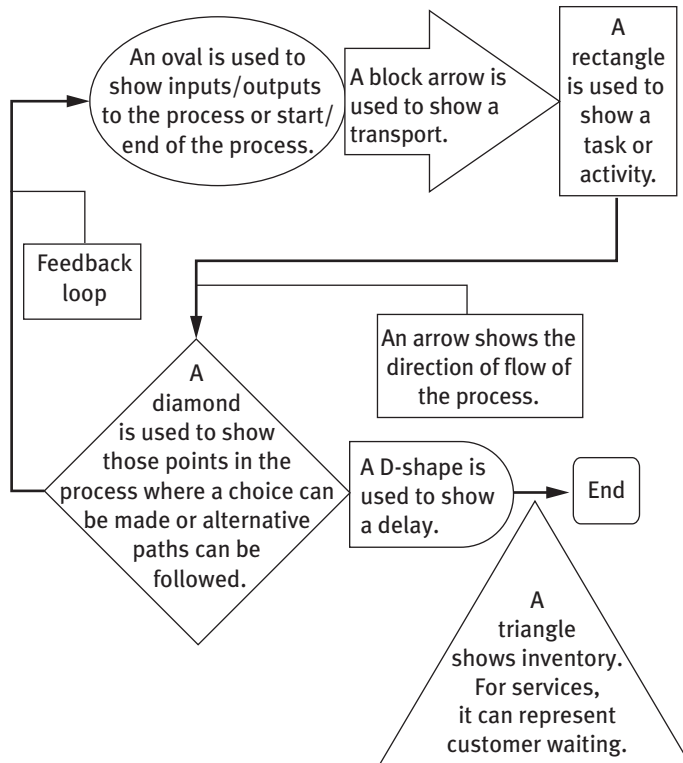
Service blueprinting (Shostack 1984) is a special form of process mapping (as is value stream mapping, covered in chapter 10). Service blueprinting begins

cross-functional process map

A map that follows the flow of a process through the various departments of the organization using dashed lines to show the work being completed by a particular department or individual in the process. Also called *swim lane process map*.

service blueprinting

A style of process mapping that separates actions into onstage (visible to the customer) and backstage (not visible to the customer) activities.

EXHIBIT 7.6**Standard
Flowchart
Symbols**

by mapping the process from the point of view of the customer. The typical purpose of a service blueprint is to identify points where the service might fail to satisfy the customer and then redesign or add controls to the system to reduce or eliminate the possibility of failure. The service blueprint separates onstage actions (those visible to the customer) from backstage actions and support processes (those not visible to the customer). A service blueprint specifies the line of interaction, where the customer and service provider come together, and the line of visibility, or what the customer sees or experiences—the tangible evidence that influences perceptions of the quality of service (exhibit 7.8).

Problem Identification Tools

root-cause analysis (RCA)

A generic term describing structured, step-by-step techniques for problem solving.

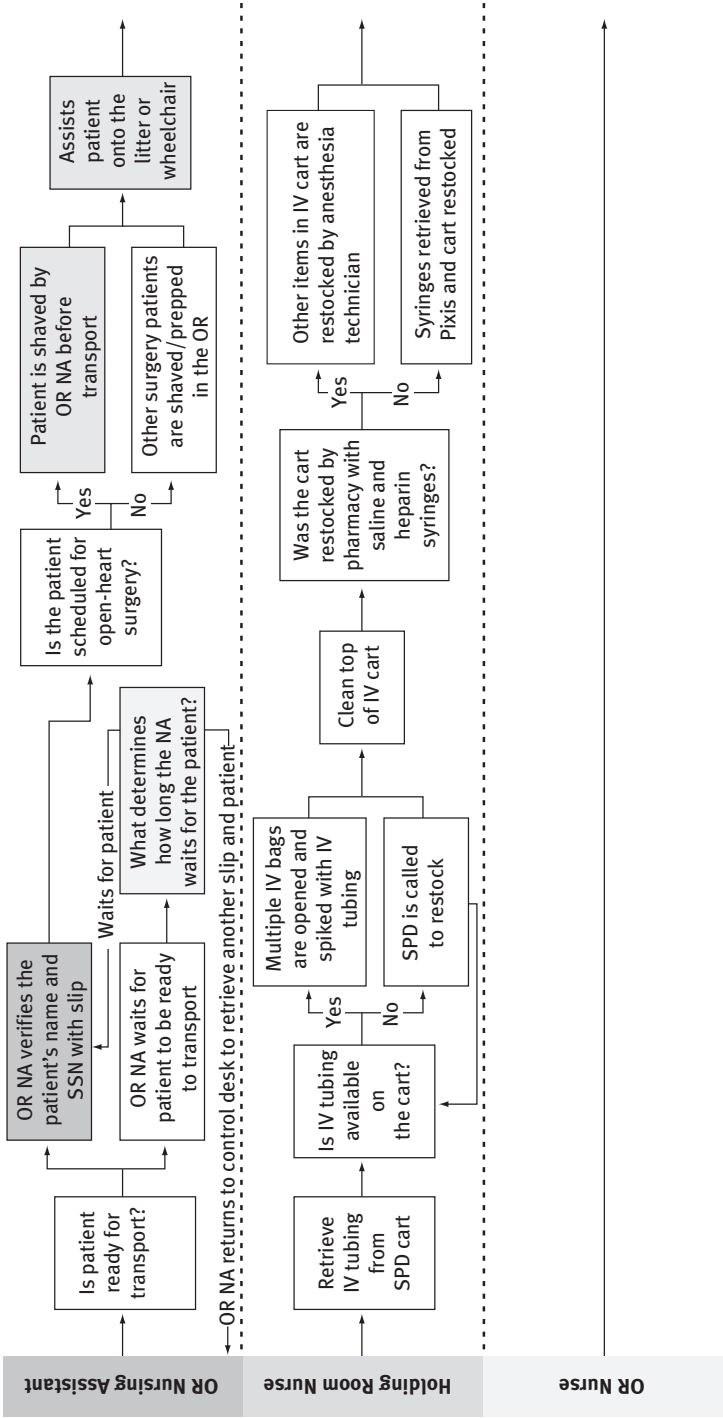
Root-Cause Analysis

Root-cause analysis (RCA) is a generic term used to describe structured, step-by-step techniques for problem solving. It aims to determine and correct the ultimate cause(s) of a problem, not just the visible symptoms, to ensure that the problem does not recur. Specifically, RCA consists of determining what happened, why it happened, and what can be done to prevent it from recurring.

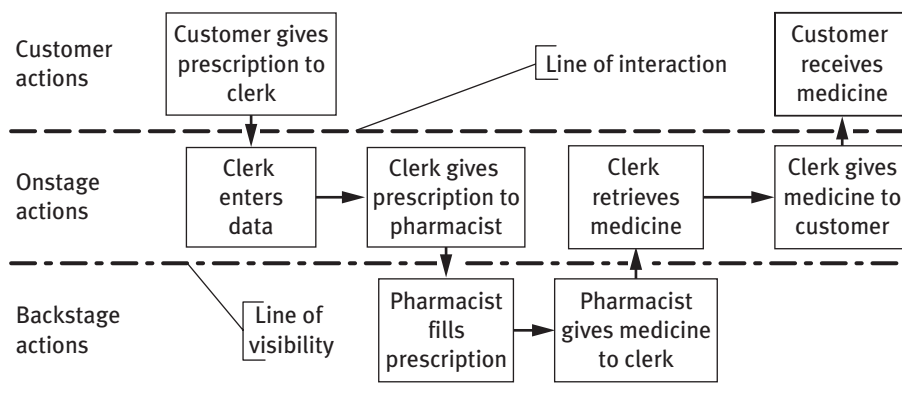
EXHIBIT 7.7

Swim Lane Process Map

Snapshot of a Portion of a Detailed Process Map for a Holding Room



Note: IV = intravenous line; NA = nursing assistant; OR = operating room; SPD = sterile processing department; SSN = Social Security number.

EXHIBIT 7.8**Service
Blueprint**

The Joint Commission (2013, 2021) requires all accredited organizations to conduct an RCA of any sentinel event (an unexpected occurrence involving death or serious physical or psychological injury, or the risk thereof) and provides tools to help an organization conduct that analysis. Not only are these tools useful for resolving sentinel events and adhering to Joint Commission requirements, but they also provide a framework for any RCA. A variety of commercial software is available for conducting RCAs.

Although an RCA can be conducted in many different ways, its basis is always in asking why something happened, again and again, until the ultimate cause is found. Typically, some element of the system or process, rather than human error, is found to be the ultimate cause. The five whys technique and cause-and-effect diagram are examples of tools used in RCA.

Five Whys Technique**five whys
technique**

A technique that uses a series of logical questions to find the root cause of a problem.

The **five whys technique** is a simple yet powerful tool. It consists of asking why the condition occurred, noting the answer, and then asking why for each answer over and over (five times is a good guide) until the root causes are identified. Often, the reason for a problem is only a symptom of the real cause. This technique can help eliminate the focus on symptoms, discover the cause, and point the way to eliminating it and ensuring that the problem does not occur again. The following list demonstrates how the five whys technique progresses:

1. A patient received the wrong medication.
 - Why?
2. The doctor prescribed the wrong medication.
 - Why?
3. Relevant information was missing from the patient's chart.
 - Why?

- 4. The patient’s most recent lab test results were not entered into the chart.
 - Why?
- 5. The lab technician sent the results, but they were in transit and the patient’s record was not updated.

The root cause here is the time lag between the test and data entry. Rather than simply concluding that the doctor made a mistake, find the root cause to help determine different possible solutions to the problem. The system may now be changed to increase the speed with which lab results are recorded or, at least, to allow a note to be documented on the chart that lab tests have been ordered but not yet recorded.

Cause-and-Effect Diagram

Using only the five whys technique for an RCA can be limiting because of the assumption that an effect is the result of a single cause at each level of why. Often, a set of causes is related to an effect. A cause-and-effect diagram can overcome this limitation.

Typically, a team uses a cause-and-effect diagram to investigate and eliminate a problem. The problem should be stated or framed as clearly as possible, including who is involved and where and when the problem occurs, to ensure that everyone on the team is attempting to solve the same problem. One of the seven basic quality tools, the cause-and-effect diagram is used to explore and display all of the potential causes of a problem. This type of graphic is sometimes called an Ishikawa diagram (after its inventor, Kaoru Ishikawa [1985]) or a **fishbone diagram** (because it looks like the skeleton of a fish).

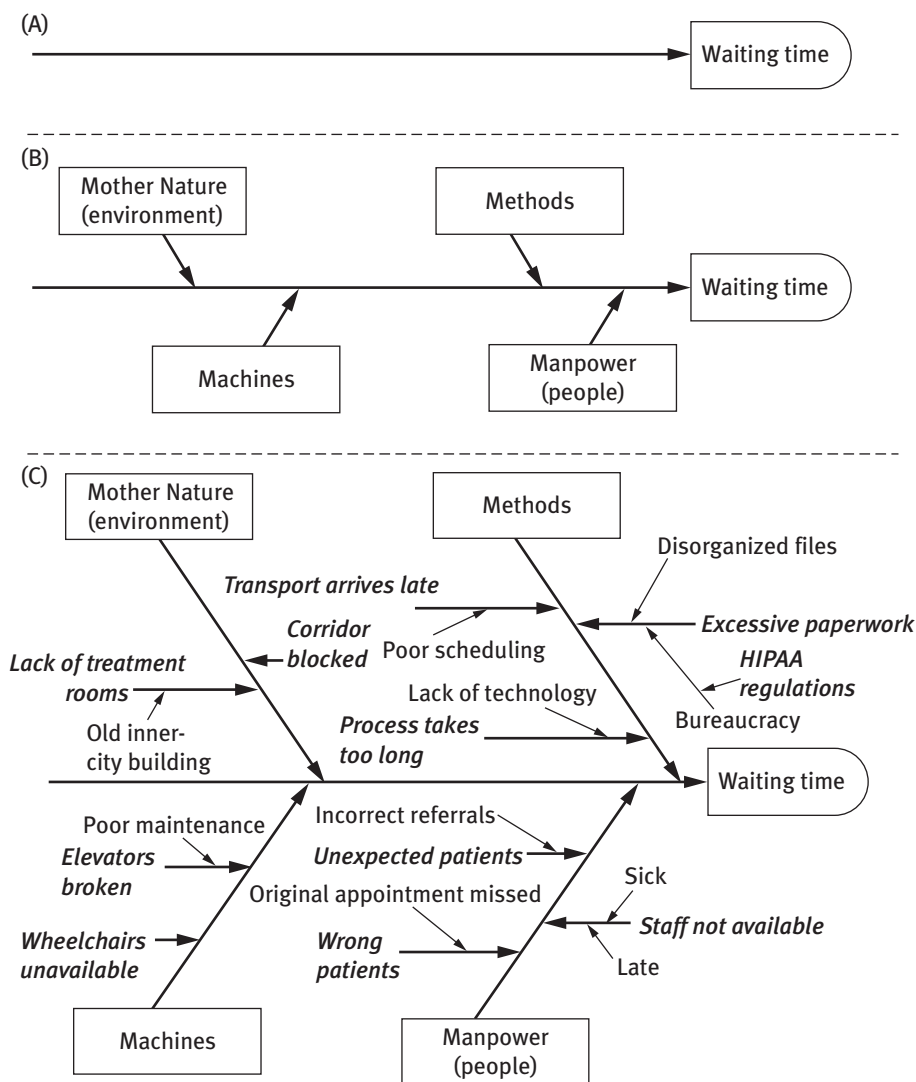
The problem or outcome of interest is the “head” of the fish. The rest of the diagram consists of a horizontal line leading to the problem statement and several branches, or “fishbones,” vertical to the main line. The branches represent different categories of causes. The categories chosen may vary according to the problem, but some categories are commonly used (exhibit 7.9).

fishbone diagram
A graphical technique used to display the relationship between the potential causes of a problem and the effect created by the problem. Sometimes called *Ishikawa diagram*.

Service (Four Ps)	Manufacturing (Six Ms)
Policies	Machines
Procedures	Methods
People	Materials
Plant/technology	Measurements
	Mother Nature (environment)
	Manpower (people)

EXHIBIT 7.9
Typical Cause-and-Effect Diagram

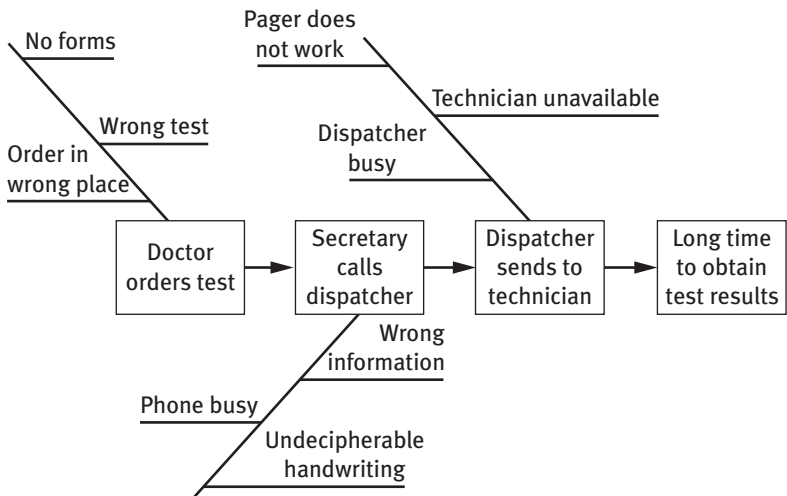
EXHIBIT 7.10
Cause-and-
Effect Example



Possible causes are attached to the appropriate branches. Each possible cause is examined to determine if a deeper cause lies behind it (stage C in exhibit 7.10); subcauses are attached as additional bones. In the final diagram, causes are arranged according to relationships and distance from the effect. This arrangement can help identify areas to focus on and allow comparison of the relative importance of different causes.

Cause-and-effect diagrams can also be drawn as tree diagrams. From a single outcome, or trunk, branches extend to represent major categories of inputs or causes that create that single outcome. These large branches then lead to smaller and smaller branches of causes all the way out to twigs at the

EXHIBIT 7.11
Process-Type
Cause-and-
Effect Diagram



ends. A process-type cause-and-effect diagram (exhibit 7.11) can be used to investigate causes of problems at each step in a process. A process RCA is similar to failure mode and effects analysis (FMEA) (as discussed in detail later) but is less quantitative in nature.

An example from VVH illustrates the cause-and-effect diagramming process. The hospital has identified excessive waiting time as a problem, and a team is assembled to address the issue. The problem is placed in the head of the fish, as shown in exhibit 7.10, stage A. Next, branches are drawn off the large arrow representing the main categories of potential causes. Typical categories are shown in exhibit 7.10, stage B, but the categories selected should suit the particular situation. Then, all of the possible causes inside each main category are identified. Each cause should be thoroughly explored to identify the causes of causes. This process continues, branching off into more and more causes of causes, until every possible cause has been identified (stage C in exhibit 7.10).

Much of the value gained from building a cause-and-effect diagram comes from undertaking the exercise itself with a team of people. A common and deeper understanding of the problem develops, enabling ideas to emerge for further investigation.

Once the cause-and-effect diagram is complete, an assessment of the possible causes and their relative importance should be undertaken. Obvious, easily fixable causes can be dealt with quickly. Additional data may be needed to assess the more complex possible causes and solutions. A Pareto analysis (chapter 9) of the various causes is often used to separate the vital few from the trivial many.

Building a cause-and-effect diagram is not necessarily a onetime exercise. The diagram can be used as a working document and updated as more data are collected and different solutions are tried.

failure mode and effects analysis (FMEA)

A technique developed by the US military to identify the ways in which a process (or piece of equipment) might fail and to determine how best to mitigate those risks.

Failure Mode and Effects Analysis

The **failure mode and effects analysis (FMEA)** process was developed by the US military in the late 1940s, originally aimed at equipment failure. More recently, FMEA has been adopted by many service industries, including health-care, to evaluate process failure. Hospitals accredited by The Joint Commission are required to conduct at least one FMEA or similar proactive analysis annually (Joint Commission Resources and Joint Commission International 2010). Whereas RCA is used to examine the underlying causes of a particular event or failure, FMEA is used to identify the ways in which a process (or piece of equipment) might potentially fail, and its goal is to eliminate or reduce the severity of such a potential failure. By proactively looking at the potential causes of failure, risk of failure is either eliminated or reduced.

A typical FMEA consists of the following steps:

1. *Identify the process to be analyzed.* Typically, this process is the highest priority for the organization.
2. *Assemble and train the team.* Processes usually cross functional boundaries; therefore, the analysis should be performed by a team of relevant personnel. No one person or functional area has the knowledge needed to perform the analysis.
3. *Develop a detailed process flowchart,* including all steps in the process.
4. *Identify each step or function* in the process.
5. *Identify potential failures (or failure modes)* at each step in the process. Note that more than one failure may potentially occur at each step.
6. *Determine the worst potential consequence (or effect)* of each possible failure.
7. *Identify the cause(s) (contributory factor)* of each potential failure. An RCA can be helpful in this step. Note that each potential failure may have more than one cause.
8. *Identify any failure “controls”* that are present. A control reduces the likelihood that causes or failures will occur, reduces the severity of an effect, or enables the occurrence of a cause or failure to be detected before it leads to the adverse effect.
9. *Rate the severity* of each effect (on a scale of 1 to 10, with 10 being the most severe). This rating should reflect the impact of any controls that reduce the severity of the effect.
10. *Rate the likelihood (occurrence score)* that each cause will occur (on a scale of 1 to 10, with 10 being certain to occur). As with step 9, this rating should reflect the impact of any controls that reduce the likelihood of occurrence.
11. *Rate the effectiveness* of each control (on a scale of 1 to 10, with 1 being an error-free detection system).

12. *Multiply the three ratings* by one another to obtain the risk priority number (RPN) for each cause or contributory factor.
13. *Use the RPNs to prioritize problems for corrective action.* All causes that result in an effect with a severity of 10 should be high on the priority list, regardless of RPN.
14. *Develop an improvement plan* to address the targeted causes (who, when, how assessed, etc.).

Exhibit 7.12 is an example of an FMEA for patient falls from the Institute for Healthcare Improvement (IHI). IHI provides an online interactive tool for FMEA and shares many real-world examples that can be used as a basis for FMEAs in other organizations (IHI 2021). The National Center for Patient Safety (2021) of the US Department of Veterans Affairs has developed a less complex FMEA process, which rates only the severity and probability of occurrence and uses the resulting number to prioritize problem areas.

Theory of Constraints

The **theory of constraints (TOC)** was first described in the business novel *The Goal* (Goldratt and Cox 1986). The TOC maintains that every organization is subject to at least one constraint that limits its movement toward or achievement of its goal. For many organizations, the goal is to make money now as well as in the future. Some healthcare organizations may have a different, but still identifiable, goal. Eliminating or alleviating the constraint can enable the organization to move toward its goal. Constraints can be physical (e.g., the capacity of a machine) or nonphysical (e.g., an organizational procedure).

Five steps are involved in the TOC:

1. *Identify the constraint or bottleneck.* What is the limiting factor stopping the system or process from achieving the goal?
2. *Exploit the constraint.* Determine how to get the maximum performance out of the constraint without major system changes or capital improvements.
3. *Subordinate everything else to the constraint.* Other nonbottleneck resources (or steps in the process) should be synchronized to match the output of the constraint. Idleness at a nonbottleneck resource costs nothing, and nonbottlenecks should never produce more than can be consumed by the bottleneck resource. For example, if the operating room is a bottleneck and it has an adjacent or associated surgical ward, a traditional view might encourage filling the ward. However, nothing would be gained—and operational losses would be incurred—by putting more patients on the ward than the operating room can serve. Thus, the TOC solution is to lower ward occupancy to match the

theory of constraints (TOC)
The idea that every organization and process is subject to at least one constraint that limits its movement toward or achievement of its goal.

EXHIBIT 7.12

Patient Falls FMEA

Fall prevention 3E						
United States Hospital-Community						
Aim: Reduction of preventable falls by 50% for 2005						
Process Data Date: 03/28/2005						
Step Description 1 Fall assessment completed upon admission						
Failure Mode	Causes	Effects	Occ	Det	Sev	RPN Actions
Potential to fall	Effects of anesthesia, analgesia.	Potential injury	1	1	10	10 Patients are ambulated with assistance for first 24 hours per policy. Placed on fall risk precautions.
Patient is not assessed at time of admission.	Complete information not available regarding patient history. Patient may not be able or willing to cooperate with interview process	Inaccurate fall risk assigned to patient	2	2	8	32 24 hour chart audits to assure completion of admission evaluation
Step Description 2 Inaccurate fall assessment						
Failure Mode	Causes	Effects	Occ	Det	Sev	RPN Actions
Potential to fall	Slip, trip, equipment, IV tubing, drains, drainage bags, liquid on floor, urinary urgency, diarrhea	No injury to severe injury	1	1	8	8 All patients are assigned fall risk category
Patient not identified as a fall risk through current process	Not using assessment tool(s) properly	Fall interventions are not implemented correctly.	2	2	7	28 Provide in orientation training on Fall prevention. Monitor Fall events for specific criteria.
Step Description 3 Interventions not able to be implemented						
Failure Mode	Causes	Effects	Occ	Det	Sev	RPN Actions
Slip, trip fall	Tangled in tubing, trip on tubing, trip on drain bag, forget bag attached to bed, slip on drainage leaking form bag.	no injury to severe injury	1	10	3	30 Educate patient, monitor for leaking drains, assist patient to ambulate with IV and drain tubes.
Due to safety issues of a psychiatric unit, interventions may cause more harm than good.	Failure to implement safe alternatives for behavioral patients who are at risk of falls.	Patients are more unstable	2	2	8	32 Focused education with staff to review safe alternatives for fall prevention. Charge Nurse to include fall prevention in patient shift assessments
Step Description 4 Medication Assessment/evaluations						
Failure Mode	Causes	Effects	Occ	Det	Sev	RPN Actions
Patients are overmedication -potential for falls	Patients are admitted agitated requiring stronger medication approach.	Patients become quickly drowsy and fall.	3	2	8	48 Medication training to identify sedative potentials. Post alerts on patients with high medication potential. Charge Nurse to include fall risk in shift assessment
Medications may slow judgement or increase ataxia	Medications that are being administered have sedating and ataxic effects	Slips, falls	8	2	9	144 Staff education regarding medications Charge Nurse to include fall risk in shift assessment
Calculated Totals Total Risk Priority Number for the process						
						332
Occ: Likelihood of Occurrence (1-10) Det: Likelihood of Detection (1-10) NOTE: 1 = Very likely it WILL be detected 10 = Very likely it WILL NOT be detected Sev: Severity (1-10)						

Source: IHI (2005). This material was accessed from the Institute for Healthcare Improvement's website, <http://www.ihi.org/resources/Pages/Tools/FailureModesandEffectsAnalysisTool.aspx>.

operating room's throughput, even if resources (heating, lighting, fixed staff costs, etc.) seem to be wasted.

4. *Elevate the constraint.* Take some action (expend capital, hire more people, etc.) to increase the capacity of the constraining resource until it is no longer the constraint. Some other factor will become the new constraint.
5. *Repeat the process* for the new constraint.

The process must be reapplied, perhaps several times. Many constraints are of an organization's own making, through entrenched rules, policies, and procedures that have developed over time. Avoid allowing inertia to become one of those constraints.

The TOC and Operations Measurement

The TOC defines three operational measurements for organizations:

1. *Throughput*—the rate at which the system generates money, in the form of selling price minus cost of raw materials (labor costs are part of operating expense rather than throughput).
2. *Inventory*—the amount of money the system has invested in products or services it will sell; inventory includes the products on hand as well as buildings, land, and equipment.
3. *Operating expense*—the amount of money the system spends turning inventory into throughput, including what is typically called overhead.

The following four measurements are then used to identify results for the organization:

Net profit = Throughput – Operating expense

Return on investment = (Throughput – Operating expense) ÷ Inventory

Productivity = Throughput ÷ Operating expense

Turnover = Throughput ÷ Inventory

These measurements can help employees make local, or frontline, decisions. A decision that results in increasing throughput, decreasing inventory, or decreasing operating expense generally is a good decision for the organization.

The TOC has been applied in healthcare at macro and micro levels to analyze and improve systems. De Mast and colleagues (2011) developed a model that demonstrated a 37 percent increase of patients through a system, accounting for more than \$300,000 in increased revenue. In a CT (computed tomography) scanning department, the model was deployed to help improve the utilization of the scanning room, which was identified as the constraint in the process. The model raised utilization of the bottleneck from 88 percent to more than 93 percent.

Stratton and Knight (2010) used the TOC to help improve patient flow. The results of their study show a nearly 25 percent reduction in overall length of stay—from 8.6 days to 6.3. In this instance, patient length of stay was reduced because the hospital was able to keep the constraint working on critical items by managing time effectively. Because the TOC focused on the

entire hospital system, the researchers were able to demonstrate the theory in practice—and improve systems—by working on the discharge process. For a surgical suite or an emergency department to serve more patients, it would need to accommodate each patient with an available hospital room. This model helped free up rooms so that patients could move through the system more quickly than before the TOC was applied.

Another way to manage constraints in a system is to accept that a bottleneck will always exist and to determine where it should be. Designing the system so that the bottleneck can be managed or controlled is a powerful way to deal with it.

Analytical Tools

Decision Analysis

decision analysis

A structured process for examining and evaluating decisions.

Decision analysis is a process for examining and evaluating decisions in a structured manner. A **decision tree** is a graphic representation of the order of events in a decision-making process. This structured process enables an organization to evaluate the risks and rewards of choosing a particular course of action.

decision tree

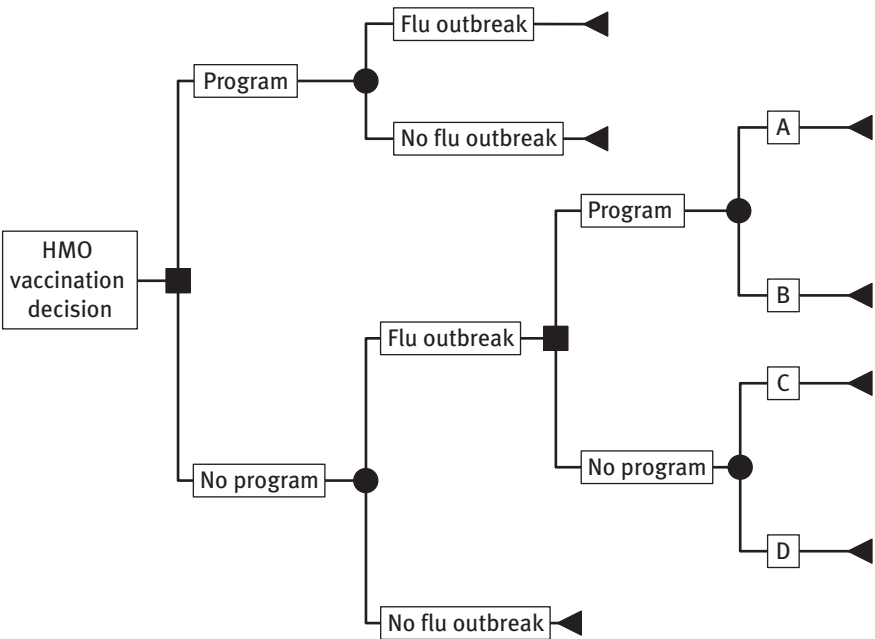
A graphical representation of the order of future and current events for how decisions are made.

In the construction of a decision tree, events are linked from left to right in the order in which they would occur. Three types of events, represented by nodes, can take place: decision or choice events (squares), chance events (circles), and outcomes (triangles). Probabilities of chance events occurring and benefits or costs for event choices and outcomes are associated with each branch extending from a node. The result is a tree structure with branches for each event extending to the right.

A simple example helps illustrate this process. A health maintenance organization (HMO) is considering the economic benefits of a preventive influenza vaccination program. If the program is not offered, the estimated cost to the HMO if a flu outbreak occurs is \$8 million with a probability of occurrence of 0.4 (40 percent) and \$12 million with a probability of 0.6 (60 percent). The program is estimated to cost \$7 million, and the probability of a flu outbreak occurring is 0.7 (70 percent). If a flu outbreak does occur and the HMO offers the program afterward, it will still cost the organization \$7 million, but the resulting costs to the HMO would be reduced to \$4 million with a probability of 0.4 (40 percent) or \$6 million with a probability of 0.6 (60 percent). What should the HMO decide? The decision tree for the HMO vaccination program is shown in exhibit 7.13.

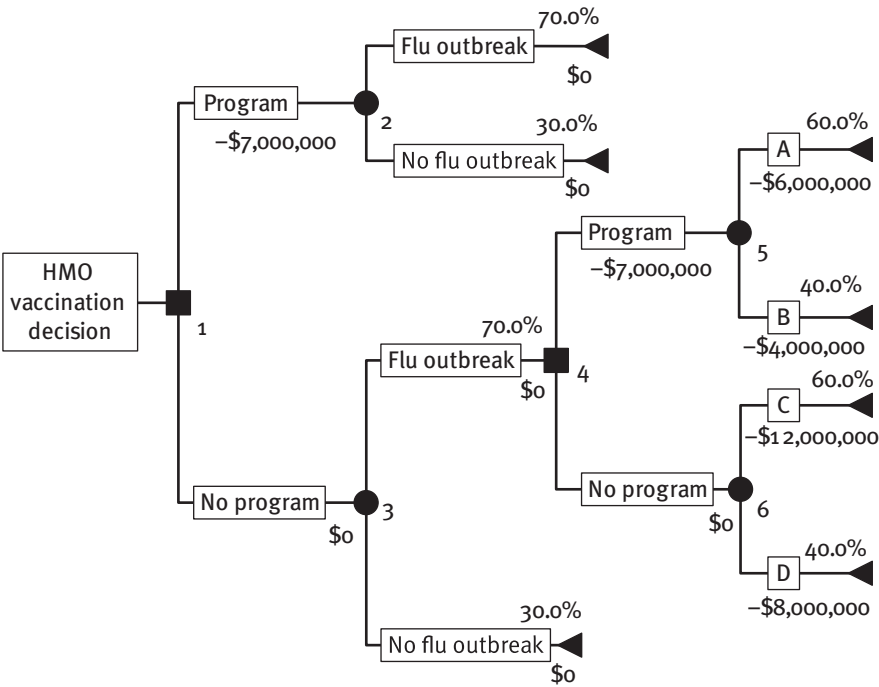
The probability estimates for each chance node, benefits (in this case, costs) of each decision branch, and outcomes at the end of each branch are added to the tree (exhibit 7.14).

EXHIBIT 7.13
HMO
Vaccination
Program
Decision Tree 1



Note: The tree diagrams in exhibits 7.13 through 7.17 were drawn with the help of PrecisionTree, a software product of Palisade Corp., Ithaca, NY: www.palisade.com.

EXHIBIT 7.14
HMO
Vaccination
Program
Decision Tree 2



The value of a node can be calculated once the values for all subsequent nodes are found. The value of a decision node is the largest value of any branch out of that node. The assumption is that the decision that maximizes the benefits will be made. The value of a chance node is the expected value of the branches out of that node. Working from right to left, the value of all nodes in the tree can be calculated. The expected value of chance node 6 is $[0.6 \times (-12)] + [0.4 \times (-8)] = -10.4$. The expected value of chance node 5 is $[0.6 \times (-6)] + [0.4 \times (-4)] = -5.2$. The expected value of the secondary vaccination program is $-7 + (-5.2) = -12.2$, and the expected value of not implementing the secondary vaccination program is -10.4 . Therefore, at decision node 4, the choice would be to not implement the secondary vaccination program.

At chance node 3 (no initial vaccination program), the expected value is $[0.7 \times (-10.4)] + (0.3 \times 0) = -7.28$. The expected value at chance node 2 is $0.7 \times 0 + 0.3 \times 0 = 0$, and the expected value of the initial vaccination program branch is $-7 + 0 = -7$. Therefore, at decision node 1, the choice would be to implement the initial vaccination program at a cost of \$7 million, as choosing not to implement the initial vaccination program is expected to cost \$7.28 million (exhibit 7.15).

A risk analysis on this decision-making process can then be conducted (exhibit 7.16). Choosing to implement the vaccination program results in a cost of \$7 million with a probability of 1. Choosing not to implement the initial vaccination program results in a cost of \$12 million with a probability of 0.42, \$8 million with a probability of 0.28, and no cost with a probability of 0.3. Choosing not to implement the vaccination program would be less costly 30 percent of the time, but 70 percent of the time, implementing it would be less costly.

A sensitivity analysis might also be conducted to determine the impact of changing some or all of the parameters in the analysis. For example, if the risk of a flu outbreak were 0.6 rather than 0.7 (and all other parameters stayed the same), the optimal decision would be to not offer either vaccination program 1, in the original HMO decision, or vaccination program 2, initiated after the flu outbreak later in the decision tree (exhibit 7.17).

For this example, dollars were used to represent costs (or benefits), but any type of score can be used. In the medical field, decision trees are often used to decide among a variety of treatment options and cost models for medical applications (Freitas 2011; Ribas et al. 2011).

Decision trees can be powerful aids to evaluating and choosing the optimal course of action. However, care must be taken when using them. Possible outcomes and the probabilities and benefits associated with them are only estimates, and these estimates may differ greatly from reality. Also, when

using expected value (or expected utility) to choose the optimum path, the underlying assumption is that the decision will be made over and over. On average, the expected payout is received, but in each individual situation, different amounts are received.

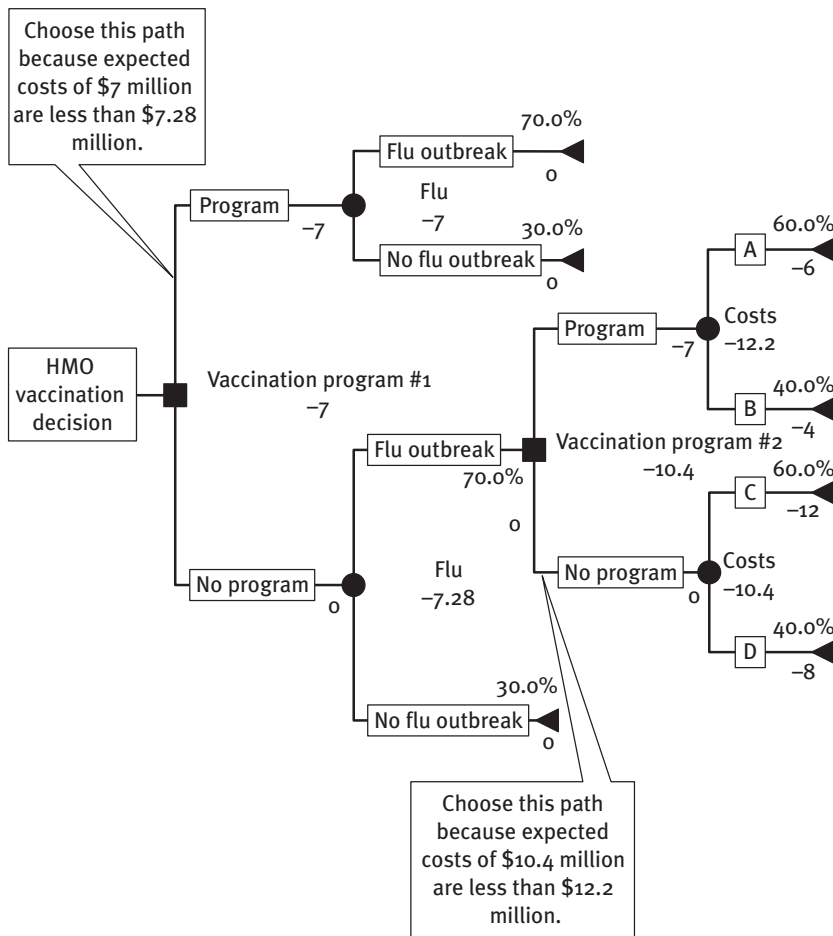


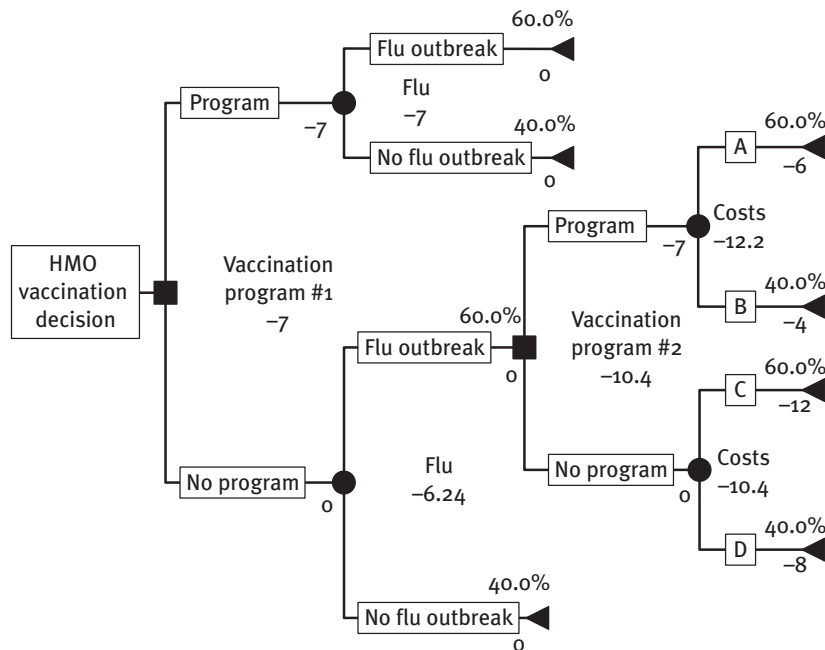
EXHIBIT 7.15
HMO
Vaccination
Program
Decision Tree 3

Number	Initial Vaccination Program		No Initial Vaccination Program	
	<i>X</i>	<i>P</i>	<i>X</i>	<i>P</i>
1	-7	1	-12	0.42
2			-8	0.28
3			0	0.30

EXHIBIT 7.16
Risk Analysis
for HMO
Vaccination
Program
Decision

Note: *X* = cost in millions of dollars; *P* = probability.

EXHIBIT 7.17
Decision
Analysis
Sensitivity to
Change in Risk
of Flu Outbreak



Implementation: Force Field Analysis

force field analysis
A graphical technique that demonstrates all the forces for and against making a key change.

Derived from the work of Kurt Lewin (1951), **force field analysis** is a technique for evaluating all of the various forces for and against a proposed change. It can be used to decide if a proposed change can be successfully implemented. Alternatively, if a decision to change has already been made, force field analysis can be used to develop strategies that enable the change to be implemented successfully.

In any situation, driving forces help to achieve a change, and restraining forces work against the change. Force field analysis identifies these forces and assigns relative scores to each. Exhibit 7.18 lists typical forces that should be considered. If the total score of the restraining forces is greater than the total score of the driving forces, the change may be doomed to failure. Force

EXHIBIT 7.18
Common Forces
to Consider
in Force Field
Analysis

Available resources	Institutional policies or norms
Costs	Personal or group attitudes and needs
Vested interests	Social or organizational norms and values
Regulations	
Organizational structures	
Present or past practices	

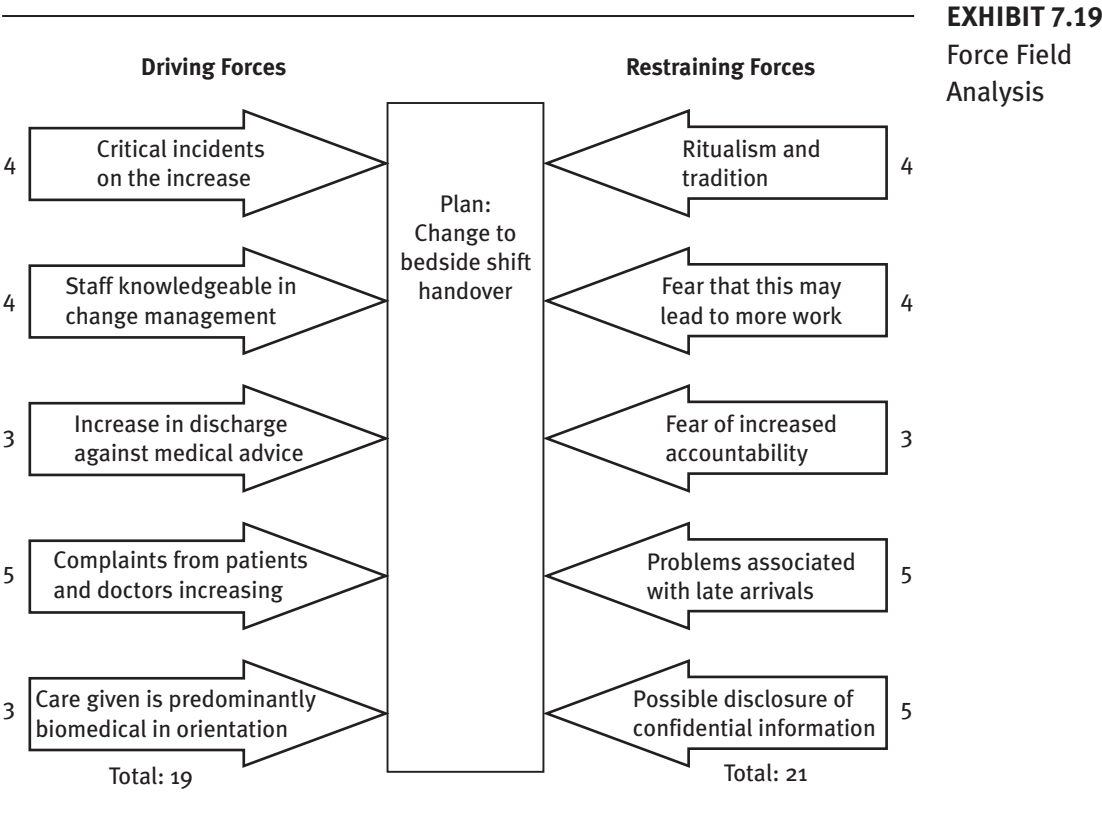
field analysis is typically used to determine how to strengthen or add driving forces or weaken the restraining forces to enable successful implementation of a change.

Application of Force Field Analysis at Vincent Valley Hospital and Health System

Patients at VVH have expressed a belief that they are insufficiently involved in and informed about their care. After analyzing this problem, hospital staff expect to solve (or lessen) it by moving the location of shift change handovers from the nurses' station to the patients' bedsides. A force field analysis has been conducted and is illustrated in exhibit 7.19.

Although the restraining forces are greater than the driving forces in this example, the decision is made to implement the change in handover procedures. To improve the project's chances for success, a protocol is developed for the actual procedure, making explicit the following guidelines:

- Develop and disseminate the protocol (new driving force +2).
- Exchange confidential information at the nurses' station, not at the bedside handover (decrease fear of disclosure by 2).



- Follow solution-based directives developed and incorporated into the protocol to address delayed handovers (decrease problems associated with late arrivals by 2).

These changes thus increase the driving forces by 2, to 21, and decrease the restraining forces by 4, to 17. The change has been successfully implemented; more important, patients now feel involved in their care and the number of complaints is reduced.

Conclusion

The tools and techniques outlined in this chapter are intended to help organizations along the path of continuous improvement. The choice of tool and when to use that tool depends on the problem to be solved; in many situations, several tools from this and other chapters should be used to ensure that the best possible solution is found.

Discussion Questions

1. Answer the following questions quickly for a fun illustration of some of the 10 decision traps (Russo and Schoemaker 1989):
 - Can a person living in Milwaukee, Wisconsin, be buried west of the Mississippi River?
 - If you had only one match and entered a room with a lamp, an oil heater, and some kindling wood, which would you light first?
 - How many animals of each species did Moses take along on the ark?
 - If a doctor gave you three pills and said to take one every half hour, how long would they last?
 - If you have two US coins totaling 55 cents and one of the coins is not a nickel, what are the two coins?What decision traps did you fall into when answering these questions?
2. Discuss a problem your organization solved or a suboptimal decision the organization made because the frame was incorrect.

Exercises

1. For the HMO vaccination program example provided in the chapter, reanalyze the situation assuming that the probability of a flu outbreak is 65 percent and the cost of the vaccination program is \$8 million. What is your decision under these new conditions?

2. In the DRG case-mix problem, VVH determined that it could convert 15 of its routine beds to ICU beds for a cost of \$2,000. What should VVH do, and why?
3. The high cost of medical care and insurance is a growing societal problem. Develop a mind map of this issue. (Advanced: Use Inspiration software.)
4. Individually or in teams, develop a map of a healthcare process or system with which you are familiar. Make sure that your process map has a start and an endpoint, all inputs and outputs are defined, and all key process steps are included. Explain your map to the rest of the class—this step may help you determine if anything is missing. (Advanced: Use Microsoft Visio.)
5. Choose a service offered by a healthcare organization, and create a service blueprint of it. You may have to imagine some of the systems and services that take place backstage if you are unfamiliar with them.
6. Think of a problem in your healthcare organization. Perform an RCA of the identified problem using the five whys technique and a fishbone diagram.
7. Pick one solution to the problem identified in exercise 6, and conduct a force field analysis of it.

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HEALTHCARE ANALYTICS

Operations Management in Action

Analytics has played a pivotal role in combating the spread and impact of COVID-19. Two examples follow. First, the Centers for Disease Control and Prevention (CDC) created a live dashboard of COVID-19 statistics to track the number of cases, hospitalization rates, and mortality rates broken down by state, county, gender, race, and age. These dashboards were pivotal in not only showing the number of infections but also in managing disease hot spots. When cases rose rapidly in certain areas of the county, the CDC could adjust its guidelines and inform local authorities of the greater transmission rates. The CDC developed a separate analytics dashboard to show the number and percentage of people who received a COVID-19 vaccination (exhibit 8.1).

Second, predictive analytics models are being used to identify high-risk COVID-19 patients in order to reduce the severity of their cases. One of the unexpected adverse outcomes of COVID-19 was the stop in elective procedures as resources were redirected to counter the pandemic. Health Catalyst indicates that hospitals lost more than \$60 billion monthly because of this halt, which also has had an enormous effect on patient health (Health Catalyst Editors 2021). Using machine learning and other predictive models, Health Catalyst has been able to quantify the impact of primary care provider disruptions on health and financial outcomes. These models help to prioritize high-risk patients to ensure they are getting the proper care and reduce the overall cost of their healthcare. Exhibit 8.2 is a simple predictive-model output that clearly shows the first patient had a primary care provider disruption that could incur significant costs. Such patients then can be prioritized for care to help reduce the mortality rate and financial impact of COVID-19 on the health system.

OVERVIEW

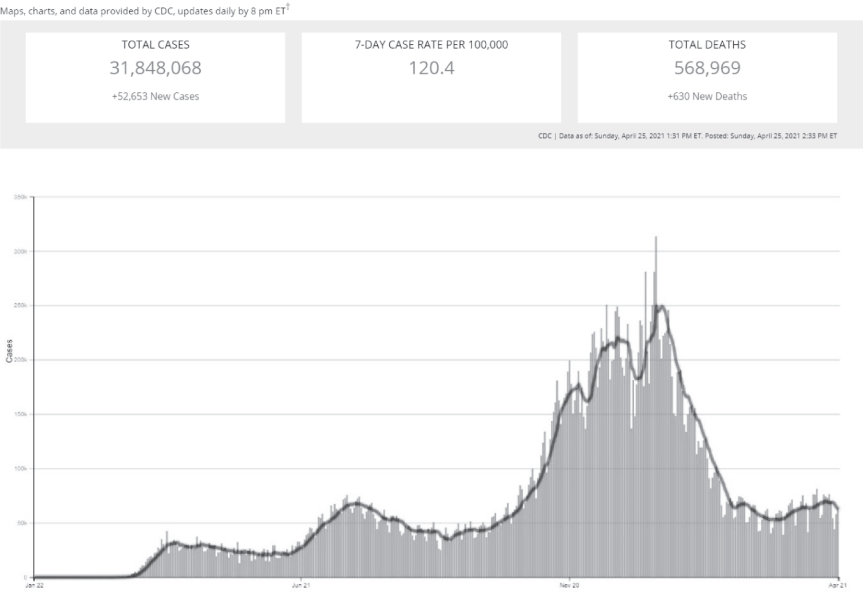
“Too much data and not enough information” has never resonated more than in today’s healthcare environment. In response, the disciplines of analytics, big data, and informatics have exploded and even become commonplace in hospital and health system operations.

What Is Analytics in Healthcare?

In 2007, Thomas Davenport and Jeanne Harris wrote their seminal book, *Competing on Analytics: The New Science of Winning*. This text demonstrates how companies from many different industries can use analytics to create value and improve organizational performance.

EXHIBIT 8.1
United States
COVID-19 Cases
and Deaths by
State

United States COVID-19 Cases and Deaths by State



Source: Centers for Disease Control and Prevention (2021).

EXHIBIT 8.2
A Predictive
Model with PCP
Disruption as a
Feature

Age	Gender	Diabetes	CHF	Had PCP Visit Disruption		Total Cost (Target Outcome)
79	M	Y	N	Y	➡	\$100,000
79	M	Y	N	N	➡	\$20,000
65	F	N	Y	Y	➡	\$30,000

Source: Exhibit from “Data Science Reveals Patients at Risk for Adverse Outcomes Due to COVID-19 Care Disruptions” (at <https://www.healthcatalyst.com/insights/healthcare-data-science-reveals-high-risk-patients>) by Health Catalyst, Inc., and is used under license.

Note: CHF = congestive heart failure; PCP = primary care provider.

Analytics, defined by one source as the “the systematic computational analysis of data or statistics” (Oxford Living Dictionaries 2016), has become particularly popular across the healthcare landscape for a number of reasons:

- More data than ever before are generated and available—particularly with the wide adoption of electronic health records (EHRs).
- The current regulatory environment requires the reporting of thousands of measures.

- Hospitals and health systems are facing increased pressure to improve clinical, operational, and financial results.
- Population health has become a competitive strategy, and analytics is crucial to shaping effective population health initiatives.
- Information technology and software are increasingly sophisticated, allowing analysis of data on a massive scale.

More Data

Due to ever-increasing computing power and the advent of cloud storage, smartphones, and other technologies, more data and information are available today than ever before. This availability presents both challenges and opportunities in data storage, security, and management. In large part because of the availability of funds—and new mandates—from the American Recovery and Reinvestment Act of 2009, most hospitals and clinics have installed EHR systems. The massive conversion from paper charts and records was difficult for many organizations to accomplish, but EHRs are finally stable enough to be used as a good data resource. Epic Systems Corporation and Cerner Corporation are the two largest software companies to have created platforms to store health records. The widespread use of these systems has given healthcare providers the capability to longitudinally collect data on patients, which offer healthcare systems comprehensive insights and, potentially, the capability to improve care decision making.

Regulatory Environment

The effective use of analytics can help healthcare organizations manage mounting regulatory pressures. The Centers for Medicare & Medicaid Services require every hospital to report approximately 1,700 quality measures for regulatory compliance (Blumenthal, Malphrus, and McGinnis 2015). The sheer number of data points that must be collected forces organizations to dedicate significant resources to collecting and managing the data. And this effort does not take into account the additional resources required to analyze and make decisions with the data.

Pressure to Produce Results

In Minnesota, a unique relationship was formed between Allina Health and Health Catalyst. Health Catalyst provides analytics services to Allina to assist in project management, continuous improvement, population health analysis, and financial analytics. The use of large-scale data allows the healthcare system to focus on achieving results through coordinated efforts. Data have been used to analyze a variety of system elements, including doctors' efficiency, clinic efficiency, and overall system effectiveness.

Healthcare regulation and competition pressure have changed the marketplace for health systems. Organizations need a systematic approach to

reducing costs and finding new market opportunities. The operations improvement tools discussed in many of the chapters of this book can be made more powerful with the use of advanced analytics.

Population Health

Kindig and Stoddart (2003) define population health as “the health outcomes of a group of individuals, including the distribution of such outcomes within the group” (p. 380). The increased use of EHRs gives health systems the ability to understand the costs and clinical trends related to the patients they serve. This capability allows the development of specific treatments for diseases and conditions, which leads to improved outcomes. One of the hallmarks of big data analysis in healthcare is the use of predictive models.

Winters-Miner (2014) identifies seven ways predictive analytics can improve healthcare:

1. Improves diagnosis
2. Helps with preventive medicine and public health efforts
3. Provides answers to physicians for the treatment of individual patients
4. Provides employers and hospitals tools to predict insurance product costs
5. Allows smaller test cases to be used to prove models
6. Helps pharmaceutical companies meet the needs of the public for medication
7. Potentially helps improve outcomes

Sophisticated Technology

Technology breakthroughs are enabling analysts to tackle increasingly complex problems. Analytics technology not only allows larger data sets to be used but also increases the speed at which analysis can be completed. The advanced technology used in analytics today can enable organizations to perform better and more sophisticated analytics. Data visualization software can easily replicate dashboard charts and graphs with new data. Statistical software can find relationships in large data sets once too difficult to analyze. Such software is a critical tool in the development and deployment of advanced analytics in healthcare.

Introduction to Data Analytics

The goal of data (big and small) analytics is to obtain actionable insights that result in smarter decisions and better business outcomes. Many of the tools and techniques from chapters 7 and 9 can be applied in an analytics environment.

The basic work of an analyst is to build a data framework through the following major goals:

- *Gathering data*—Data are the facts provided by databases.
- *Building information*—Information is the layer on top of data that helps make sense of the data. Without essential knowledge of the business situation, the information is likely not valuable.
- *Gaining actionable insights*—Actionable insights are those nuggets of knowledge from the information that affect the organization. The insights should enhance a leader's ability to make improved decisions.

This framework for data analysis provides the background for the various forms of analytics.

What Is Statistical Thinking?

As defined by Joseph Juran, statistical thinking is the collection, organization, analysis, interpretation, and presentation of data (Juran and De Feo 2010). In most business systems in the healthcare industry, statistical thinking is lacking. Knowledge-based management and improvement require that decisions be based on facts rather than on feelings or intuition. Collecting the right data and analyzing them correctly enable fact-based decision making.

The importance of understanding statistical concepts in developing high-performing healthcare systems cannot be overstated. Delivering high-quality healthcare in a sustained manner depends on understanding and controlling variance. Variance is present in all systems, but the ability of leadership to understand and control variance distinguishes high-performing systems from poorly run systems. *The irony of this relationship is that many clinical quality and safety rules and regulations are designed and driven by the understanding of variance, whereas the supporting business systems are often designed simply to meet regulatory agency requirements and not to manage the variance in the system. The good news is that this situation provides the opportunity to make massive changes to system and financial performance simply by understanding data and metrics.*

Analytics can be described as taking place in three distinct phases:

1. Descriptive analytics
2. Predictive analytics
3. Prescriptive analytics

Descriptive Analytics

Descriptive analytics is the process of condensing large data sets into meaningful information that can assist in decision making. Descriptive statistics examine past performance and summarize data to discern trends and patterns to explain

behavior. In healthcare, reporting mechanisms such as regulatory compliance, quality measures, and financial results commonly use descriptive analytics.

Descriptive analytics makes up the largest subset of the analytics field. One main feature of data visualization is making data consumable by people. The process of converting raw data is necessary because data alone are not typically usable to managers.

Examples of descriptive analytics outputs include the following:

business

intelligence

The process of converting raw data through a variety of methods into information that can assist with decision making.

- **Business intelligence** reports
- Dashboards with key performance indicators (KPIs)
- Descriptive statistics
- Traditional data visualization techniques

Predictive Analytics

Predictive analytics builds models on the basis of data that can help forecast the future in terms of probabilities. Models cannot perfectly predict the future but can provide insights for individuals to make effective decisions. Predictive analytics uses a variety of statistical techniques, ranging from regression modeling to machine learning to data mining, to make projections about future events.

In healthcare, the use of predictive models has become popular in disease management and population health. For example, some healthcare organizations have begun to examine early indicators of diabetes to help prevent and lower costs associated with diabetes management (Barton 2021). This analytics activity is important because, according to the CDC (2009), more than 75 percent of total healthcare spending in the United States is related to chronic healthcare conditions.

At Hennepin County Medical Center (HCMC), population health analysts discovered that individuals diagnosed with HIV also suffered from poor nutrition. A predictive model was constructed that showed the positive impact of improved nutrition on healthcare costs. Today, HCMC distributes healthy food with HIV medications to many of the patients in this population and have found total costs to be reduced.

In short, predictive models have become a common approach to help reduce costs, improve quality outcomes, and lower overall patient risk.

Predictive Tools

Three approaches are typically used for developing predictive models: regressions, decision trees, and neural networks.

Regressions

A number of regression-type approaches can be used to predict future performance from historical data. Most analytical software (e.g., SAS, SPSS) packages include numerous regression tools.

Decision Trees

Decision trees are a form of “supervised learning” tools. The decision tree algorithm first suggests a split of the databases into a series of “leaves,” whereby each data point is allocated to one leaf. If the analyst agrees with the computer’s selection of leaves, the computer then suggests a further subdivision of the leaves. This process continues until the analyst believes the full tree represents a good model of the data.

Although regressions may be more accurate in their predictive capability, decision trees are useful for explaining the predictions to nonanalysts. A version of the decision tree tool was used to create the Medicare diagnosis-related group (DRG) system in 1983. Exhibit 8.3 demonstrates the use of a decision tree to predict annual costs for Medicare patients.

Neural Networks

Neural networks attempt to mimic the human brain in the following ways:

- Input units obtain the values of input variables and, if the analyst chooses, standardize those values.
- Hidden units perform internal computations, providing the nonlinearity that makes neural networks powerful.
- Output units compute predicted values and compare those predicted values with the values of the target variables.

Units pass information to other units through connections. Connections are directional and indicate the flow of computation in the network.

Once a neural network is created, it can be applied to predict outputs on the basis of new inputs. A challenge in using neural networks is that they are sensitive to the initial data used to calibrate the network. In addition, because of the hidden computations, neural networks are difficult to diagnose and correct if they are not operating properly.

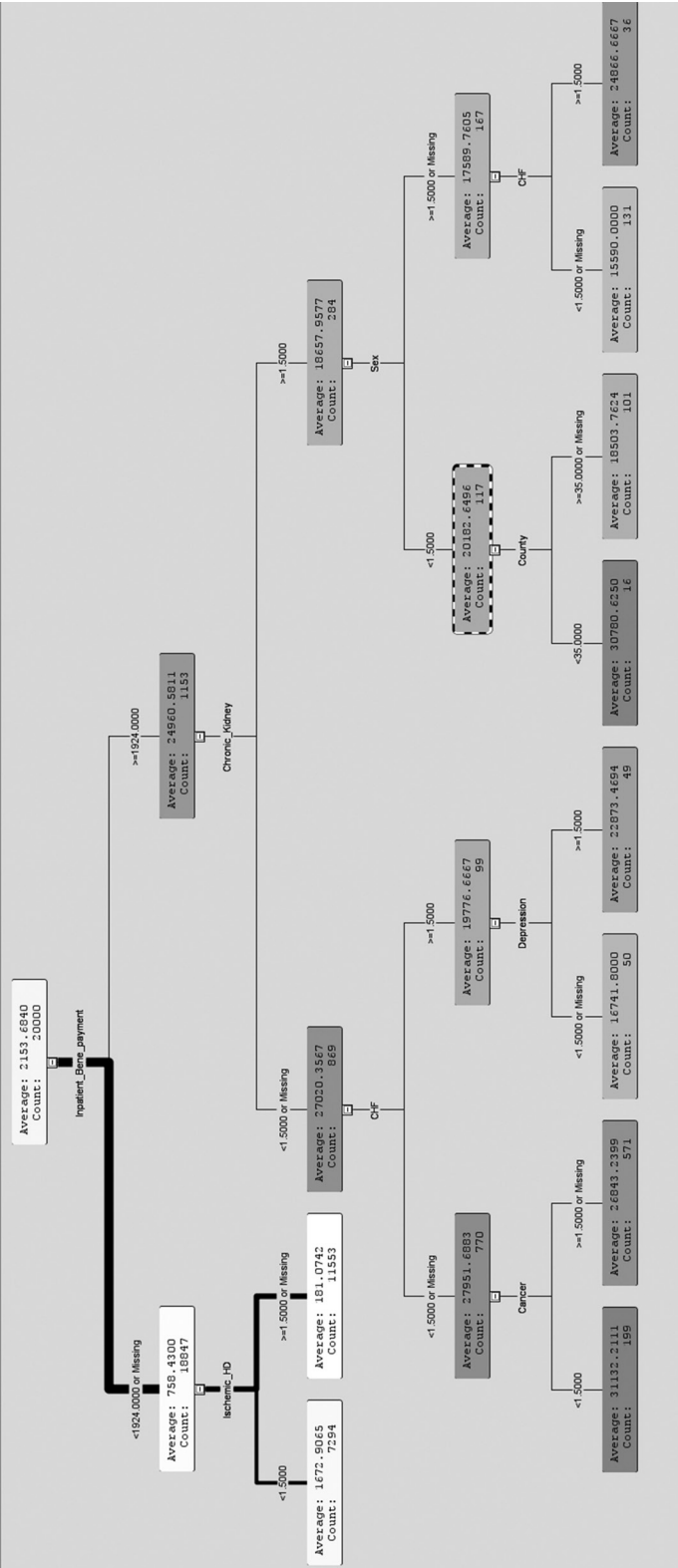
Prescriptive Analytics

Prescriptive analytics provides decision makers with models that offer guidance in the form of recommendations. These models use a combination of predictive models, optimization, mathematical models, and other techniques to generate prescriptive solutions. Examples of prescriptive models include the following:

- Models for staffing that maximize quality outcomes and minimize costs
- Models to maximize capacity in operating rooms
- Strategic models that demonstrate efficient allocation of capital investments
- Risk models that minimize adverse health events

EXHIBIT 8.3

Decision Tree Example



Note: Diagram created with SAS Miner. Data are simulated Medicare diagnosis and annual inpatient payments.

Healthcare problems are complex and multidimensional and can be difficult to model. In the modeling process, many assumptions are made in prescriptive models such as optimization. Decision makers can use prescriptive models in combination with their knowledge of the healthcare system to make effective decisions.

Data Visualization

Data visualization tools help decision makers extract value from raw big data. They enable users to quickly view, and make sense of, large amounts of data and to combine several data sources.

When dealing with most real-world data sets, the analyst can expect to spend up to 80 percent of her time finding, acquiring, loading, cleaning, and transforming data. Some of this process can be performed with automated tools, but almost any data cleaning involving two or more data sets requires some level of manual work.

Many forms of data visualization have been developed. Those discussed in this section include traditional charts and graphs and dashboards. These examples represent just a few of the common forms of visualization used today in hospitals and health systems.

Traditional Charts and Graphs

Bar Graphs

Bar graphs, or column graphs, help users visualize the scale of differences between categories. Exhibit 8.4 is a bar graph showing how much a hospital

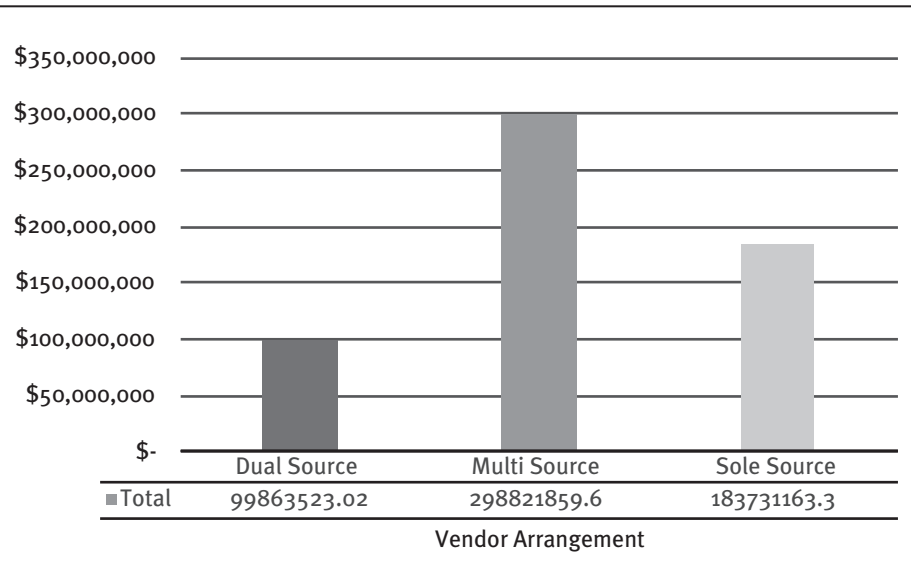
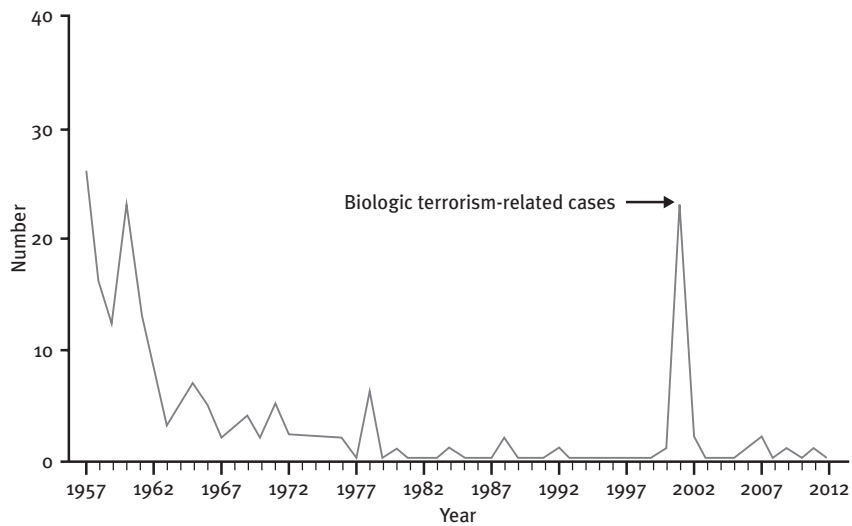


EXHIBIT 8.4
Bar Graph
Showing Total
Allocation by
Vendor Type

EXHIBIT 8.5

Line Graph
Showing
Number of
Biological Agent
Cases Reported,
1957–2012



Source: Adams et al. (2014).

system is spending on purchasing by vendor type. This is a classic example of a traditional business intelligence report created in Microsoft Excel.

Line Graphs

Another traditional business intelligence report is a classic line graph. Line graphs are useful in examining data over time. Exhibit 8.5 is a line graph showing the number of cases of biological agents reported to the CDC from 1957 to 2012. The peak in the early 2000s represents the anthrax cases reported in the time frame following the 9/11 terrorist attacks on New York City and Washington, DC, in 2001. As the exhibit demonstrates, line graphs reveal opportunities to explore trends and peaks in activity.

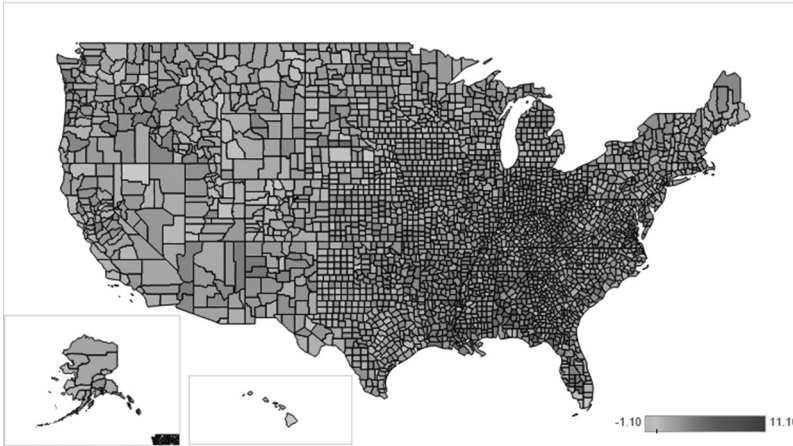
Map Functionality

Exhibit 8.6 is an example of a map of diabetes concentration by county in the United States created in Tableau. Tableau is powerful data analysis and visualization software that allows a user to create pictures by inputting data. Although such mapping does not have any predictive capability, exhibit 8.4 demonstrates its effectiveness in showing, for example, where the highest concentrations of reported individuals with diabetes reside. These types of maps help decision makers understand the concentration of data in geographic locations.

Histograms and Scatter Plots

Scatter plots show the relationships between two variables, and histograms are graphical representations of the distribution of data. These visualization techniques are covered in more detail in chapter 9.

EXHIBIT 8.6
Interactive Map
of Diabetes
Prevalence by
US County,
2004–2012



Source: Cook (2015). Used with permission.

Note: Higher numbers and darker grayscale indicate an increase in diabetes prevalence.

Dashboards¹

A key purpose of an analytics department is to collect and define metrics and KPIs for executive and operational dashboards. Although the techniques discussed here can be used across many different business intelligence gathering efforts, they are also useful for collecting and organizing business data into a format for effective dashboard design.

With the explosion of dashboard tools and technologies in the business intelligence market, many people have different understandings of what a dashboard, metric, and KPI consist of. In an effort to create a common vocabulary, we define a set of terms that form the basis of our discussion. Although the definitions provided in the following subsection might seem onerous and require a second reading to fully understand them, once grasped, these concepts avail you of a powerful set of tools for creating dashboards with effective and meaningful metrics and KPIs.

Metrics and Key Performance Indicators

Metrics and KPIs are the building blocks of many dashboard visualizations, as these components are the most effective means of alerting users to their progress toward achieving their objectives. In addition to being the products of an organization's goals and objectives, metrics and KPIs may arise from strategy maps (discussed in chapter 5).

The definitions that follow build from one concept to the next and help inform dashboard design. Take the time to understand each definition and the related concepts before moving on to the next definition.

Metrics

The term *metric* refers to a direct numerical measure that represents a piece of business data in relationship with one or more dimensions. One example is gross sales by week. The measure is dollars (gross sales), and the dimension is time (week). For any given measure, viewing the values across different hierarchies in a dimension may be helpful. For instance, a display of gross sales by day, week, and month shows the dollars (gross sales) measure along different hierarchies (day, week, and month) in the time dimension. The term *grain* refers to the association of a measure with a specific hierarchical level in a dimension.

Looking at a measure across more than one dimension, such as gross sales by territory and time, is called multidimensional analysis. Most dashboards do not leverage multidimensional analysis except in a limited and static way; more dynamic “slice and dice” tools are available in the business intelligence market. This qualification is important to note. Say you uncover a significant need for this type of analysis in the requirements gathering process. Knowing that these robust tools exist, you have the option of supplementing your dashboards with some type of multidimensional analysis tool.

Key Performance Indicators

A KPI is simply a metric that is tied to a target. Most often, a KPI represents the distance a metric is above or below a predetermined target. KPIs usually are shown as a ratio of actual to target and are designed to instantly let a business user know if he is on or off track without having to consciously focus on the metrics represented. For instance, an organization may decide that, to hit the quarterly sales target, it needs to sell \$10,000 worth of syringes per week. The metric is syringe sales per week, and the target is \$10,000. Using a percentage gauge visualization to represent this KPI, and assuming we had sold \$8,000 in syringes by Wednesday, the user would instantly see that he is at 80 percent of the goal.

When selecting targets for KPIs, remember that a target is needed for each grain you want to view in a metric. Having a dashboard that displays a KPI for gross sales by day, week, and month, for example, requires that targets be identified for each associated grain.

Scorecards, Dashboards, and Reports

The difference between a scorecard, a dashboard, and a report can be one of fine distinctions. Each of these tools can combine elements of the other, but at a high level they all target distinct and separate levels of the business decision-making process.

Scorecards

Starting at the highest, most strategic level of the business decision-making spectrum are scorecards. Scorecards are primarily used to help align operational

EXHIBIT 8.7

Sample Hospital Scorecard

Goal	Target	Owner	Review Frequency	Aug-16	Sep-16	Oct-16	YTD 2016
Finance							
Patient Information Accuracy Rate	99%	Paul	Monthly	99%	100%	97%	100%
Denials and Write-offs as % of Overall Charges	4%	Sarah	Monthly	5%	4%	3%	5%
Number of Days Charged in A/R	5	Sarah	Monthly	2	6	1	4
People							
Absenteeism Hours	30	Joseph	Monthly	15	20	30	22
Acceptable Overtime Hours	7%	Joseph	Monthly	8%	4%	5%	6%
Staffing: Open Positions	3	Jennifer	Monthly	2	1	1	1
Clinical							
Hospital-Wide 30 Day Readmissions	10.0%	Mark	Monthly	13.0%	11.0%	9.8%	12.2%
Heart Failure Mortality	13.2%	Mark	Monthly	12.7%	11.0%	9.0%	10.7%
Inpatient LOS (Days)	3	Catherine	Monthly	2.7%	2.3%	2.6%	2.5%

Source: Exhibit from “Healthcare Dashboards vs. Scorecards: Use Both to Improve Outcomes” (at www.healthcatalyst.com/healthcare-dashboards-vs-scorecards-to-improve-outcomes) by Health Catalyst, Inc., and used under license.

execution with business strategy. The goal of a scorecard is to keep the business focused on a common strategic plan by monitoring real-world execution and mapping the results of that execution back to a specific strategy (see chapter 5). The primary measurement used in a scorecard is the KPI. These indicators are often a composite of several metrics or other KPIs that measure the organization’s ability to execute a strategic objective.

Exhibit 8.7 is an example of a hospital scorecard. In this example the scorecard demonstrates how well the hospital is doing on key strategic measures (KPIs). By examining this scorecard, a decision maker can quickly observe that the 30-day readmission rate needs improvement.

Dashboards

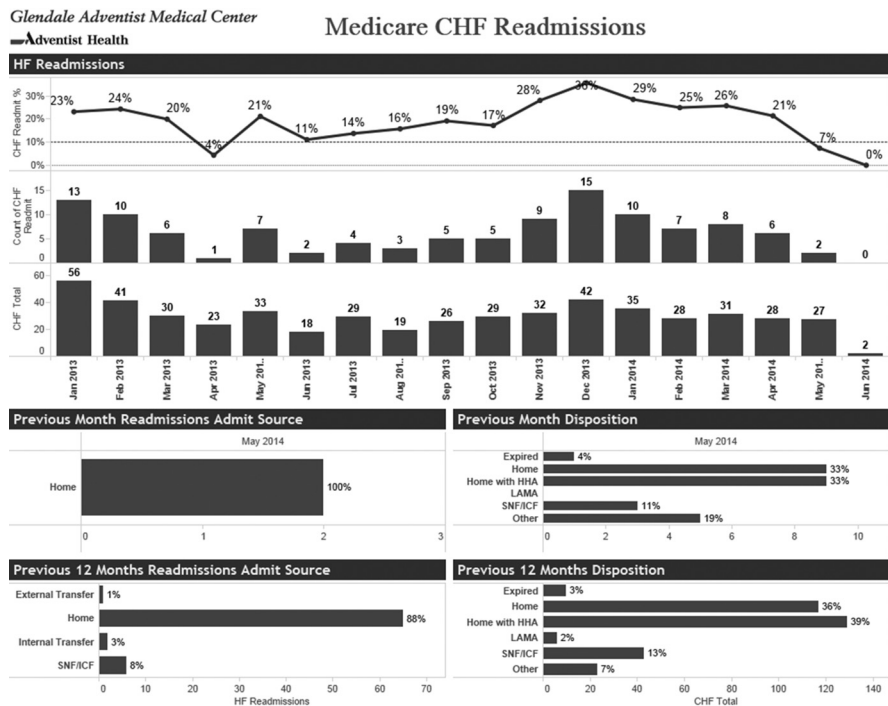
A dashboard resides one level down from a scorecard in the business decision-making process, as it is less focused on a strategic objective and more tied to operational goals. An operational goal may directly contribute to one or more high-level strategic objectives. In a dashboard, execution of the operational goal itself becomes the focus, not the high-level strategy. Dashboards are a key tool in the implementation of the balanced scorecard discussed in chapter 5.

The purpose of a dashboard is to provide the user with actionable business information in a format that is both intuitive and insightful. Dashboards leverage operational data primarily in the form of metrics and KPIs.

Exhibit 8.8 shows an example of a sample dashboard created using a popular data visualization software (Tableau). The decision maker can easily examine the visual and determine the status of readmissions for the organization. The key to the dashboard is that it presents real-time information that enables the organization to act quickly. What makes the dashboard different from the scorecard is both the granularity of the report and the individuals

EXHIBIT 8.8

Sample Tableau Dashboard



Source: Reprinted with permission from Corbett (2014).

for whom the report is intended. Scorecards are often used by organizational leaders, whereas dashboards are often used by operational managers who make daily decisions.

Reports

Probably the most prevalent business intelligence tool seen in business today is the traditional report. Reports can be simple and static in nature, such as a list of sales transactions for a given period, or more sophisticated cross-tab reports with nested groupings, rolling summaries, and dynamic drill-through or linking. Reports are most appropriate when the user needs to look at raw data in an easy-to-read format.

When combined with scorecards and dashboards, reports allow users to analyze the specific data underlying their metrics and KPIs.

Gathering Key Performance Indicator and Metric Requirements for a Dashboard

Traditional business intelligence projects often take a bottom-up approach in determining requirements, where the focus is on the domain of data and the relationships that exist in those data. When collecting metrics and KPIs for your dashboard project, however, taking a top-down approach is preferred.

A top-down approach starts with the business decisions that must be made first and then works down into the data needed to support those decisions. To take a top-down approach, you must involve the business users who will be using these dashboards, as these are the only people who can determine the relevancy of specific business data to their decision-making process.

Data Mining for Discovery

The vast majority of work being performed in healthcare analytics today is in reporting (descriptive analytics), with some highly specialized work in predictive and prescriptive analytics. Almost all of these tasks share a common characteristic: They entertain a specific hypothesis. Examples are as follows:

- I believe that patients of some doctors experience significantly longer lengths of stay than those of other doctors for the same DRG.
- I believe I can predict the amount of time a health plan will take to remit payment.
- I believe I can predict which patients will not fill their prescriptions on the basis of their zip code.

However, another powerful approach—data mining—is being used in industries outside of healthcare. In this approach, data are explored without a specific hypothesis being established, relying only on a general sense that the data might reveal insights. Data mining is a subfield of computer science that uses algorithms to discover patterns of data interactions in large data sets. It uses artificial intelligence machine learning, classical statistics, and advanced database systems such as Hadoop. Examples of data mining tools are clustering and text mining. Cognitive computing tools such as IBM's Watson also support data mining.

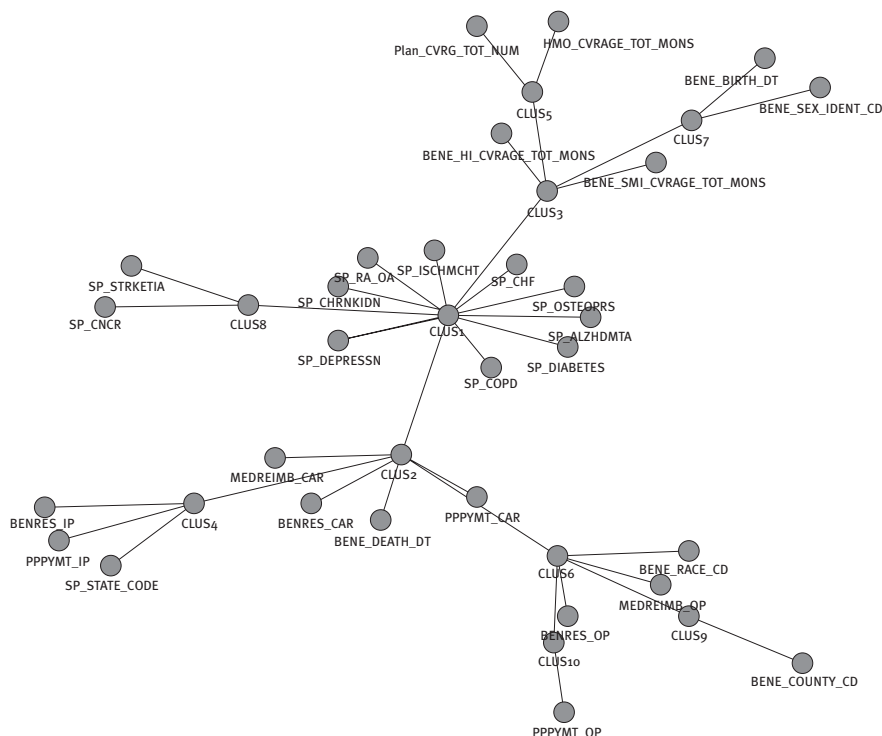
Clustering

Clustering places objects into groups, or clusters, suggested by the nature of the data. The objects in each cluster tend to be similar to each other in some sense, and objects in different clusters tend to be dissimilar. If obvious clusters or groupings are developed prior to the analysis, the clustering analysis can be performed by simply sorting the data.

The clustering methods perform disjoint cluster analysis on the basis of Euclidean distances computed from one or more quantitative variables and seeds that are generated and updated by the algorithm. The user can specify the clustering criterion used to measure the distance between data observations and seeds. The observations are divided into clusters so that every observation belongs to at most one cluster.

EXHIBIT 8.9

Cluster Analysis of Sample Medicare Data



Note: Data used in this exhibit are the same as those used for the decision tree in exhibit 8.3.

After clustering is performed, the characteristics of the clusters can be examined graphically using a clustering package in software such as R or SAS statistical packages. Exhibit 8.9 is a cluster analysis of the same Medicare data used for the decision tree in exhibit 8.3. Note that beneficiaries with chronic conditions cluster together because of their high use of inpatient services.

Text Mining

EHRs contain a significant amount of text, such as doctors' and nurses' notes. Therefore, a useful subset of data mining tools for healthcare providers is text miners. The case study that follows demonstrates the applicability of text mining to public health initiatives.

Case Example: Text Mining at the State Fair

The authors undertook an engagement in 2015 to assist a local nonprofit, Health Fair 11, an annual event sponsored by a local television station in Minneapolis–St. Paul in conjunction with the Minnesota State Fair (for more information, visit <https://www.kare11.com/article/news/health/healthfair-11/a-healthy-minnesota-state-fair-tradition/89-296307902>). The initiative

provides fairgoers with access to medical workers who check pulses, blood pressures, glucose levels, weight, and eyes and ears for potential health problems. Flu shots are also available, and advocacy groups are on hand to share health information on topics from gluten-free diets to stroke prevention to memory loss. Vendor groups include nonprofit organizations, professional associations, and for-profit companies.

The managers of Health Fair 11 were interested to know if their operational strategy needed adjustment. They surveyed a sample of 351 participants over six days. One of the key questions we asked was, “Why did you choose to get health screening at the state fair?” The general hypothesis was that the reason fairgoers used the Health Fair 11 screening services was either low cost or convenience. In addition to the results from these two options on our data collection form, we collected text answers (comments written freehand on the form).

Next, the managers engaged researchers who used the tools in SAS’s text miner Topic to cluster the text responses. Exhibit 8.10 is the clustered response. Much to the investigators’ surprise, the word *fun* appeared frequently. This unexpected result allowed the managers to pursue this concept with the organization and its vendors. They came to understand that the fairgoers felt empowered and engaged in this screening, as they were in control and did not have to go through the many gatekeepers of the traditional health system. This finding has proved useful to Health Fair 11 and carries important implications for primary care and population health.

W3 - Why did you get screening here?	
Topic	No. of documents
1 fun,+learn,fun-check,doctor,doc’s office	5
2 +screening,clinic,+check,office,health assessment	6
3 md,md’s office,fair,offer,sucha	1
4 +learn,+live,fun-check,doctor,doc’s office	3
5 time,fun-check,doctor,doc’s office,doc	2
6 fair,information,valuable-love,access,convenient	2
7 +check,work,industry,+thing,health	4
8 doctor,fun-check,+visit,test,doc’s office	2
9 sitting,down,cool,fan,fun-check	1
10 health assessment,keep,assessment,awareness,+build	2
11 random check,random,check,fun-check,doctor	1
12 doc’s office,doc,office,+screening,work	3

EXHIBIT 8.10
Text Clustering
Results from
Health Fair 11
Survey

Cognitive Computing for Data Mining

As discussed earlier, major challenges for the analyst are data preparation and deployment of the analytical tools in the most sophisticated software packages. To address this issue, a number of technology firms are developing cognitive computing systems to simplify this work. Cognitive computing systems are designed to mimic human thought and provide natural language interfaces. A leading example is IBM Watson Analytics. Users load data into the system, and Watson performs significant preprocessing to suggest interesting correlations for the analyst to examine.

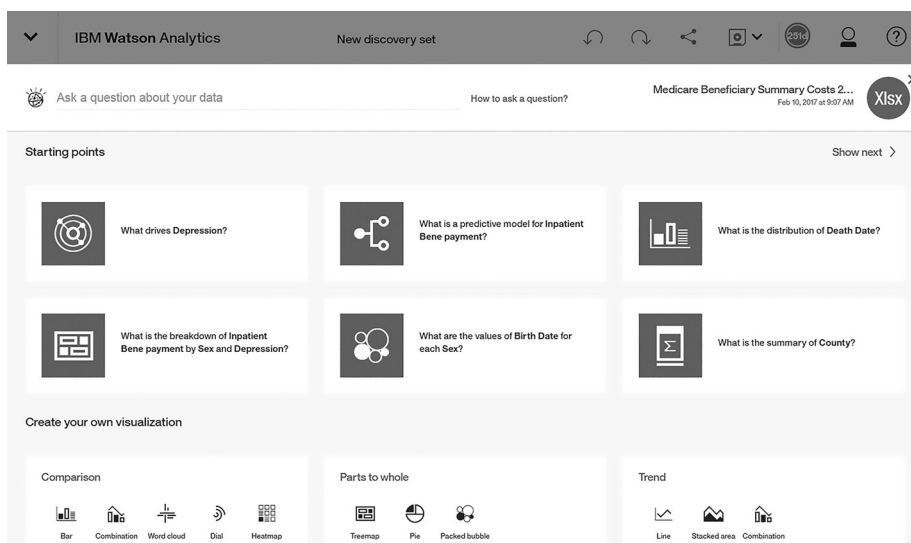
Exhibit 8.11 shows the starting screen from Watson as it looks at the Medicare beneficiary data used in earlier examples. It immediately offers six questions for the analyst to pursue. It also provides a natural language inquiry interface to delve deeper into the data.

Watson is a sophisticated example of a supervised learning tool and will continue to evolve as its underlying artificial intelligence software improves.

Conclusion

Analytics has become increasingly prevalent in healthcare. Hospitals and healthcare systems are using analytics as a means to gain insights into strategic, operational, and clinical issues. Today, the technology enables healthcare analytics to produce better visuals, build more sophisticated models, and analyze much more complex large data sets than at any time in the past. When

EXHIBIT 8.11
Opening Page
Screenshot
from Watson
Analytics



Source: IBM Watson Analytics. Used with permission.

executed correctly, data are converted into actionable insights that allow enhanced decision making.

Discussion Questions

1. Identify a healthcare operating issue that could benefit from each of the analytical techniques:
 - a. Descriptive
 - b. Predictive
 - c. Prescriptive
2. How could text mining be used to improve the care of patients with chronic disease?
3. Design a dashboard for each of the following care delivery types:
 - a. Inpatient intensive care unit
 - b. Outpatient imaging center
 - c. Dental office
 - d. Home health agency

Note

1. Portions of this section are adapted from BrightPoint Consulting (Gonzalez 2019). Used with permission.

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QUALITY IMPROVEMENT IN HEALTHCARE

**Operations Management
in Action**

Health Catalyst has partnered with healthcare systems to improve quality, using a data-driven approach to find quality opportunities that lead to process improvement. The following are some examples of process improvement projects. Note that these projects are clinical outcome and financial outcome driven, using data analytics and traditional process improvement techniques. (More success stories can be found at <https://www.healthcatalyst.com/knowledge-center/success-stories/>.)

***Pharmacist-Led Project
Reduces Cost of Care***

To reduce medication-related adverse events, Minnesota-based Allina Health System initially considered expanding the involvement of pharmacists performing medication therapy management. Instead, Allina took the approach to improve the current process to better administer medications appropriately to patients. The analysis showed the following results:

- \$2,085 average total cost of care reduction per patient
- 12 percent reduction in hospital admissions and 10 percent

OVERVIEW

Although there are many different definitions of quality improvement, the US Health Resources and Services Administration (2011, 1) defines it as “systematic and continuous actions that lead to measurable improvement in healthcare services and the health status of targeted patient groups.”

Quality problems such as clinical variation, preventable medical errors, hospital-acquired infections, and many others have contributed to the cost explosion and poor cash-flow management in the healthcare system. Later in this textbook we will discuss the role of technology and innovation in improving healthcare. Quality improvement is a key driver for lower costs and improved outcomes for our healthcare system.

Quality management in healthcare accelerated in the 1990s, culminating with the landmark Institute of Medicine (IOM 1999) report *To Err Is Human*. The report details alarming statistics on the number of people harmed by the US healthcare system and recommends major improvements in quality as related to patient safety. The healthcare industry is facing increasing pressure not only to increase quality but also to reduce costs. This chapter provides an introduction to quality management tools and techniques that healthcare organizations now use successfully. Major topics covered include the following:

- Defining quality
- The costs of quality
- Quality management approaches
- Tools and techniques, including the seven basic quality tools, statistical process control, process capability, quality function deployment, Taguchi methods, and *poka-yoke*

From an operations management perspective, quality management is about understanding and controlling processes that lead

(continued)

reduction in
emergency
department
visits

- Reduction
in total
medications
given

The net effect
of the program was
significant reduction
in total care costs.

OVERVIEW (*continued*)

to poor-quality outcomes. Process improvement is a vital role that increases quality outcomes, and this chapter will present the operations management approach to improving process quality and performance.

After completing this chapter, readers should have a basic understanding of quality, quality programs, and quality tools, enabling their application of the tools and techniques so they can begin improving quality in their organizations.

Optimizing Sepsis Care Improves Early Recognition and Outcomes

Sepsis—the body’s extreme response to an infection—causes patients to become severely ill and is a major driver of mortality in the United States. Identifying sepsis early can be challenging because patients are often asymptomatic or have nonspecific symptoms, which delays recognition, diagnosis, and treatment, and increases mortality rates.

The processes that North Carolina’s Mission Health System had developed for identifying patients with sepsis and initiating care were not consistent across the departments in the system. By using a data-driven approach to facilitate early sepsis identification and standardize treatment, Mission Health improved sepsis identification and related outcomes. Health Catalyst reports that the quality improvement approach has led to the following improvements:

- 1 percent relative reduction in mortality for patients
- 4 percent relative reduction in emergency department length of stay for patients

Systematic, Data-Driven Approach Lowers Length of Stay and Improves Care Coordination

Hospital leaders at the Memorial Health System, Springfield, Illinois, embraced the challenge of reducing length of stay to lower costs and lessen patient risk. By a proven quality approach, Memorial has achieved significant results, including the following:

- \$2 million in cost savings because of decreased length of stay
- Improved care coordination and physician engagement
- The 30-day readmission rate stayed the same

In each of these examples, data analysis using quality tools such as histograms and Pareto diagrams led to improvement projects that transformed the quality and cost of care.

Defining Quality

Although most people agree that ensuring quality in healthcare is of the utmost importance, many disagree on what the term *quality* means. The supplying organization's perspective includes performance (or design) quality and conformance quality. Performance quality includes the features and attributes designed into the product or service. Conformance quality is concerned with how well the product or service conforms to desired goals or specifications.

In his groundbreaking article, Garvin (1987) defines eight dimensions of product quality from the customer's perspective:

- *Performance*—operating characteristics
- *Features*—supplements to the basic characteristics of the product
- *Reliability*—the probability that the product will work over time
- *Conformance*—product adherence to established standards
- *Durability*—length of time that the product will continue to operate
- *Serviceability*—ease of repair
- *Esthetics*—beauty related to the look or feel of the product
- *Perceived value*—ideas of the product's worth

From the healthcare perspective, most agree that the elements of quality relate to the patient. The 2001 IOM report *Crossing the Quality Chasm* outlines six dimensions of quality in healthcare: safe, effective, patient centered, timely, efficient, and equitable. In addition, the Quality Assurance Project (2003) found nine dimensions of quality in healthcare: technical performance, access to services, effectiveness of care, efficiency of service delivery, interpersonal relations, continuity of services, safety, physical infrastructure and comfort, and choice. Finally, the Triple Aim highlights patient care, population health, and cost as the critical components of healthcare. Obviously, as in general industry, quality and its various dimensions in healthcare may be viewed in many ways. For each hospital or health system, quality is a vital dimension of how it operates.

Cost of Quality

Joseph Juran is one of the key individuals who started the quality revolution in the industrial sector in the 1950s. In the foundational text he cowrote with

cost of quality

The costs associated with producing poor-quality goods and services, including tangible costs, such as scrap and rejects, and intangible costs, such as lost customer goodwill.

Joseph De Feo, Juran defines the costs of quality as those costs associated with providing a poor-quality product or service (Juran and De Feo 2010). Crosby (1979, 15) notes that the **cost of quality** is “the expense of nonconformance—the cost of doing things wrong.”

Quality improvement initiatives and projects cannot be justified simply because “everyone is doing it”; they must be considered on the basis of financial or societal benefits. Goldstein and Iossifova (2011) demonstrated that hospitals with significant financial resources were able to benefit greatly from the use of quality management practices.

As noted in chapter 1, waste in the US healthcare system accounts for approximately 25 percent of its costs. These wastes include failure of care delivery or coordination, overtreatment or low-value care, pricing failure fraud and abuse, and administrative complexity. All waste can be minimized through the application of the quality improvement tools discussed in this chapter.

According to Juran and De Feo (2010), the cost of quality is usually separated into four parts:

- *External failure*—costs associated with failure after the customer receives the product or service (e.g., sentinel event, incorrect billing)
- *Internal failure*—costs associated with failure before the customer receives the product or service (e.g., overtime for nurses because of treatment errors, reinserting an intravenous line several times)
- *Appraisal*—costs associated with inspecting and evaluating the quality of supplies or the final product or service (e.g., X-ray costs associated with ensuring that no surgical equipment was left inside patients, hiring a person to inspect supply cabinets to make sure the right equipment is in place)
- *Prevention*—costs incurred to eliminate or minimize appraisal and failure costs (e.g., Six Sigma training costs, automated equipment for laboratory testing)

Often, the costs associated with prevention are seen as expenses, whereas the other, less apparent costs of appraisal and failure are hidden in the system (Suver, Neumann, and Boles 1992). However, preventing quality problems is usually less costly than fixing quality failures. Striving for continuous improvement not only improves quality but also can enhance an organization’s financial situation.

Although some companies use the costs of quality as a mechanism to categorize their overall quality costs, most apply the concept as a way of

thinking about quality in the system. Particularly in healthcare, where providers are taught to save the patient at all costs—literally and figuratively—the actual costs related to that mentality can be extreme. For example, suppose a hospital experiences a sentinel event in which a scope was not cleaned prior to surgery. As a result of the problems encountered, one physician starts to clean his own scopes to make sure they are sterile prior to surgery. What are the costs associated with that doctor cleaning his own scopes?

It may seem that the doctor is doing the right thing by cleaning the scope each time to ensure the quality of the surgery. However, he is considered an expensive resource whose time spent on such an activity is not cost-efficient. How many surgeries does the hospital lose as a result of the doctor not being available?

Viewing the situation from another perspective, the doctor may not be qualified to clean scopes; a lower-cost technician has the appropriate training to perform this job. If no such technician is on staff because the hospital administrator says the budget has no room to hire one to perform this task, someone with higher-cost credentials must do it. These are all costs of poor quality.

Changing the employees' mindset to see the cost of poor quality can be a difficult undertaking, as staff are inclined to "do whatever it takes" to get the job done. Such workarounds often lead to lowered overall system quality, and changing the mindset is essential if a continuous improvement program is to survive in healthcare.

Quality Analytics and Dashboards

As evident in the examples earlier in this chapter, the use of data and data analysis has become more prevalent and important to quality management. Use of data analytics is not new in quality management. Programs such as Six Sigma and total quality management use tools that provide key insights from data to address quality issues in the system. However, with the explosion of data science and analytics across industries, the capability to analyze data has grown. Today's computer systems and programs allow an analyst to quickly understand large, complex data sets and pinpoint opportunities for improving the system. A core tenet of all quality management systems is understanding system variance and striving either to minimize its impact or remove it from the system.

Modern healthcare-quality dashboards contain clinical and nonclinical measures to indicate the level of quality in the system, visually displaying the results in a way that allows management to take action (exhibit 9.1).

EXHIBIT 9.1
Requirements
for a Quality
Dashboard

Theme	Requirements
Choosing performance indicators	1. Allow users to select which performance indicators are displayed
Assessing performance	2. Where evidence-based standards exist, make it easy to assess how performance compares to that standard
	3. Support identification and evaluation of trends over time
	4. Allow users to select the time period over which performance indicators are displayed
	5. Support comparison against the national average
	6. Allow users to select particular organizations to compare with
Identifying causes	7. Enable users to “drill down,” e.g., to look at particular subgroups of patients
	8. Provide access to information about other clinical areas within the organization
	9. Support simultaneous interaction for discussion at the clinical team level
Communicating from ward to Board	10. Enable easy identification of when a clinical area is an outlier within a particular audit
Data quality	11. Provide timely data
	12. Use sources of data that staff trust

Source: Adapted from Randell et al. (2020), table 5.

For effective quality management, the following five steps are critical in the development of the dashboard.

1. *Choosing the performance indicators:* In a quality management situation, both clinical and nonclinical measures should be a part of the quality dashboard. These indicators reveal the health of the organization and provide insight into where to make changes through continuous improvement.
2. *Assessing performance:* Comparison to key and historical benchmarks. The critical piece of assessing performance is having a relational standard to make comparisons.
3. *Identifying causes:* What truly makes a quality management dashboard unique is the ability to identify potential causes, which can be tested to determine where continuous improvements should be deployed.

4. *Communication*: Mechanisms to communicate both the clinical and nonclinical results. A key component of any dashboard is the management structure, which allows for timely and effective communication of the information.
5. *Data integrity*: The utility of a dashboard only goes as far as the reliability of the information it contains. An effective dashboard should have mechanisms to ensure data integrity and reliability.

The design and use of dashboards in a quality management system provide the opportunity to use tools and techniques to address the problems and improve quality.

The Six Sigma Quality Program

Six Sigma was developed in the 1980s at Motorola as the organization's in-house quality improvement program. Since that time, the methodology has become the defining quality strategy for many organizations. General Electric adopted Six Sigma as a mechanism to gain strategic advantage through quality, and the company is widely recognized as having experienced the greatest success with Six Sigma programs.

Critical to Six Sigma is its focus on strategy with an emphasis on eliminating defects through removal of variance in business systems. Six Sigma has been defined as a philosophy, a methodology, a set of tools, and a goal. The Six Sigma philosophy transforms the culture of the organization. Its methodology employs a project team-based approach to process improvement using the define-measure-analyze-improve-control (DMAIC) cycle. As a set of tools, Six Sigma is composed of quantitative and qualitative statistically based tools used to provide management with facts to allow improvement of an organization's performance. Finally, Six Sigma as a mathematical term (6σ) signifies a goal of no more than 3.4 defects per million opportunities (DPMOs).

Six Sigma programs can take many forms, depending on the organization adopting them, but those that are successful share some common themes:

- Top management support for Six Sigma as a business strategy
- Extensive change management training to pave the way for a new way of conducting business
- Team-based projects for improvement that directly affect the organization's strategic success and financial health
- Extensive training at all levels of the organization in the methodology and use of tools and techniques
- Emphasis on the DMAIC approach and use of quantitative measures of project success

The success of Six Sigma programs hinges on the organization's ability to use the program as a technique for achieving strategic goals. When properly executed, Six Sigma drives a series of projects to help propel the organization's strategy forward. Use of the dashboard and analytics enables Six Sigma to track progress in a new way. The integration of clinical and operations measures in the dashboard provides a clear picture of progress.

Define-Measure-Analyze-Improve-Control

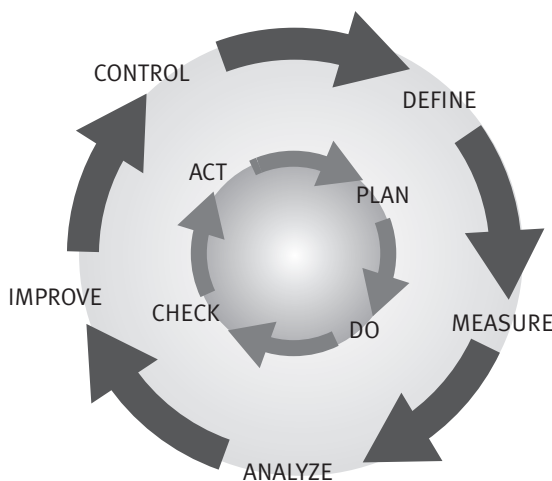
DMAIC is the acronym for how Six Sigma projects are conducted, named after the five phases of such a project: define, measure, analyze, improve, and control. The DMAIC framework, or improvement cycle (exhibit 9.2), is used almost universally to guide Six Sigma process improvement projects. DMAIC is based on the plan-do-check-act continuous improvement cycle developed by Shewhart and Deming (see chapter 2) but is much more specific.

Some observers have defined *insanity* as doing the same thing over and over again and expecting different results. Six Sigma uses this definition as a fundamental tenet of its philosophy. At its core, this definition assumes that if we do the same things over and over again, the system in which we do those things will produce the same results. The DMAIC process is designed to help develop consistently repeatable processes that deliver value to the end customer—the patient in the healthcare system.

Define

In the definition phase, the Six Sigma team chooses a project that is aligned with the strategic objectives of the business and the needs or requirements of the customers of the process. The problem to be solved (or process to be

EXHIBIT 9.2
DMAIC Process



improved) is operationally defined in terms of measurable results. “Good” Six Sigma projects typically have the following attributes:

- The project will save or make money for the organization.
- The desired process outcomes are measurable.
- The problem is important to the business, has a clear relationship to organizational strategy, and is (or will be) supported by the organization.

A benchmarking study of project selection found that most organizations (89 percent of respondents) prioritized Six Sigma projects on the basis of financial savings (Evans and Lindsey 2019). The survey also found that the existence of formal project selection processes, process documentation, and rigorous requirements for project approval were all important to the success of Six Sigma projects.

In the definition phase, internal and external customers of the process are identified and their “critical to quality” characteristics (CTQs) are determined. CTQs are the key measurable characteristics of a product or process for which minimum performance standards desired by the customer can be determined. Often, CTQs must be translated from a qualitative customer statement to a quantitative specification. In this phase, the team also defines project boundaries and maps the process (mapping is discussed in chapter 7).

Measure

In the measurement phase, team members must understand how well the process they are analyzing meets the requirements set by the customer. To gain this knowledge, the team determines the current capability and stability of the process. Using the function $Y=f(x)$ as a mechanism to understand how process outputs (Y) are affected by certain activities or tasks (x), the team begins by collecting data on the key process output variables. Once the key variables are identified, reliable metrics are determined for them (exhibit 9.3). The inputs to the process are identified and prioritized. Root-cause analysis (RCA) or

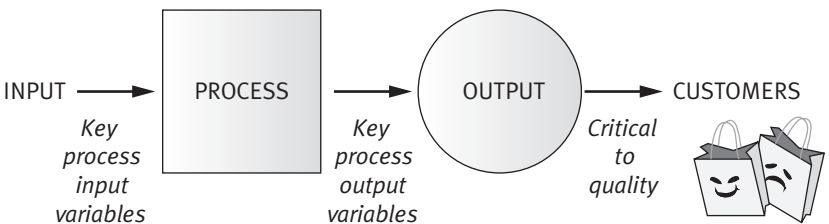


EXHIBIT 9.3
Six Sigma
Process Metrics

failure mode and effects analysis (FMEA) is sometimes used here to determine the key process input variables. Valid, reliable metrics are determined for the input variables as well. A data collection plan for the process is established and implemented related to the input and output variables. The purpose of this phase of the project is to establish the current state of the process to evaluate the impact of any changes to it.

Analyze

In the analysis phase, the team studies the data that have been collected to determine true root causes, or which of the many input variables can be best used to eliminate variation or failure in the process and improve the outcomes.

Improve

In the improvement phase, the team identifies, evaluates, and implements the improvement solutions. Possible solutions are identified and evaluated in terms of their probability of successful implementation. A plan for deployment of solutions is developed, and the solutions are put in place. Here, actual results should be measured to quantify the impact of the project.

Critical to the improvement phase is ensuring that the tested and implemented solutions address the problems identified in the project. People on Six Sigma teams often arrive with preconceived notions on how to solve problems and may manipulate the data results to justify their solution (Bednarz 2012). For example, say a director wants to hire a new doctor. To justify his request, he looks at the results and points to a lack of capacity in the system. However, the constraint in the system may not be due to physician understaffing, and the director's solution, if implemented, would increase rather than reduce spending and have no impact on system capacity.

In other words, the solutions that are put in place should address the issues uncovered in the data analysis phase of the project. When team members push solutions that do not resolve the issues uncovered by the data, inferior solutions may reduce performance and increase costs. Over time, as inferior solutions continue to be implemented, the organization abandons programs such as Six Sigma because of lack of positive results from the program. The implementation and control phases of any project are the most difficult in which to achieve success.

Control

In the control phase, controls (discussed in chapter 7) are put in place to ensure that process improvement gains are maintained and the process does not revert to the "old way of doing things." The improvements are institutionalized through modification of structures and systems (training, incentives, monitoring). This hardwiring of the change eventually becomes the new baseline for the system.

Seven Basic Quality Tools

The seven fundamental tools used in quality management and Six Sigma were first popularized by Kauro Ishikawa (1985), who believed that up to 95 percent of quality-related problems could be solved with the following tools (see exhibit 9.4):

- *Fishbone diagram (cause-and-effect diagram)*—tool for analyzing and illustrating the root causes of an effect (chapter 7)
- *Check sheet*—simple form used to collect data in which hatch marks are used to record frequency of occurrence for various categories; frequently used to produce histograms and Pareto charts
- *Histogram*—graph used to show frequency distributions
- *Pareto chart*—sorted histogram, used to separate the vital few from the trivial many, founded on the idea that 80 percent of quality problems are due to 20 percent of causes
- *Flowchart*—also called a process map (chapter 7)
- *Scatter plot*—graphical technique to analyze the relationship between two variables
- *Run chart*—plot of a process characteristic, in chronological sequence, used to examine trends; control charts, discussed hereafter under “Statistical Process Control,” are a type of run chart

Check Sheets

An essential tool used in problem solving is the check sheet. Check sheets are custom-designed forms that allow users to collect data on problems and defects. The form has checkbox items that describe typical problems in the system. When an employee uses a check sheet, he selects the appropriate box every time an error occurs. This type of tool is designed to collect data in real time as it is being created. The gathering of check sheet data is necessary prior to conducting analysis.

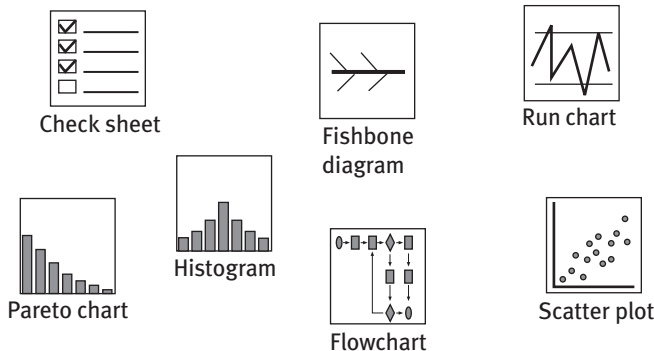


EXHIBIT 9.4
Seven Quality
Tools Flowchart

Although effective check sheets may be simple to develop and comprehend, they are difficult tools to execute well. The most effective check sheets have the following characteristics:

- They are simple to use.
- The data points reflect a consistent level of analysis.
- They include just a few boxes for the user to check.
- Data are collected as they occur.

When executed correctly, a check sheet allows a data analyst to access current data that can be used to demonstrate the state of a problem. However, many issues are encountered with the use of check sheets, mostly related to the process of collecting the data. Many people complete check sheets incorrectly because the sheets are not clear; some staff fail to fill them out as the data are created.

Data Visualization Techniques

Once valid data are collected, they need to be analyzed to answer the original question or make a decision. The data must be examined not only to determine their general characteristics but also to look for interesting or unusual patterns. Subsequent sections of this chapter cover numeric tools that can be employed for this purpose.

The human mind is powerful and has the ability to discern patterns in data, which can then be validated through numeric methods. Visual representations of the data aid in both answering questions and convincing others of the accuracy of those answers. This section taps insights into graphic analysis tools from Tufte (1997, 1990, 1983), which provide guidance on visually presenting data. The first step in data analysis is always to graph the data.

Histograms and Pareto Diagrams

Histograms and Pareto diagrams are two of the seven basic quality tools introduced in chapter 7. A **histogram** (exhibit 9.5) is used to summarize discrete or continuous data. These graphs can be useful for investigating or illustrating important characteristics of the data, such as their overall shape, symmetry, location, and spread, and the outliers, clusters, and gaps that emerge. Worth noting, however, is that for some distributions, a particular choice of bin width (interval in which frequency of data points is measured) can distort the features of a data set.

To construct a histogram, the data are divided or grouped into classes.

For each group, a rectangle is created with its base equal to the range of values in the group and its area proportional to the number of observations falling

histogram

A graph summarizing discrete or continuous data. Histograms visually display how much variation exists in the data.



On the web at
ache.org/books/OpsManagement4

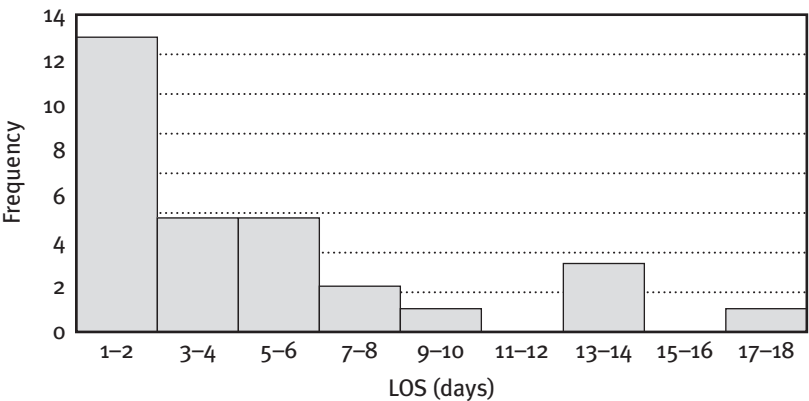


EXHIBIT 9.5
Histogram of
Hospital Length
of Stay (LOS)

into the group. If the ranges are the same length, the height of the histogram is also proportional to the number of observations falling into that group.

In this way, histograms allow an analyst to see the shape of the distribution of the data. She can quickly see if data points follow patterns of tight variation or wide variation, or simply if some data points might be considered outliers to the overall data set.

The histogram in exhibit 9.5, which depicts an example of hospital length of stay (LOS), demonstrates a distribution that is skewed to the right, revealing that the majority of inpatients stay between one and two days.

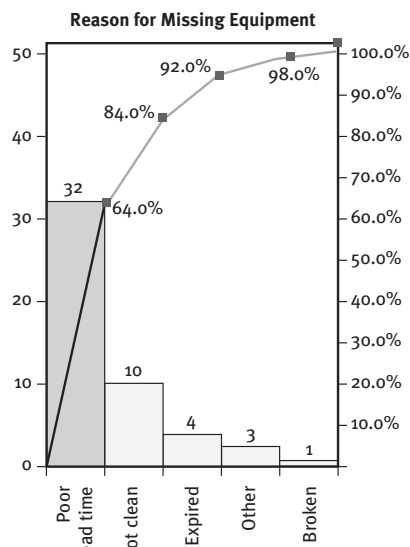
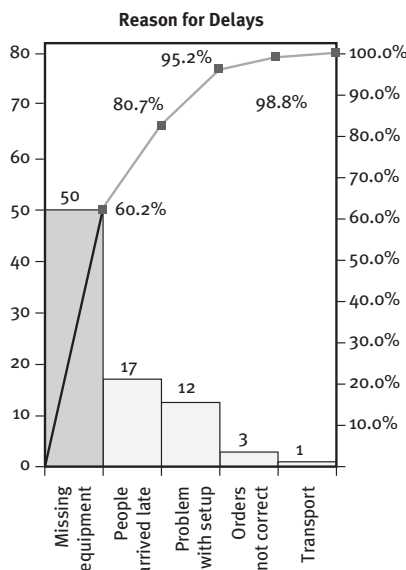
Pareto diagrams are a type of frequency diagram, which indicates the number of times a particular item occurs in a situation. The Pareto principle, or the 80/20 rule, dictates that 80 percent of costs, defects, or other types of issues are attributable to 20 percent of the items being measured. In exhibit 9.6, a hospital collected data related to a high percentage of late starts for surgeries. In the first diagram, 80 percent of all issues are related to just two issues: missing equipment at the start of surgery and late-arriving patients. Using another Pareto diagram to dissect the reasons for missing equipment demonstrated that 64 percent of those cases had insufficient lead time to clean, prepare, and load the surgery cart to arrive in time for the surgery. This analysis allowed a problem-solving team to focus its efforts on improving those few activities that made an immediate impact on the situation.

Pareto diagram
A rank-ordered frequency chart that indicates the number of times a particular item occurs in a situation.

Scatter Plots

Scatter plots are another of the seven basic quality tools. A scatter plot graphically displays the relationship between a pair of variables and can offer an initial indication of whether two variables are related, how strongly they are related, and the direction of the relationship. For example, is a relationship present between hospital LOS and a patient’s weight? Does LOS increase (decrease)

scatter plot
A graph displaying two variables that indicates whether they are related, how strongly they are related, and the direction of the relationship.

EXHIBIT 9.6**Causes for
Delays in
Surgery**

as weight increases? How strong is the relationship between LOS and weight? A scatter plot can help to answer these questions. Regression—the statistical tool related to scatter plots that gives more detailed, numeric answers to these questions—is discussed later in this chapter.

To construct a scatter plot related to the aforementioned questions, data on LOS and patient weight from the population of interest are collected. Typically, the cause, or independent variable, is on the horizontal (x) axis and the effect, or dependent variable, is on the vertical (y) axis. Each pair of variables is plotted on this graph.

Scatter plots are useful tools for determining what variables in the system need to be controlled to obtain desired outputs. Much like a Pareto diagram, a scatter plot helps narrow the number of variables an analyst needs to consider in solving the problem. A typical scatter plot is shown in exhibit 9.7.

Statistical Process Control

Statistical process control (SPC) is a statistics-based methodology for determining when a process is moving out of control. All processes have variation in output, some of it caused by factors that can be identified and managed, known as assignable or special variation, and some of it inherent in the process, called common variation. SPC aims to discover variation due to assignable causes so that adjustments can be made and “bad” output is not produced.

In SPC, samples of process output are taken over time, measured, and plotted on a control chart. From statistics theory, we know that the sample

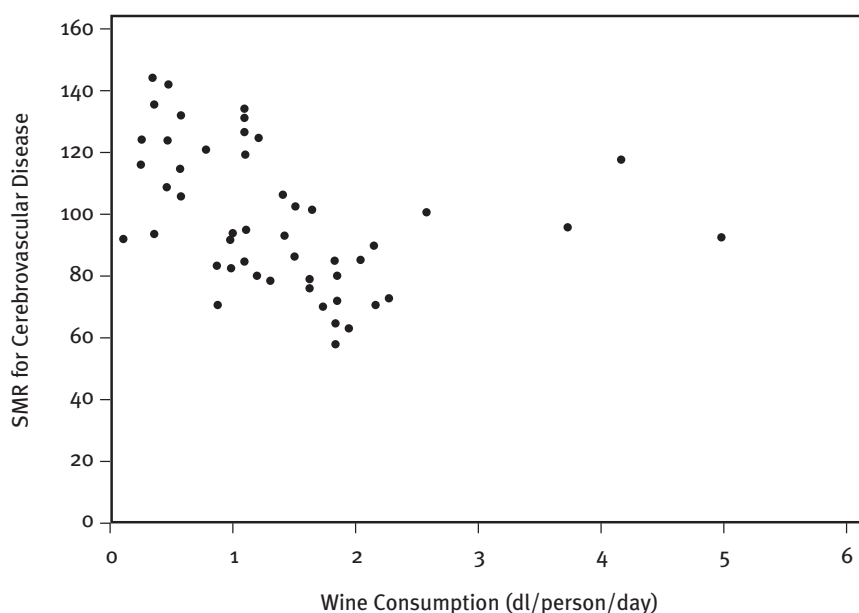


EXHIBIT 9.7
Scatter Plot
Between Wine
Consumption
and Vascular
Disease

Source: Reprinted from Truelsen and Grønbaek (1999).

Note: SMR = standardized mortality ratio.

means follow a normal distribution. From the central limit theorem, 99.7 percent of sample means have a sample mean within a positive or negative three standard errors ($\pm 3 SE$) of the overall mean and 0.3 percent have a sample mean outside those limits. If the process works as intended, only 3 times out of 1,000 would a sample mean outside the $\pm 3 SE$ limits be obtained. These $\pm 3 SE$ limits ($s_{\bar{x}}$) are the **control limits** on a control chart.

If the sample means fall outside the control limits (or follow statistically unusual patterns), the process is likely experiencing variation due to assignable or special causes and is out of control. The special causes should be found and corrected. After the process is fixed, the sample means should fall within the control limits and the process should again be in control.

Some statistically unusual patterns that indicate a process is out of control are shown in exhibit 9.8. A more complete list can be found in Pyzdek and Keller (2014).

Often, the sample mean ($\bar{X}$, called X-bar) or **X-bar chart** is used in conjunction with a **range (r) chart**. r-Charts follow many of the same rules as X-bar charts and can be used as an additional check on the status of a process. In addition, c-charts are used when the measured process output is the count of discrete events (e.g., number of occurrences in a day), and p-charts are used when the output is a proportion. Lim (2003) describes more sophisticated types of control charts that can be used in healthcare organizations.

control limits

Common variation limits that are ± 3 standard deviations from the mean.

X-bar chart

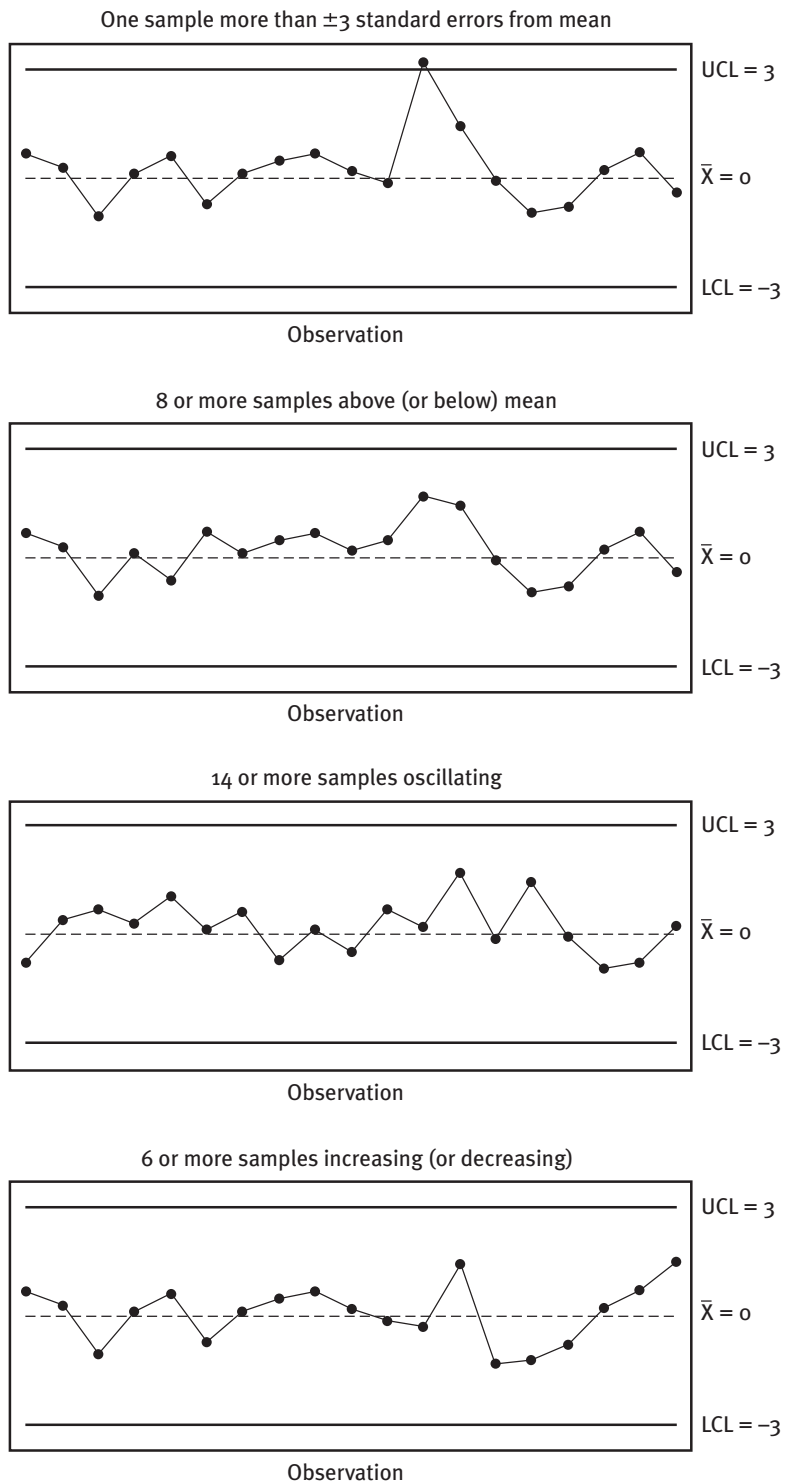
Measures process performance of sample means for continuous data.

range (r) chart

Measures process performance of sample ranges for continuous data.

EXHIBIT 9.8

Out-of-Control Patterns



Note: LCL = lower control limit; UCL = upper control limit.

A control chart may also be set up using individual values rather than sample means. However, this step often is not taken for two reasons. First, the individual values must be normally distributed. Second, data collection can be expensive; typically, collecting samples of the data costs less than collecting all of the data.

Riverview Clinic Statistical Process Control

The Riverview Clinic of Vincent Valley Hospital and Health System (VVH) is undertaking a Six Sigma project to reduce its waiting times. In the measurement phase of the project, data have been collected on waiting time and a control chart format selected to help management understand the current situation. Six observations of waiting time are made over 20 days. At randomly chosen times throughout each of the 20 days, the next patient to enter the clinic is chosen. The time from when this patient enters the clinic until he exits is recorded (exhibit 9.9).

Riverview uses the standard deviation of all of the observations to estimate the standard deviation of the population. The three-sigma control limits for the X-bar chart are calculated as follows:

$$\begin{aligned}\bar{\bar{x}} - z_{\alpha/2} \times \sigma_{\bar{x}} &\leq \mu \leq \bar{\bar{x}} + z_{\alpha/2} \times \sigma_{\bar{x}} \\ \bar{\bar{x}} - z_{\alpha/2} \times \frac{s}{\sqrt{n}} &\leq \mu \leq \bar{\bar{x}} + z_{\alpha/2} \times \frac{s}{\sqrt{n}} \\ 30 - 3 \times \frac{4.4}{\sqrt{6}} &\leq \mu \leq 30 + 3 \times \frac{4.4}{\sqrt{6}} \\ 30 - 5.4 &\leq \mu \leq 30 + 5.4 \\ 24.6 &\leq \mu \leq 35.4.\end{aligned}$$

Looking at the control chart (exhibit 9.10), it appears that day 15 was out of control. An investigation found that on day 15, the clinic was short-staffed because of a school holiday. The control chart cannot be used as is because of the out-of-control point. Knowing that they may either continue to collect data until all points are in control or recalculate the control chart limits excluding day 15, Riverview leaders choose to recalculate, and the new three-sigma limits are

$$\begin{aligned}\bar{\bar{x}} - z_{\alpha/2} \times \sigma_{\bar{x}} &\leq \mu \leq \bar{\bar{x}} + z_{\alpha/2} \times \sigma_{\bar{x}} \\ \bar{\bar{x}} - z_{\alpha/2} \times \frac{s}{\sqrt{n}} &\leq \mu \leq \bar{\bar{x}} + z_{\alpha/2} \times \frac{s}{\sqrt{n}} \\ 30 - 3 \times \frac{4.1}{\sqrt{6}} &\leq \mu \leq 30 + 3 \times \frac{4.1}{\sqrt{6}} \\ 30 - 5.0 &\leq \mu \leq 30 + 5.0 \\ 25.0 &\leq \mu \leq 35.0.\end{aligned}$$

EXHIBIT 9.9
Riverview Clinic
Wait Times, in
Minutes

Day	1	2	3	4	5	6	Sample Mean	Sample Range
Observation								
1	29	29	22	31	29	31	28.50	9
2	24	29	40	26	36	30	30.83	16
3	28	33	25	26	28	33	28.83	8
4	26	31	38	30	23	28	29.33	15
5	36	29	24	29	26	32	29.33	12
6	26	27	32	25	30	29	28.17	7
7	22	33	30	31	37	34	31.17	15
8	40	29	26	29	32	30	31.00	14
9	32	32	21	34	28	29	29.33	13
10	34	26	35	27	31	26	29.83	9
11	35	30	29	30	31	27	30.33	8
12	31	39	32	32	30	31	32.50	9
13	36	24	30	29	31	26	29.33	12
14	25	23	29	31	25	23	26.00	8
15	38	43	37	35	38	32	37.17	11
16	35	29	30	25	28	30	29.50	10
17	26	29	20	33	30	28	27.67	13
18	22	29	26	30	36	28	28.50	14
19	33	33	34	37	28	30	32.50	9
20	26	26	34	34	25	36	30.17	11
Standard Deviation = 4.42							Overall Mean = 30.00	

Unless the system is changed, 50 percent of Riverview patients will experience a wait time longer than 30 minutes (50 percent will experience a wait time of less than 30 minutes), and 10 percent of Riverview patients will experience a wait time of greater than 35.3 minutes (90 percent will experience a wait time of less than 35.3 minutes).

$$\mu \leq \bar{X} + z_{\alpha} \times \sigma_x$$

$$\mu \leq x + \alpha \times s; \quad z_{0.9} = 1.3$$

$$\mu \leq 30 + (1.3 \times 4.1)$$

$$\mu \leq 30 + 5.3$$

$$\mu \leq 35.3.$$

If Riverview's goal for its Six Sigma project is to ensure that 90 percent of patients experience a wait time of no more than 30 minutes, the clinic needs to improve the system. The Six Sigma team's aim would be to reduce mean wait time to 24.7 minutes if the process variation remains the same (exhibit 9.11).

$$\mu \leq x + z_{\alpha} \times \sigma_x$$

$$\mu \leq x + z_{\alpha} \times s; \quad z_{0.9} = 1.3$$

$$\mu \leq 30$$

$$\mu \leq 24.7 + 5.3; \quad x = 24.7$$

Process Capability and Six Sigma Quality

Process capability measures how well a process can produce output that meets desired standards or specifications. This critical measurement in Six Sigma systems determines how well the internal processes conform to customer

process capability
A measure of how well a process can produce output that meets desired standards or specifications.

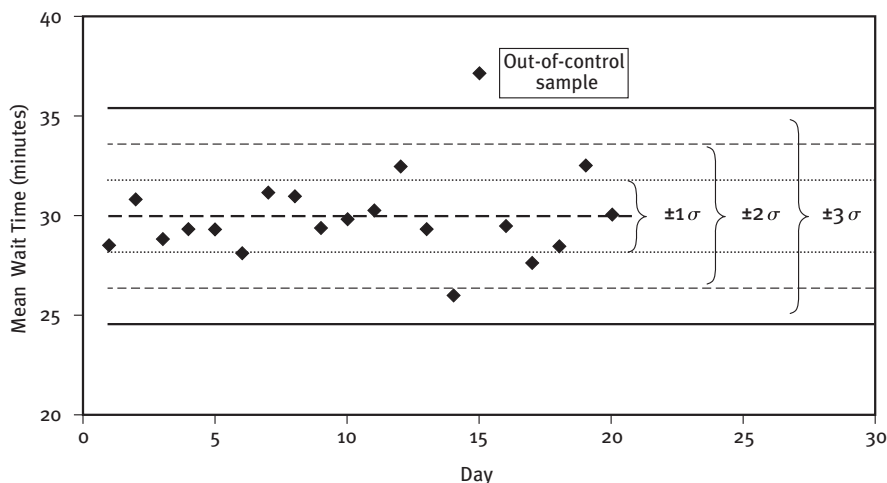
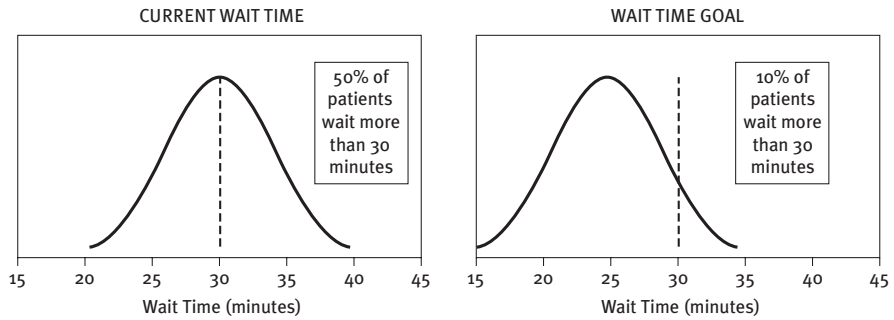


EXHIBIT 9.10
Riverview Clinic
Wait Times:
X-Bar Control
Chart

EXHIBIT 9.11

Riverview Clinic Wait Time



requirements. Process capability is measured by comparing the natural (or common) variability of an in-control process, the process width, to the specification width. Specifications are determined by outside forces (such as customers or management), but process variability is not determined—it is simply a natural part of any process. A capable process is one that produces few defects, where a defect is defined as an output outside specification limits.

The two common measures of process capability are C_p and C_{pk} . C_p is used when the process is centered on the specification limits; the mean of the process is the same as the mean of the specification limits. C_{pk} is used when the process is not centered. A capable process shows a C_p or C_{pk} greater than 1. At a C_p of 1, the process produces about 3 defects per 1,000 attempts or opportunities.

$$C_p = \frac{USL - LSL}{6s} \text{ and is estimated by } \hat{C}_p = \frac{USL - LSL}{6s}$$

$$C_{pk} = \min \frac{\bar{x} - LSL}{3s} \text{ or } \frac{USL - \bar{x}}{3s}$$

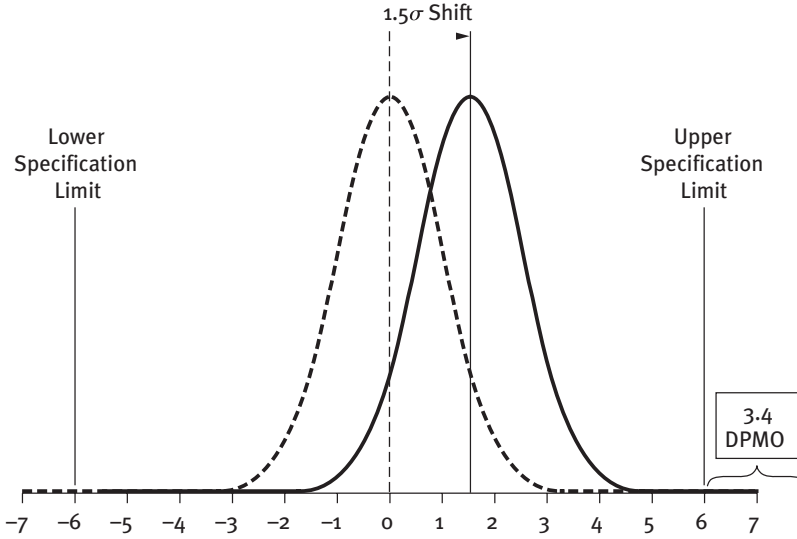
$$\text{and is estimated by } \hat{C}_{pk} = \min \frac{\bar{x} - LSL}{3s} \text{ or } \frac{USL - \bar{x}}{3s},$$

where USL = upper specification limit and LSL = lower specification limit.

Recall that Six Sigma quality is defined as fewer than 3.4 DPMOs. This definition can be somewhat confusing, as it corresponds to the 4.5σ one-tail probability limit for the normal distribution. Six Sigma allows for a 1.5σ shift in the mean of the process and $C_{pk} = 1.5$ (exhibit 9.12).

Riverview Clinic Process Capability

Riverview Clinic management has decided that no patient should wait more than 40 minutes, or a waiting time USL of 40 minutes. The Six Sigma team

EXHIBIT 9.12**Six Sigma
Process
Capability
Limits**

wants to determine if the process is capable of achieving that wait time threshold. Note that because no lower specification limit is specified (waiting time less than some lower limit would not be considered a defect), C_{pk} is the correct measure of process capability.

$$\hat{C}_{pk} = \left(\frac{USL - \bar{x}}{3s} \right) = \frac{40 - 30}{3 \times 4.1} = \frac{10}{12.3} = 0.81$$

The C_{pk} is less than 1. Therefore, the process is not capable, and 7,000 DPMOs are expected [$x \sim N(30, 16.8)$, $P(x > 40) = 0.007$].

The team determines that to ensure Six Sigma quality, the specification limit needs to be 48.8 minutes:

$$\hat{C}_{pk} = 1.5 = \frac{USL - \bar{x}}{3s} = \frac{USL - 30}{12.3} = \frac{48.8 - 30}{12.3} \therefore USL = 48.8.$$

If the Riverview Six Sigma team determines that Six Sigma quality with a specification limit of 40 minutes is a reasonable goal, it may reduce average wait time, reduce the variation in the process, or seek some combination of both.

$$\hat{C}_{pk} = \frac{USL - \bar{x}}{3s} = \frac{USL - \bar{x}}{12.3} = \frac{40 - 21}{12.3} \therefore \bar{x} = 21$$

$$1.5 = \frac{40 - 30}{3s} = \frac{10}{3 \times 2.2} \therefore s = 2.2$$

Average wait time must be reduced to 21 minutes, or the standard deviation of the process reduced to 2.2 minutes, to reach the goal.

Rolled Throughput Yield

rolled throughput yield (RTY)

The probability that a unit (of product or service) will pass through all process steps free of defects.

Rolled throughput yield (RTY) measures overall process performance. It is the probability that a unit (of product or service) will pass through all process steps free of defects. For example, consider a process composed of four steps or subprocesses. If each step has a 5 percent probability of producing an error or defect (95 percent probability of an error-free outcome), the RTY of the overall process is 81 percent—considerably lower than that in the individual steps (exhibit 9.13).

Additional Quality Tools

quality function deployment (QFD)

A technique that translates customer requirements to specific product or process requirements.

In addition to the quality tools and techniques commonly associated with Six Sigma, many other tools can be used in process improvement. **Quality function deployment (QFD)** and Taguchi methods are often applied in the development of new products or processes to ensure quality outcomes. However, they can also be used to improve existing products and processes. Benchmarking helps to determine best practices and to adapt them to the organization to achieve superior performance. Mistake proofing, or poka-yoke, is used to minimize the possibility of an error occurring. All of these tools are essential components of an organization’s quality toolbox.

Quality Function Deployment

QFD is a structured process for identifying customer needs and wants and translating them to a product or process that meets those needs. This tool is most often used in the development phase of a new product or process, but it can also be applied to redesign an existing product or process. Typically, QFD is found in a design for Six Sigma project, where the goal is to design the process to meet Six Sigma goals. The QFD process uses a matrix called the house of quality (exhibit 9.14) to organize data in a usable fashion.

EXHIBIT 9.13
Rolled
Throughput
Yield

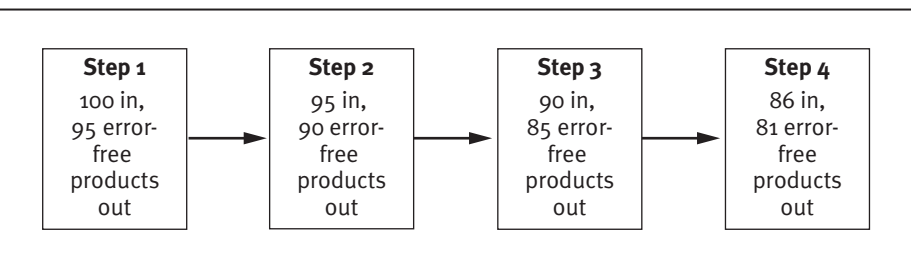
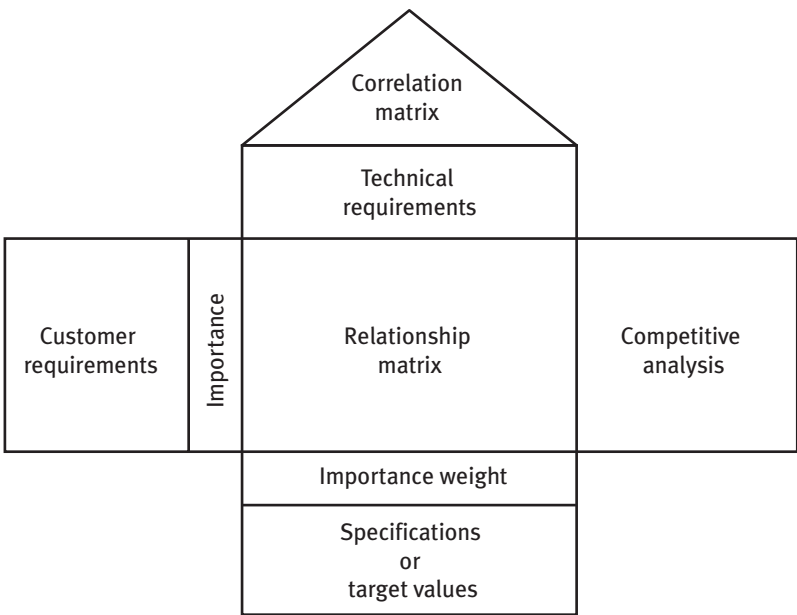


EXHIBIT 9.14
House of
Quality
Correlation
Matrix



The first step in QFD is to determine customer requirements. Customer requirements represent the voice of the customer (VOC) and are often stated in customer terms, not technical terms. A particular product or service can have many customers, and the voice of all must be heard.

Market research tools are used to capture the VOC. The many customer needs discovered are organized into a few key customer requirements, which are weighted on the basis of their relative importance to the customer. Typically, a scale of 1 to 5 is used, with 5 representing the most important. The customer requirements and their related importance are listed on the left side of the QFD diagram.

A competitive analysis of the identified customer needs is also performed. The question here is how well competitors meet customer needs. Typically, a scale of 1 to 5 is used here as well, with 5 indicating that the competitor completely meets the particular need. The competitive analysis is used to focus the development of the service or product on areas that present opportunities to gain competitive advantage and where the organization is at a competitive disadvantage. This assessment can help the development team focus on important strategic characteristics of the product or service. The competitors' scores on each customer requirement are listed on the right side of the QFD diagram.

Technical requirements of the product or process that relate to customer requirements are determined next. For example, if customers want speedy

service time, a related technical requirement might be that 90 percent of all service times be less than 20 minutes. The technical requirements are listed horizontally across the top of the QFD diagram, and the relationship between the customer requirements and technical requirements is evaluated. Usually, the relationships are evaluated as strong, medium, or weak, and symbols represent these relationships in the relationship matrix. Numeric values are assigned to the relative weights (5 = strong, 3 = medium, 1 = weak), and these values are placed in the matrix.

Positive and negative interactions among the technical requirements are evaluated as strongly positive, positive, strongly negative, and negative. Another set of symbols represents these relationships in the “roof,” or correlation matrix, of the house of quality. This framework makes clear the trade-offs involved in product and process design.

Customer importance weights are multiplied by relationship weights and summed for each technical requirement to determine the overall importance weights. Target values are then developed from the house of quality that emerges from the process.

Historically, QFD was a phased process. The previously described process is the planning phase; for product development, planning is followed by the construction of additional houses of quality related to parts, process, and production. For service development and improvement, using only the first house of quality, or the first house of quality followed by the process house, is often sufficient. For examples of QFD applications in healthcare environments, see Sarker and colleagues (2010), and for a complete review of QFD applications in healthcare and other industries, see Sharma and Rawani (2010).

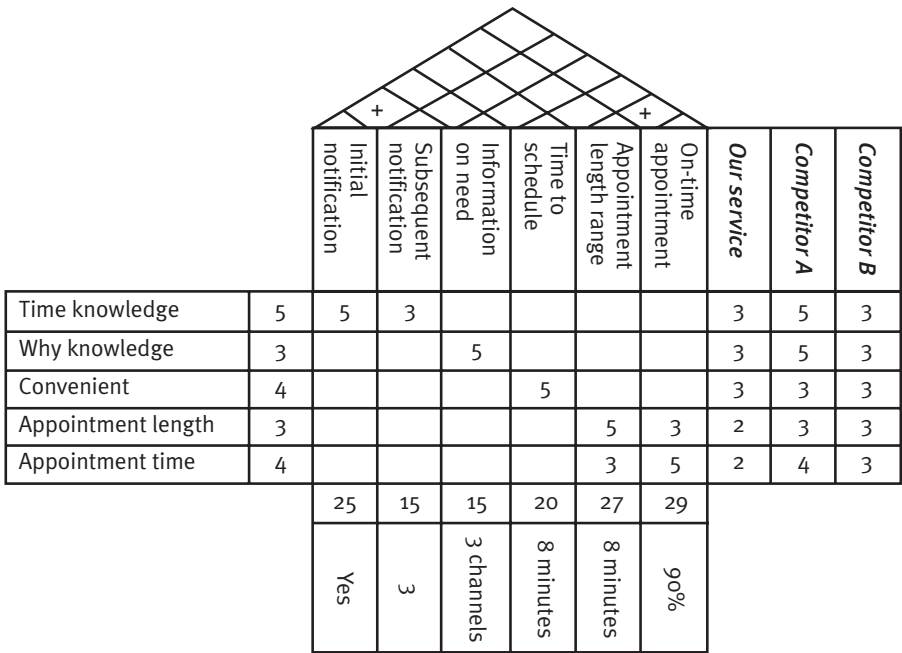
Riverview Clinic Quality Function Deployment

Many patients with diabetes at Riverview Clinic do not return for routine preventive exams. The team formed to address this problem has decided to use QFD to improve the process and begins by soliciting the VOC via focus groups. The team finds the following patient needs and wants:

- To know (or be reminded) that they need to schedule a preventive exam
- To know why an office visit is needed
- A convenient means to schedule their appointments
- That their appointments be on time
- To know that their appointments will last a certain length of time

Next, patient rankings of the importance of these needs and wants are determined via patient surveys.

EXHIBIT 9.15
Riverview
Clinic House
of Quality for
Patients with
Diabetes



A competitive analysis of Riverview Clinic’s two main competitors follows to assess how they are meeting the determined needs and wants of Riverview’s patients with diabetes. The team develops related technical requirements and evaluates the interactions between them. The resulting house of quality is shown in exhibit 9.15. On-time appointments emerge as the highest importance ranking because they affect both the time and length of appointments.

The team then evaluates various process changes and improvements related to the determined technical requirements. To meet these technical requirements, it decides to notify patients via postcard and to follow this method with email and phone notification if needed. The postcard and email contain information related to the need for an office visit and direct patients to the clinic’s website for more information. Appointment scheduling is made available via the internet as well as by phone. Staffing levels and appointment times are adjusted to ensure that appointments take place on time as scheduled and are approximately the same length. Training is conducted to help physicians and nurses understand the need to maintain appointment lengths, and tools are provided to them to ensure consistent length.

Exhibit 9.16 outlines these process changes and related technical requirements. After the changes are implemented, the team checks to ensure that the technical requirements determined by the house of quality are being met.

EXHIBIT 9.16
Riverview
QFD Technical
Requirement
and Related
Process Change

Technical Requirement	Process Change
Initial notification	Postcard mailed
Subsequent notifications	Email, phone call
Information on need	Website
Time to schedule	Website and phone
Appointment length range	Staff levels adjusted
On-time appointment	Staff training

Note: QFD = quality function deployment.

Benchmarking

According to the American Productivity and Quality Center (2005), benchmarking is “the process of identifying, understanding, and adapting outstanding practices and processes from organizations anywhere in the world to help your organization improve its performance.” Benchmarking focuses on how to improve any given process by finding, studying, and implementing best practices.

These best practices may be found in the organization, in competitor organizations, and even in organizations outside the particular market or industry. Best practices are everywhere—the challenge is to find them and adapt them to the organization.

The benchmarking process consists of deciding what to benchmark, determining how to measure it, gathering information and data, and then implementing the best practice in the organization. Benchmarking can be an important part of a quality improvement initiative, and many healthcare organizations are involved in benchmarking.

Poka-Yoke

poka-yoke
A mechanism that prevents mistakes or makes them immediately obvious to prevent adverse outcomes.

Poka-yoke (a Japanese phrase meaning to avoid inadvertent errors), or mistake proofing, is a way to prevent errors from occurring. A poka-yoke is a mechanism that either prevents a mistake from being made or makes the mistake immediately obvious so that no adverse outcomes are experienced. For example, all of the instruments required in a surgical procedure are placed on an instrument tray with unique indentations for each instrument. After the procedure is complete, the instruments are replaced in the tray. This process provides a quick means to visually check that all instruments are removed from the patient before closing the patient’s incision.

Another example of mistake proofing is locating the controls for a mammography machine in such a way that the technician cannot start the machine

unless she is shielded from radiation by a wall that separates her from the machine. In FMEA, identified fail points are good candidates for poka-yoke.

Technology can often enable poka-yoke. When patient data are put into a system, the software is often programmed to provide an error message if the data are incorrect. For example, a Social Security number is nine digits long; no more than nine digits can be entered into the Social Security field, and an error message appears if fewer than nine digits are entered. In the past, surgical sponges were counted before and after a procedure to ensure that none were left in a patient. Now, the sponges can be radio frequency identification tagged, eliminating the error-prone counting process, and a simple scan can determine if any sponges remain in the patient.

Riverview Clinic Six Sigma Generic Drug Project

Riverview Clinic's management team has determined that meeting pay-for-performance goals related to prescribing generic drugs is a strategic objective for the organization, and a project team has been organized to meet this goal. Benchmarking is performed to help the team determine which pay-for-performance measure to focus on and to define reasonable goals for the project. The team has found that 10 percent of nongeneric prescription drugs could be replaced with generic drugs, an approach taken by other clinics that have successfully met this goal.

Define

In the definition phase, the team articulates the project goals, scope, and business case. This activity includes developing the project charter, determining customer requirements, and diagramming a process map. (The charter for a similar project is found in chapter 5; it defines the project's goals, scope, and business case.)

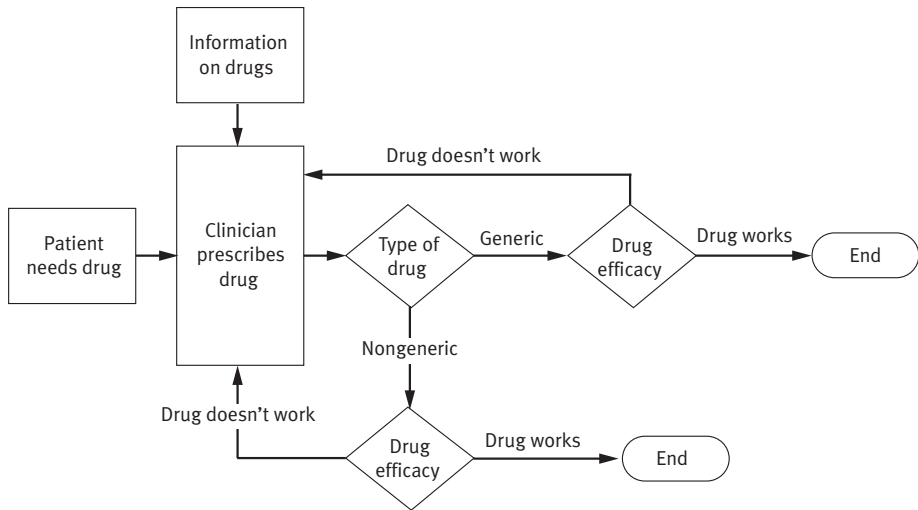
The team identifies the health plans and patients as customers of the process. The outputs of the process are identified as prescriptions and the efficacy of those prescriptions. The process inputs are physician judgment and the information technology (IT) system for drug lists. Additionally, pharmaceutical firms provide input on drug efficacy. The process map developed by the team is shown in exhibit 9.17.

Measure

The team decides to quantify the outcomes using the percentage of generic (versus nongeneric) drugs prescribed and the percentage of prescription changes following the prescribing of a generic drug. Additionally, the team tracks and records data on all nongeneric drugs prescribed by each individual clinician for one month.

EXHIBIT 9.17

Riverview Clinic Prescription Process



Analyze

After one month, the team analyzes the data and finds that, overall, clinicians prescribed 65 percent generic drugs (exhibit 9.18) and prescription changes were needed for 3 percent of all prescriptions. A sample of the data collected is shown in exhibit 9.19.

The team generates a Pareto analysis by clinician and drug to determine if particular drugs or clinicians were more problematic than others. The analysis shows that some drugs caused more problems, leading to represcribing, but that all clinicians showed roughly the same outcomes (exhibit 9.20).

The team reexamines its stated goal of increasing generic drug prescriptions by 4 percent in light of the data collected. If all prescriptions for the top four nongeneric drugs for which a generic drug is available could be changed to generics, Riverview would increase generic prescriptions by 5 percent. Therefore, management decides that the original goal is still reasonable.

EXHIBIT 9.18

Riverview Generic Drug Project: Drug Type and Availability

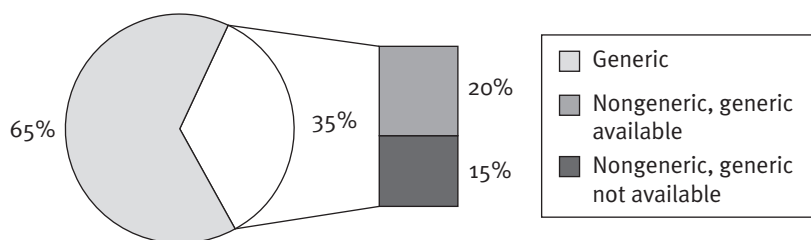


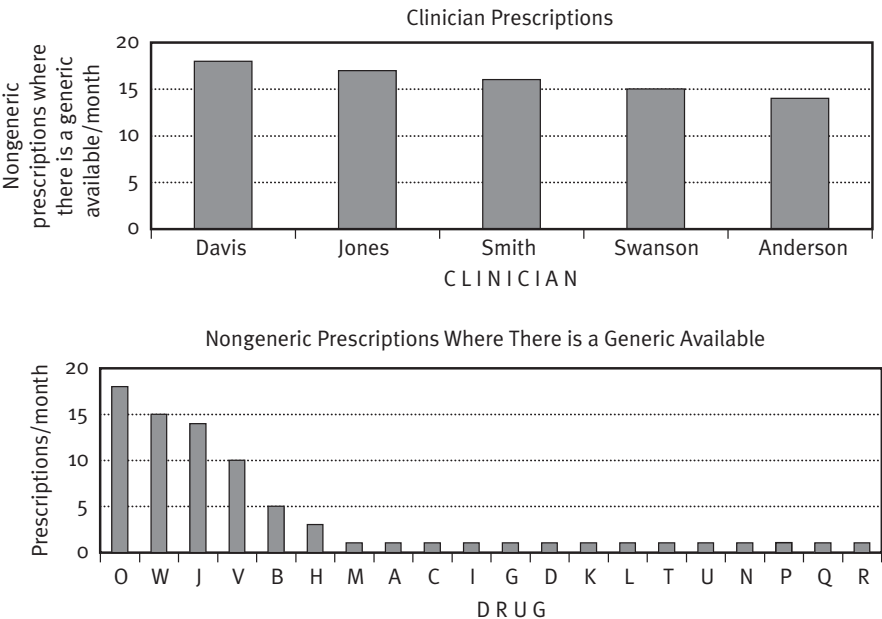
EXHIBIT 9.19
Riverview Clinic
Generic Drug
Project Sample
Data

Date	Clinician	Drug	Drug Type	Generic Available	Represcribe
1-Jan	Smith	F	Nongeneric	Yes	No
1-Jan	Davis	G	Generic	Yes	No
1-Jan	Jones	L	Generic	Yes	No
1-Jan	Anderson	F	Nongeneric	No	No
1-Jan	Swanson	R	Generic	Yes	Yes
1-Jan	Smith	S	Nongeneric	Yes	No
1-Jan	Swanson	U	Generic	Yes	No
1-Jan	Jones	P	Generic	Yes	No
1-Jan	Jones	S	Nongeneric	No	No
1-Jan	Swanson	A	Generic	Yes	No
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
31-Jan	Anderson	F	Nongeneric	Yes	No
31-Jan	Anderson	E	Nongeneric	No	No
31-Jan	Davis	T	Generic	Yes	No
31-Jan	Smith	Y	Generic	Yes	No
31-Jan	Jones	D	Generic	Yes	No
31-Jan	Swanson	J	Generic	Yes	No
31-Jan	Swanson	I	Nongeneric	Yes	No
31-Jan	Smith	T	Generic	Yes	No
31-Jan	Davis	G	Generic	Yes	No
31-Jan	Anderson	H	Generic	Yes	No

Improve

The team conducts an RCA of the reasons for prescribing nongeneric drugs and determines that the major cause was the clinicians' lack of awareness of a generic replacement for the prescribed drug. In addition to adapting the IT system to identify approved generic drugs, the team publishes a monthly top five list (on the basis of data from the previous month) of nongeneric drugs for which an approved generic exists. The team continues to collect and analyze

EXHIBIT 9.20
Riverview Clinic
Generic Drug
Project: Pareto
Diagrams



data after these changes are implemented and finds that prescriptions for generic drugs have risen by 4.5 percent after six months.

Control

To measure progress and ensure continued compliance, the team sets up a weekly control chart for generic prescriptions and continues to monitor and publish the top five list. It conducts an end-of-project evaluation to document the steps taken and results achieved and to ensure that learning from the project is retained in the organization (exhibit 9.21).

Conclusion

The Six Sigma DMAIC process is a framework for improvement. At any point in the process, revisiting an earlier step in the process may be necessary to ensure that improvement is achieved. For example, what the process improvement team thought was the root cause of a problem of interest may be found not to be the true root cause. Or when attempting to analyze the data, insufficient or incorrect data may have been collected. In both cases, the team may need to go back in the DMAIC process to ensure that a project is successful.

EXHIBIT 9.21
Quality Tools
and Techniques
Selector Chart

Tool or Technique	Define	Measure	Analyze	Improve	Control
7 quality control tools					
Cause-and-effect diagram			x		
Run chart		x	x		
Check sheet					
Histogram		x	x		
Pareto chart		x	x	x	
Scatter plot			x		x
Flowchart	x	x			
Other tools and techniques					
Mind mapping/ brainstorming	x		x	x	
5 Whys/RCA			x		
FMEA			x	x	
Pie chart			x		
Hypothesis testing			x		
Control chart		x		x	x
Process capability		x		x	x
QFD		x	x	x	
Benchmarking	x	x	x	x	
Poka-yoke				x	
Gantt chart				x	
Project planning	x			x	x
Charters	x				
Tree diagram				x	
Force field analysis				x	x
Balanced scorecard	x	x	x	x	x

Note: FMEA = failure mode and effects analysis; QFD = quality function deployment; RCA = root-cause analysis.

At each step in the DMAIC process, various tools can be used. The choice of tool is related to the problem and possible solutions. Exhibit 9.18 outlines suggestions for when to choose a particular tool or technique. This chart is only a guideline—you should use whatever tool is most appropriate for the situation.

Discussion Questions

1. Read the executive summary of the IOM (1999) report *To Err Is Human* (www.nap.edu/read/9728/chapter/2?term=executive+summary) and answer the following questions:
 - a. Why did this report spur an interest in quality management in the healthcare industry?
 - b. What does IOM recommend to address these problems?
 - c. Conduct a search and determine how much progress has been made since 1999.
2. What does quality in healthcare mean to your organization? To you personally?
3. Discuss a real example of each of the four costs of quality in a healthcare organization.
4. List at least three poka-yokes currently used in the healthcare industry. Can you think of a new one for your organization?

Exercises

1. Clinicians at VVH have been complaining about the turnaround time for blood work. The laboratory manager decides to investigate the problem and collects turnaround time data on five randomly selected requests every day for one month (shown in the following chart).
 - a. Construct an X-bar chart using the standard deviation of the observations to estimate the population standard deviation.
Construct an X-bar chart and r-chart using the range to calculate the control limits. (The Excel template on the book's companion website performs this calculation for you.)
 - b. Is the process in control? Explain.
 - c. If the clinicians feel that any time greater than 100 minutes is unacceptable, what are the C_p and C_{pk} of this process?
 - d. What are the next steps for the laboratory manager?



On the web at
ache.org/books/OpsManagement4

Day	Observation					Day	Observation				
	1	2	3	4	5		1	2	3	4	5
1	44	41	80	51	25	16	14	44	35	52	76
2	28	32	58	42	18	17	52	84	55	63	15
3	54	83	59	50	46	18	28	20	67	76	69
4	57	53	63	15	52	19	25	23	35	21	23
5	30	50	62	68	42	20	46	74	24	10	47
6	42	40	50	49	73	21	33	54	62	14	72
7	26	17	50	47	91	22	64	55	62	14	72
8	54	39	39	82	28	23	53	49	72	49	61
9	46	62	53	64	57	24	15	16	18	35	78
10	49	71	34	42	43	25	64	9	51	47	70
11	53	64	12	35	43	26	36	21	51	40	57
12	75	43	43	50	64	27	24	58	19	88	16
13	74	19	52	55	59	28	75	66	34	27	71
14	91	40	66	15	73	29	60	42	20	59	60
15	59	32	59	49	71	30	52	28	85	39	67

2. Riverview Clinic has started a customer satisfaction program. In addition to other questions, each patient is asked if she is satisfied with her overall experience at the clinic. Patients can respond “yes” if they were satisfied or “no” if they were not satisfied. Typically, 200 patients are seen at the clinic each day. The data collected for two months are shown in the following chart.

Day	Proportion of patients who were unsatisfied	Day	Proportion of patients who were unsatisfied	Day	Proportion of patients who were unsatisfied
1	0.17	15	0.15	28	0.18
2	0.13	16	0.14	29	0.19
3	0.15	17	0.13	30	0.14

(continued)

Day	Proportion of patients who were unsatisfied	Day	Proportion of patients who were unsatisfied	Day	Proportion of patients who were unsatisfied
4	0.22	18	0.15	31	0.19
5	0.16	19	0.15	32	0.10
6	0.13	20	0.22	33	0.17
7	0.17	21	0.19	34	0.15
8	0.17	22	0.15	35	0.17
9	0.11	23	0.12	36	0.15
10	0.16	24	0.16	37	0.15
11	0.15	25	0.18	38	0.15
12	0.17	26	0.14	39	0.14
13	0.17	27	0.17	40	0.19
14	0.12				

- a. Construct a p-chart using the collected data.
- b. Is the process in control?
- c. On average, how many patients are satisfied with Riverview Clinic's service? If Riverview wants 90 percent (on average) of patients to be satisfied, what should the clinic do next?
3. Think of a problem in your organization that Six Sigma could help solve. Map the process and determine the key process input variables, the key process output variables, the CTQs, and exactly how you can measure them.
4. Use QFD to develop a house of quality for the VVH emergency department (you may need to guess the numbers you do not know).

The Excel template labeled QFD.xls, available on the companion website, may be helpful in completing this problem.



On the web at
ache.org/books/OpsManagement4

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LEAN HEALTHCARE

**Operations Management
in Action**

Virginia Mason, a healthcare system in Seattle, is a leader in Lean implementation in healthcare systems. As they report, “In 2002, Virginia Mason embarked on an ambitious, system-wide program to change the way it delivers health care and in the process, improve patient safety and quality. It did so by combining basic tenets of the Toyota Production System (TPS), and elements from the philosophies of kaizen and [L]ean, to create the Virginia Mason Production System.”

Embracing the fundamental tenets of the Lean TPS program, Virginia Mason has deployed Lean to focus on improving patient safety and quality and well as lower the overall costs of delivering care.

Some amazing examples have demonstrated how well this approach has worked for the healthcare system. Virginia Mason has reported the following results from their Lean efforts:

- 50 percent reduction in antibiotic administration
- Decreased treatment time in outpatient infusions from 9 hours to 60 minutes
- Reduction of wait times in the emergency department

OVERVIEW

Lean tools and techniques have been employed extensively in manufacturing organizations since the 1990s to improve the efficiency and effectiveness of those organizations’ activities. Since that time, many healthcare organizations realized the transformative potential of Lean to improve patient safety and financial performance (Dobrzykowski, McFadden, and Vonderembse 2016).

The healthcare industry faces increasing pressure to use resources in an effective manner to reduce costs and increase patient satisfaction. This chapter provides an introduction to the Lean philosophy as well as the various Lean tools and techniques used by many healthcare organizations today. The major topics covered include the following:

- The Lean philosophy
- Defining waste
- Kaizen
- Value stream mapping
- Other Lean tools, techniques, and ideas, including the five Ss, spaghetti diagrams, kaizen events, takt time, kanbans, rapid changeover, *heijunka*, *jidoka*, *andon*, standardized work, and pull
- The Lean–Six Sigma merge

After completing this chapter, readers should have a basic understanding of Lean tools, techniques, and philosophy. This background should help them recognize how Lean may be used in their organizations and enable them to employ its tools and techniques to facilitate continuous improvement.

- Clinical improvements in opioid abuse and management practices
- Rapid establishment of COVID-19 protocols and procedures

These advances, along with many others, have helped Virginia Mason become one of the leading Lean healthcare systems in the world, and it continues its Lean Leadership today.

Source: Virginia Mason Franciscan Health (2021).

What Is Lean?

The Lean system originated from just-in-time (JIT) production and became widely adopted in many manufacturing operations. The original idea behind JIT production was to make exactly what is needed when the customers need it. However, production systems realized that waste was preventing them from achieving the ultimate goal of JIT delivery.

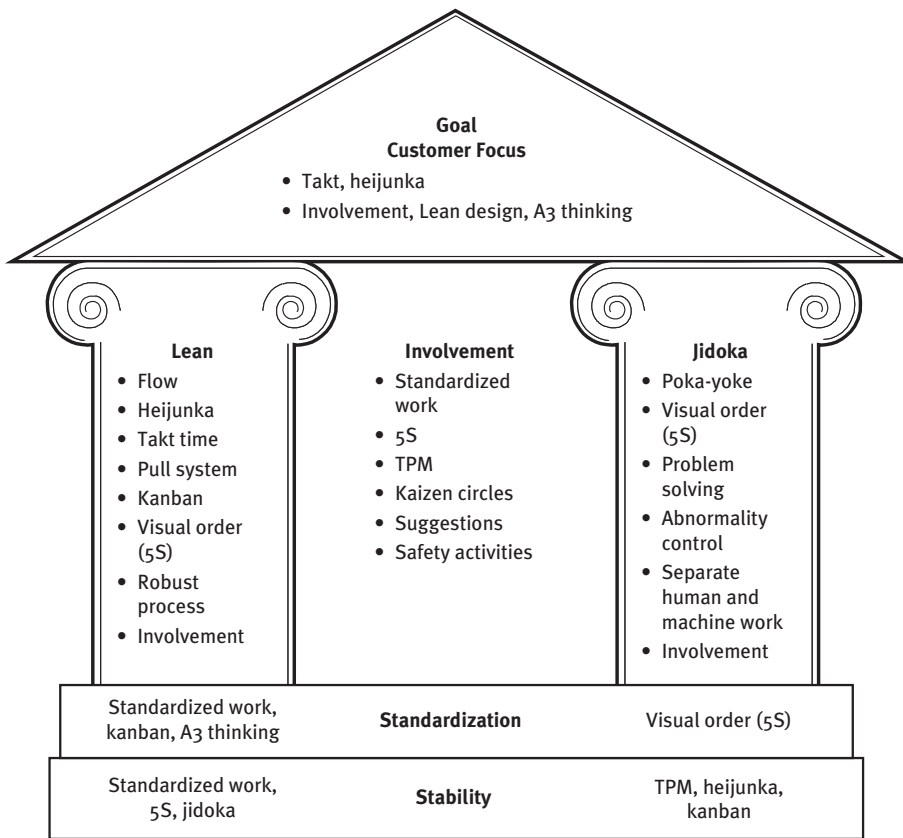
As the JIT system spread to other organizations, the term *Lean* was adopted to describe the overall approach. The process shifted from JIT production to focus more on becoming efficient and productive in daily work activities. One of the principal tenets of Lean is to eliminate wasteful activities, which liberates a company from spending unnecessary effort on activities that provide no value. Lean spread quickly to healthcare organizations because the removal of waste in the system has been shown to improve clinical measures of safety.

TPS, or the Lean Production House (exhibit 10.1), is built on a foundation of stability and standardization. The pillars of the house represent the systems that create value for the customer (the roof of the house). The left side of the structure represents producing what you need just in time for the customer. To execute this model correctly, the system must remove waste. The right side of the structure represents automation, or designing the system to stop when defects are produced and remove them. The middle section is the human factor that links the two systems. The ultimate goal is to produce as much value for the customer as possible.

A Lean organization is focused on eliminating all types of waste. Like Six Sigma, Lean has been defined as a philosophy, methodology, and set of tools. The Lean philosophy is to produce only what is needed, when it is needed, and with no waste. The Lean methodology begins by examining the system or process to determine where value is added and where it is not; steps in the process that do not add value are eliminated, and those that do add value are optimized. Lean tools include value stream mapping, the five Ss, spaghetti diagrams, kaizen events, kanbans, rapid changeover (originating with the single-minute exchange of die), heijunka, jidoka, and standardized work, all of which are explored in detail later.

EXHIBIT 10.1

Lean Production House



Source: Adapted from Pascal (2007).

Note: A3 thinking = a problem-solving approach using a worksheet of A3 (29.7 cm × 42 cm) page dimensions; 5S = the five Ss of workplace practice; TPM = Toyota's production method, Toyota Production System.

Types of Waste

In Lean, waste is called *muda*, which comes from the Japanese term for waste. Many types of waste are found in organizations. As an engineer at Toyota after World War II, Taiichi Ohno created TPS to eliminate waste and inefficiencies in the company's production system (*Economist* 2009). These wastes have since been categorized and reinterpreted as follows for services and healthcare; the simple acronym *DOWNTIME* can be used to remember them:

- **Defects**—production of a part or service that is scrapped or requires rework. In healthcare, defect waste ranges from mundane errors such as misfiling documents, to serious errors resulting in the death of a patient. The Joint Commission (2016) classifies catastrophic defects that lead to death or serious injury because of mistakes as *sentinel events*.

- *Overproduction*—producing more than is demanded or producing before the product is needed to meet demand. Printing reports and preparing meals when they are not needed are examples of overproduction in healthcare.
- *Waiting*—time during which value is not being added to the product or service. Waiting in healthcare can refer to either the patient sitting idle in a waiting room or the provider waiting for a patient to arrive. When waiting occurs, the resources in the system are not productive or adding value to the end customer in the system.
- *Nonutilized Talent* in healthcare refers to people working below their licensure. Lead nurses and doctors often perform activities that do not relate directly to patient care. The end result is that patients often wait longer and become more frustrated with their quality of care.
- *Transportation*—unnecessary travel of the primary product in the system. In healthcare, transport is so common that the word describes an entire department, whose staff are typically called to move patients in clinics and hospitals to different areas of the facility. Other forms of transportation include bringing equipment and supplies to various locations.
- *Inventory*—holding or purchasing raw materials, work in process, and finished goods that are not immediately needed. In healthcare, wasted inventory includes supplies and pharmaceuticals. Too much inventory costs money and limits the organization's ability to be profitable. In addition, the probability of having outdated drugs onsite rises, increasing patient risk.
- *Motion*—actions of providers or operators that do not add value to the product (including repetitive motion that causes injury). In healthcare, wasted motion includes unnecessary travel of the service provider to obtain supplies or information.
- *Extra Processing*—unnecessary processing, or steps and procedures that do not add value to the product or service. Numerous examples of overprocessing in healthcare relate to record keeping and documentation. Many computerized provider order-entry systems also require overprocessing to work smoothly.

Effective Lean systems focus on eliminating all waste through continuous improvement.

The Lean Dashboard

As discussed in chapter 8, “Healthcare Analytics,” organizations have become more adept at using data to make decisions. The development of dashboards to track progress for many facets of operations has become more prominent.

Lean systems use dashboards to present data on the flow of materials and people in the system and on how much waste has been removed. The following key measurements are often used in Lean and reported on Lean dashboards.

Overall Equipment Effectiveness

Overall Equipment Effectiveness (OEE) is a measurement that indicates how well a machine or work center is doing relative to optimal. In Lean terms, the OEE calculation measures the percentage of time the equipment or work center is providing value to the customer. Originally used in the manufacturing setting, the measure is now increasingly being used in healthcare (McNett 2017). The calculation is as follows:

$$\text{OEE} = \text{Quality} \times \text{Performance} \times \text{Availability}$$

These components measure independently the quality of service, the performance of the machine or work center relative to planned performance, and availability of the machine or work center (in hours per day). When multiplied together, the measurement shows the true percentage of time a work center is providing value.

Takt Time and Cycle Time

Takt is a German word meaning rhythm or beat, often associated with the rhythm set by a conductor to ensure that the orchestra plays in unison. **Takt time** determines the speed with which customers must be served to satisfy demand for the service. The calculation is as follows:

$$\text{Takt time} = \frac{\text{Available work time/Day}}{\text{Customer demand/Day}}$$

takt time

The speed at which customers must be served to satisfy demand for the service.

Cycle time is the time needed for a system to accomplish a task in that system. Cycle time for a system is equal to the longest task-cycle time in that system. Cycle time is often referred to as the “drip rate” of the system, as with a leaky faucet: The cycle time is the rate at which water drips from the faucet. In a perfect Lean system, cycle time and takt time are equal. If cycle time is greater than takt time, demand is not satisfied and customers or patients are required to wait. If cycle time is less than takt time in a manufacturing environment, inventory is generated; in a service environment, resources are underutilized. In a Lean system, the rate at which a product or service can be produced is set by customer demand, not by the organization’s ability (or inability) to supply the product or service.

cycle time

The time required to accomplish a task in a system.

throughput time

The time required for an item to complete the entire process, including waiting time and transport time.

Throughput Time

Throughput time is the time needed for an item to complete the entire process. It includes waiting time and transport time as well as actual processing time. In a healthcare clinic, for example, throughput time is the total time the patient spends at the clinic, starting when he walks through the door and ending when he walks out. It includes not only the time the patient is interacting with a clinician but also time spent idle in the waiting and examining rooms. In a perfectly Lean system, no waiting time is experienced, and throughput time is thus minimized. In most instances, throughput time is dictated by the non-value-added activities and not by the provider–patient interaction.

The Lean Toolkit

Companies employ a set of tools and techniques to become more effective on their Lean journey. The measurements in the Lean dashboard provide companies information needed to make better decisions on becoming leaner. The tools and techniques in the Lean toolkit can address a healthcare organization's weaknesses and accelerate its Lean journey.

Value Stream Mapping**value stream map**

An overview of how a system transforms supplies into finished goods for the customer.

A **value stream map** is a big-picture view of how a system transforms supplies into finished goods for the customer. Effective value stream maps include all of the steps in the process—both the value-adding and the non-value-adding steps—and their related measurements in producing and delivering a product or service. Information processing and transformational processing steps are included in a value stream map.

The value stream map shows process flow from a systems perspective and can help determine how to measure and improve the system or process of interest. Value stream mapping enables the organization to focus on the entire value stream rather than just a specific step or piece of the stream. Without a view of the entire stream, individual parts of the system tend to be optimized according to the needs of those parts, and the resulting system is suboptimal. This short-sightedness occurs frequently in healthcare organizations that are separated by departments. One department, such as lab or X-ray, may make a decision that helps its own processes but adversely impacts other areas of the organization, such as the operating rooms or emergency department.

Value stream mapping in healthcare is typically performed from the perspective of the patient, where the goal is to optimize her journey through the system. Information, material, and patient flows are captured in the value stream map. Each step in the process is classified as value-added or non-value-added. Value-added activities are those that change the item being worked on

in some way that the customer desires. Using the value stream methodology, value is classified in terms of the following questions:

- Does the patient care about the activity?
- Does the activity transform the end product in some way?
- Is the activity performed correctly the first time?

If all three questions cannot be answered in the affirmative, the activity is considered non-value-added and should be removed from the system.

Non-value-added activities can be further classified as necessary or unnecessary. An example of a necessary non-value-added activity that organizations must perform is payroll. Payroll activities do not add value for customers, but employees must be paid. Activities that are classified as non-value-added and unnecessary should be eliminated. Activities that are necessary but non-value-added should be examined to determine if they can be made unnecessary and eliminated. Value-added and necessary non-value-added activities are candidates for improvement and waste reduction. The value stream map enables organizations to see all of the activities in a value stream and focus their improvement efforts.

A common measurement for the progress of Lean initiatives is percent value added. The total time for the process to be completed is also measured. These metrics can be captured by measuring the time a single item, customer, or patient spends to complete the entire process. At each step in the process, the value-added time is measured using the following ratio:

$$\% \text{ Value added} = \frac{\text{Value-added time}}{\text{Total time in system}} \times 100.$$

The goal of Lean is to increase percent value added by increasing this ratio. Many processes have a percent value added of 5 percent or less. Best-in-class value-added time is often 20 percent or less.

Value streams help organizations focus on flow and not on waiting. Value streams with low value-added percentages are often full of wait times. Traditional healthcare processes involving several departments having less than 1 percent total value-added time are not uncommon.

Vincent Valley Hospital and Health System Value Stream Mapping

Vincent Valley Hospital and Health System (VVH) has identified its birthing center as an area in need of improvement and is using Lean tools and techniques to accomplish its objectives. The goals for the Lean initiative are to decrease costs and increase patient satisfaction. Project management tools (chapter 6) are used to ensure success.

VVH has formed a team to improve the operations of the birthing center. The team consists of the manager of the birthing unit (the project manager), two physicians, three nurses (one from triage, one from labor and delivery, and one from postpartum), and the manager of admissions. All team members have been trained in Lean tools and techniques. They begin the project by developing a high-level value stream map over the course of several weeks (exhibit 10.2). In it, the team maps patient and information flows in the birthing center and collects data related to staffing type and level, as well as length of time for the various process steps. The high-level value stream map helps the team decide where to focus its efforts; it then develops a plan for the coming year on the basis of the opportunities identified.

Riverview Clinic Timing Issues

VVH's Riverview Clinic has collected the data shown in exhibit 10.3 for a typical patient visit. Here, the physician exam and consultation involves the longest task time, 20 minutes; therefore, the cycle time for this process is 20 minutes. Assuming that the physician is available to work with the patients and not performing other tasks, every physician should be able to "output" one patient from this process every 20 minutes. However, the throughput time is equal to the total amount of time a patient spends in the system:

$$3 + 15 + 2 + 15 + 5 + 10 + 20 = 70 \text{ minutes.}$$

The available work time per physician day is 5 hours (Riverview Clinic physicians work 10 hours per day, but only 50 percent of that time is spent with patients), the clinic has 8 physicians, and 100 patients are expected at the clinic every day:

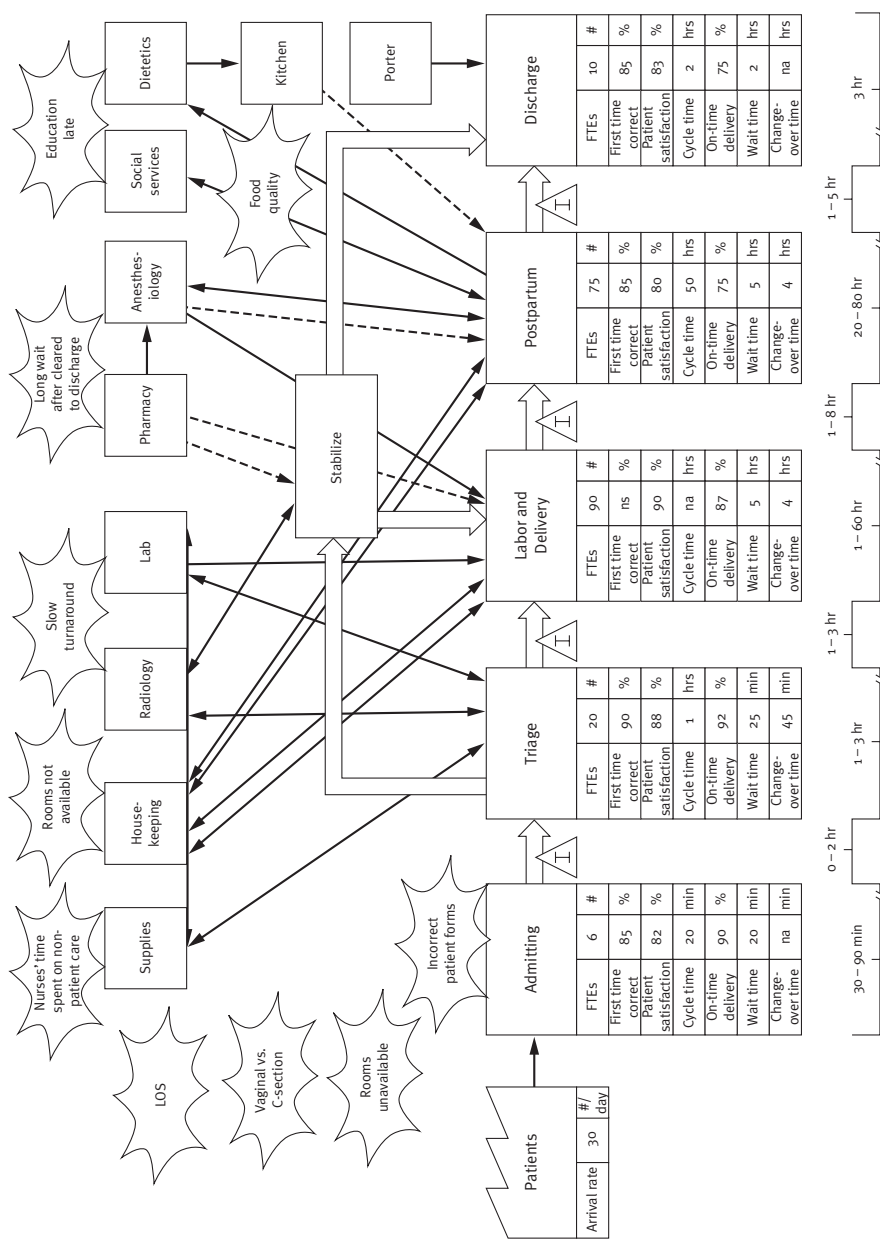
$$\begin{aligned} \text{Takt time} &= \frac{8 \text{ physicians} \times 5 \text{ hours/day}}{100 \text{ patients/day}} = 0.4 \text{ physician hours/patient} \\ &= 24 \text{ physician minutes/patient.} \end{aligned}$$

Therefore, to meet demand, the clinic needs to serve one patient every 24 minutes. Because cycle time (20 minutes) is less than takt time (24 minutes), the clinic can meet demand.

Assuming that (1) patient check-in is necessary but non-value-added and (2) both the nurse preliminary exam (5 minutes) and the physician exam and consultation (20 minutes) are value-added tasks, the value-added time for this process is

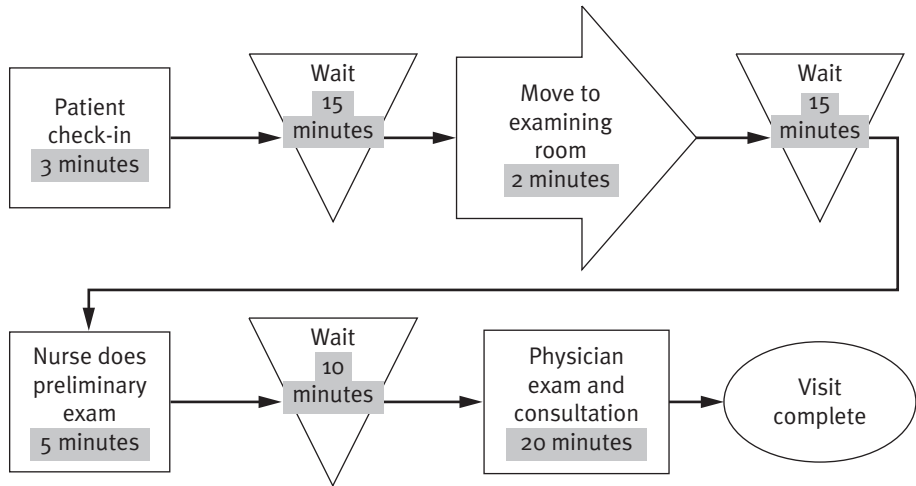
$$5 + 20 = 25 \text{ minutes}$$

EXHIBIT 10.2
VVH Birthing Center Value Stream Map



Note: Created with evSM software from GumshoeKI, Inc., a Microsoft Visio add-on. FTE = full-time equivalent; LOS = length of stay; na = not applicable.

EXHIBIT 10.3
Riverview
Clinic Cycle,
Throughput,
and Takt Times



Note: Created with Microsoft Visio.

and the percent-value-added time is

$$25 \text{ minutes} \div 70 \text{ minutes} = 36\%.$$

This example assumes that all of the steps of the check-in process are value-added. The reality is that many of the steps we perform in any given activity in a process are non-value-added. A Lean system works toward decreasing throughput time and increasing percent-value-added time. The tools discussed in the following sections can aid in achieving these goals as building blocks to the overall Lean system.

Five Ss

The five Ss are workplace practices that constitute the foundation of other Lean activities; the Japanese words for these practices all begin with *S*. The five Ss essentially are ways to ensure a clean and organized workplace. Often, they are seen as obvious and self-evident—a clean and organized workplace is more efficient than a cluttered area is. However, without a continuing focus on these five practices, workplaces often become disorganized and inefficient.

The five practices, with their Japanese names and the English terms typically used to describe them, are as follows:

1. *Seiri (sort)*—Separate necessary from unnecessary items, including tools, parts, materials, and paperwork, and remove the unnecessary items.

2. *Seiton (set in order)*—Arrange the necessary items neatly, providing visual cues to where items should be placed.
3. *Seiso (shine)*—Clean the work area.
4. *Seiketsu (standardize)*—Standardize the first three Ss so that cleanliness is maintained.
5. *Shitsuke (sustain)*—Ensure that the first four Ss continue to be performed on a regular basis.

Many hospitals and healthcare organizations have adopted a sixth S in the system, safety, considered paramount in the design of the sustainable process. Adopting the five (or six) Ss is often the first step an organization takes in its Lean journey because so much waste can be eliminated by establishing and maintaining an organized and efficient workplace. An effective five S program requires that the organization build discipline to continue the efforts in the long term. If an organization cannot sustain a simple mechanism to keep an area clean and organized, it will struggle with more complex systems. Five S systems can be easy to build but are difficult to maintain. Exhibit 10.4 displays a form for scheduling regular audits to make sure the system is sustainable.

Spaghetti Diagram

A **spaghetti diagram** is a visual representation of the movement or travel of materials, employees, or customers. In healthcare, a spaghetti diagram is often used to document or investigate the movements of caregivers or patients. Typically, the patient or caregiver spends a significant amount of time moving from place to place and often backtracks. A spaghetti diagram (exhibit 10.5) helps find and eliminate wasted movement in the system.

spaghetti diagram

A visual representation of the movement or travel of materials, employees, or customers.

Standardized Work

Standardized work is an essential part of Lean that provides the baseline for continuous improvement. Standardized work refers to the methods by which a process is executed. All effective standardized work procedures include written documentation of the precise way every step in a process should be performed. It should not be seen as a rigid system of compliance, but rather as a means of communicating and codifying current best practices in the organization. Standardized work is critical to developing an effective Lean system as it represents the baseline against which all future improvements will be measured.

standardized work

Documentation of the precise way in which every step in a process should be completed.

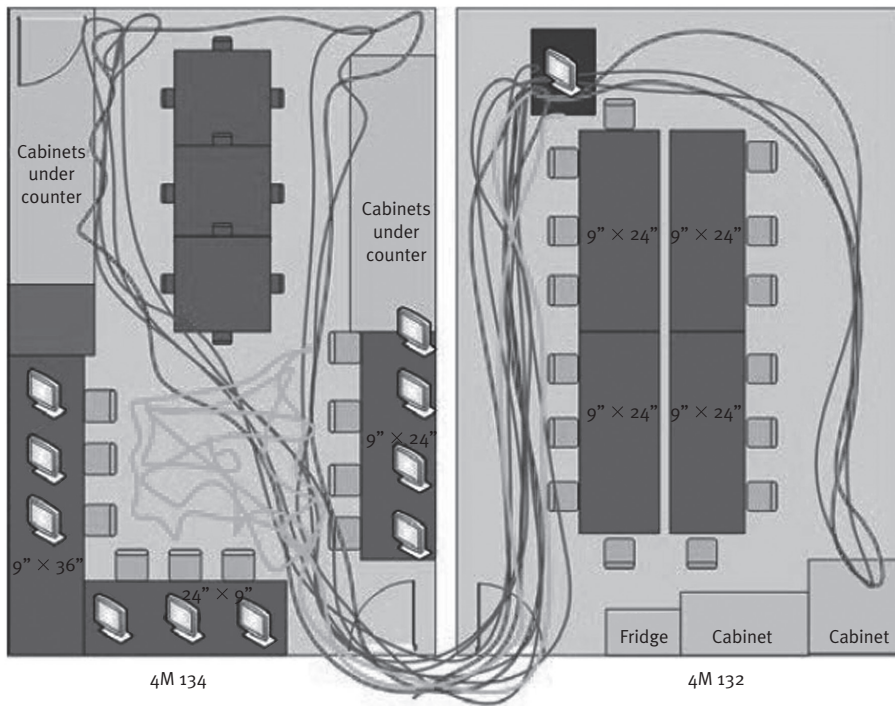
All relevant stakeholders of the process should be involved in establishing standardized work. Standardizing work in this way assumes that the people most intimately involved with the process have the most knowledge of how to best perform the work. Such involvement can promote employee buy-in, ownership of the process, and responsibility for improvement. Clear documentation and specific work instructions ensure that variation and waste are minimized.

EXHIBIT 10.4
Sample 5S Audit Form, Veterans Health Administration, Minneapolis

5S AUDIT FORM		Area: _____		Date: _____	
Sort				Comments:	
Only required items for the work area are present					
High-use items are readily available					
Appropriate items are grouped together					
1S		Yes	No	Date corrected	
Set in order				Comments:	
Materials properly stored so they can be used and returned easily					
All floor locations and work areas clearly marked with tape or paint					
Cabinets, shelves, and containers are labeled and organized					
2S		Yes	No	Date corrected	
Shine				Comments:	
Floors and entire area are clean and free of clutter					
All equipment is clean, free from leaks, chips, and soiled spots					
All work surfaces, cabinets, and shelves are clean and free from clutter					
3S		Yes	No	Date corrected	
Standardize				Comments:	
Appropriate inventory on hand					
Appropriate number of each type of equipment present					
Pictures and/or labels are standardized and visible					
4S		Yes	No	Date corrected	
Sustain				Comments:	
Life Safety Code requirements compliant					
Labels, signals, and area demarcations are maintained					
5S corrective actions completed from last audit					
5S		Yes	No	Date corrected	
Immediate Corrective Action(s):					

Note: 5S = the five Ss of workplace practices.

EXHIBIT 10.5
Spaghetti Map
for Setting Up
Education Room



Standardized work should be seen as a step on the road to improvement. It allows doctors and nurses to perform activities at their licensure level more often than in nonstandard work because basic business processes run effectively using standardized work (Lowe et al. 2012). This allowance to work at top of license then leads to standardized measures that lead to cost-effectiveness and improvement of patient outcomes.

In the healthcare industry, examples of standardized work include treatment protocols and the establishment of **care paths**. (Care paths are also examples of evidence-based medicine, which is explored in chapter 3.) A care path is the sequence and timing of interventions by physicians, nurses, and other staff for a particular diagnosis or procedure, designed to minimize delays and maximize the quality of care. Care paths define and document specifically what should happen to a patient the day before surgery, the day after surgery, and on following postsurgical days.

As part of an overall program to improve practices and reduce costs, Massachusetts General Hospital developed and implemented a care path for coronary artery bypass graft (CABG) surgery. The care path was not intended to dictate medical treatment but to standardize procedures as much as possible to reduce variability and improve the quality of outcomes.

The team that developed the care path was composed of 25 participants representing the various areas involved in treatment. It spent more

care path

A sequence of best practices for healthcare staff to follow for a diagnosis or procedure, designed to minimize waste and maximize quality of care.

than a year developing the initial care path. Because of its breadth of inclusion and applicability, resistance to implementation was minimal. The care path resulted in an average length of stay reduction of 1.5 days, and significant cost savings were associated with that reduction. After the successful implementation of the CABG surgical care path, Massachusetts General established more than 50 additional care paths related to surgical procedures and medical treatments.

Standardized work processes can be used in clinical, support, and administrative operations of healthcare organizations. The development and documentation of standardized processes and procedures can be a powerful way to engage and involve everyone in the organization in continuous improvement.

Jidoka and Andon

jidoka

The ability to prevent defects by stopping a process when an error occurs.

In Lean systems, **jidoka** refers to the ability to stop the process in the event of a problem. The term stems from the weaving loom invented by Sakichi Toyoda, founder of the Toyota Group. The loom stopped itself if a thread broke, eliminating the possibility that defective cloth would be produced.

Jidoka prevents defects from being passed from one step in the system to the next and enables the swift detection and correction of errors. If the system or process is stopped when a problem is found, everyone in the process works quickly to identify and eliminate the source of the error.

andon

A visual or audible signaling device used to indicate a problem in the process, typically used in conjunction with jidoka.

In ancient Japan, an **andon** was a paper lantern used as a signal; in a Lean system, an andon is a visual or audible signaling device used to indicate a problem in the process. Andons are typically used in conjunction with jidoka.

In his book *The Checklist Manifesto*, Atul Gawande (2009) highlights the benefits that hospitals gain by using simple checklists prior to anesthetizing a patient for surgery. These checklists are a mechanism to make sure everyone in the surgical suite is in agreement on the details of the patient and procedure about to take place, and they give the surgical team a chance to “stop the line” if protocol has not been properly followed.

Virginia Mason Medical Center implemented an andon system called the Patient Safety Alert System. If a caregiver believes something is not right in the care process, not only can she stop the process but she is obligated to do so. The person who has noticed the problem alerts the patient safety department. The appropriate process stakeholders or relevant managers move immediately to determine and correct the root cause of the problem. After two years, the number of alerts per month rose from 3 to 17, enabling Virginia Mason to correct most problems in the process before they became more serious. The alerts are primarily related to systems issues, medication errors, and problems with equipment or facilities.

Kanban

Kanban is a Japanese term for signal. A kanban uses containers of a certain size to signal the need for more production or the movement of product. The customer indicates that he wants a product, a kanban is released to the last operation in the system to signal the customer demand, and that station begins to produce the product in response. As incoming material is consumed at the last workstation, another kanban is emptied and sent to the previous workstation to signal that production should begin at that station. The empty kanbans go backward through the production system to signal the need to produce in response to customer demand (see exhibit 10.6). This system ensures that production is only undertaken in response to customer demand, not simply because production capacity exists.

In a healthcare environment, kanbans can be used for supplies or pharmaceuticals to signal the need to order more. For example, a pharmacy would have two kanbans; when the first kanban is emptied, this signals the need to order more of the drug and an order is placed. The pharmacists empty the second kanban while waiting for the order to arrive. Ideally, the first kanban is received from the supplier at the point that the second kanban is empty and the cycle continues. The size of the kanbans is related to demand for the pharmaceutical during lead time for the order. The number and size of the kanbans determine the amount of inventory in the system.

In a healthcare environment, kanbans can be used to control patient flow, ensuring continuous movement. For example, for patients needing both an echocardiography (echo) procedure and a computed tomography (CT) scan, where the echo procedure is to be performed before the CT scan, the CT scan could pull patients through the process. When a CT is performed, a patient is taken from the pool of patients between CT and echo. A kanban (signal) is sent to the echo station to indicate that another patient should receive an echo

kanban

A visual signal that triggers the movement of inventory or product in a system.

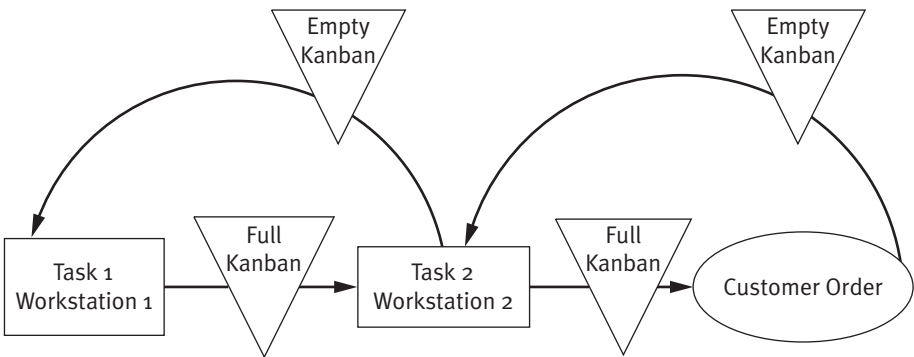
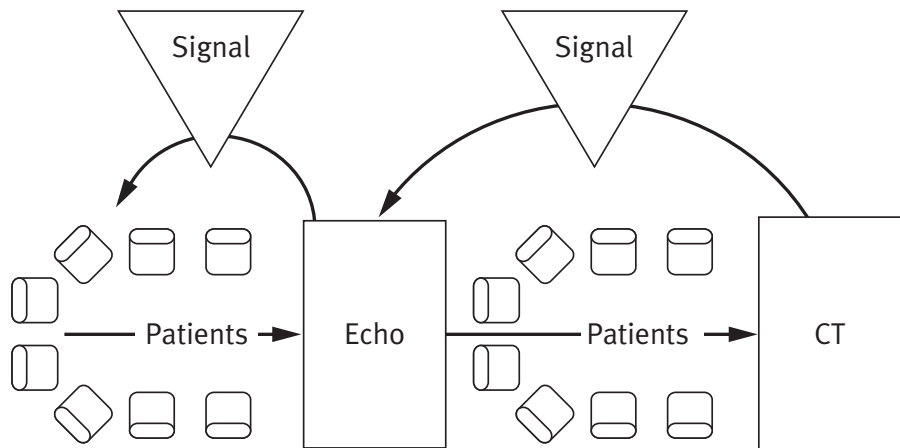


EXHIBIT 10.6
Kanban System

Note: Created with Microsoft Visio.

EXHIBIT 10.7
Kanban for
Echo/CT Scan



Note: Created with Microsoft Visio. CT = computed tomography; echo = echocardiogram.

(see exhibit 10.7). This method keeps a constant pool of patients between the two processes. The patient pool should be large enough to ensure that the CT is busy even when disturbances in the echo process occur. However, its size must be balanced with the need to keep patients from waiting for long periods. Eventually, in a Lean system, the pool size is reduced to one.

Rapid Changeover

The rapid changeover, or single-minute exchange of die (SMED) system, was developed by Shigeo Shingo (1985) of Toyota. Originally, it was used by manufacturing organizations to reduce changeover or setup time—the time between producing the last good part of one product and the first good part of a different product. Currently, the technique is used to reduce setup time for both manufacturing and services. In healthcare environments, the SMED system translates better as *rapid changeover*. Setup is the time needed, or taken, between the completion of one procedure and the start of the next, or between the checkout of one patient and the arrival of a new patient.

The rapid changeover technique consists of three steps:

1. Separating internal activities from external activities
2. Converting internal setup activities to external activities
3. Streamlining all setup activities

Internal activities are those that must be performed in the system; they cannot be done offline. For example, cleaning an operating room (OR) prior to the next surgery is an internal setup activity; it cannot be completed outside the OR. However, organizing the surgical instruments for the next surgery is

an external setup, as it can be completed outside the OR to allow for speedier changeover of the OR.

Setup includes finding and organizing instruments, gathering supplies, cleaning rooms, and obtaining paperwork. In the healthcare environment, rapid changeover can help alleviate surgery suite backlogs and cancelations because the room can be turned over quickly and the surgery teams can maximize the amount of time they are in surgery (AHRQ 2007).

To streamline activities, Lean teams must look for opportunities to perform tasks in parallel and find ways to automate the process. For example, many manufacturers have facilitated the turnover of surgery rooms by manufacturing disposable sleeves that cover all of the lights and fixtures in the room. Instead of having to scrub all of those fixtures, a team simply replaces the sleeves.

Heijunka and Advanced Access

Heijunka is a Japanese term meaning to make flat and level. It refers to eliminating variations in volume and variety of production to reduce waste. In healthcare environments, making flat and level often means determining how to level out patient demand. Producing goods or services at a steady rate allows organizations to be increasingly responsive to customers and make optimal use of their own resources. In healthcare, advanced access provides a good example of the benefits of heijunka.

heijunka
The process of eliminating variations in volume and variety of production to reduce waste.

Advanced-access scheduling reduces the time between scheduling an appointment for care and the actual appointment. It is based on the principles of Lean and aims for swift, even patient flow through the system. Heijunka helps reduce the wait time for appointments, decrease patient no-show rates, and improve both patient and staff satisfaction. As a result, clinics increase their revenue and reduce administrative costs because fewer patients are rescheduled.

Although the benefits of advanced access are valuable, implementation can be difficult because the concept challenges established practices and beliefs. However, if the delay between making an appointment and the actual appointment is relatively constant, implementing advanced access should be feasible.

Centra Health, a multisite primary care organization, was able to reduce access time to three days or less. As a result, patient satisfaction increased from 72 percent to 85 percent, and continuity of care was significantly increased, such that 75 percent of visits occurred with a patient's primary physician, compared to 40 percent prior to advanced access. The most significant issue encountered was the greater demand for popular clinicians than for others and the need to address this inequity on an ongoing basis (Murray et al. 2003).

Successful implementation of advanced access requires that supply and demand be balanced. Accurate estimates of supply and demand are needed,

backlog must be reduced or eliminated, and the variety of appointment types needs to be minimized. Once supply and demand are known, demand profiles may need to be adjusted and the availability of bottleneck resources increased (Murray and Berwick 2003). The Institute for Healthcare Improvement (2006) offers extensive online resources to aid healthcare organizations in implementing advanced access, and chapter 12 discusses the concept in detail.

Kaizen

kaizen

Continuous improvement based on the beliefs that everything can be improved and that incremental changes result in an enhanced system.

Kaizen is the Japanese term for “change for the better,” or continuous improvement. Kaizen has become the vehicle by which Lean systems adjust and improve. The philosophy of kaizen involves all employees making suggestions for improvement and then implementing those suggestions quickly. Because Lean systems target removing waste, opportunity to improve should occur immediately and perpetually.

Kaizen is based on the assumptions that everything can be improved and that many small incremental changes result in an improved system. Absent kaizen, organizations generally operate under the maxim, “If it isn’t broken, leave it alone.” Those that have adopted a kaizen philosophy believe, “Even if it isn’t broken, it can be improved.” An organization that does not focus on continuous improvement is unable to compete with those that continuously improve.

Kaizen can be both a general philosophy of improvement centering on the entire system or value stream and a specific improvement technique for a particular process. The kaizen philosophy of continuous improvement consists of five basic steps:

1. *Specify value.* Identify activities that provide value from the customer’s perspective.
2. *Map and improve the value stream.* Determine the sequence of activities or current state of the process and the desired future state. Eliminate non-value-added steps and other waste.
3. *Facilitate flow.* Enable the process to progress as smoothly and quickly as possible.
4. *Allow for pull.* Enable the customer to derive products or services.
5. *Enable perfection.* Repeat the process to ensure a focus on continuous improvement.

kaizen event

A focused, short-term project aimed at improving a particular process.

Kaizen Event or Blitz

A **kaizen event** or blitz (sometimes referred to as a rapid process improvement workshop) is a focused, short-term project aimed at improving a particular

process. A kaizen event is usually performed by a cross-functional team of 8 to 10 people, always including at least one person who works with or in the process. The rest of the team should include personnel from other functional areas and even nonemployees with an interest in improving the process. In healthcare organizations, staff, nurses, doctors, and other professionals, as well as management personnel from across departments, should be represented.

Typically, a kaizen event consists of the following steps, based on the plan-do-check-act improvement cycle of Deming and Juran (see chapter 2):

1. Determine and define the objective(s).
2. Determine the current state of the process by mapping and measuring the process. Measurements are related to the desired objectives and may include such factors as cycle time, waiting time, work in progress, throughput time, and travel distance.
3. Determine the requirements of the process (takt time), develop target goals, and design the future state or ideal state of the process.
4. Create a plan for implementation, including who, what, when, and so on.
5. Implement the improvements.
6. Check the effectiveness of the improvements.
7. Document and standardize the improved process.
8. Report the results of the event on an A3 reporting form (discussed hereafter).
9. Continue the cycle.

The kaizen event is based on the notion that most processes can be quickly (and relatively inexpensively) improved, in which case it makes sense to “just do it” rather than be paralyzed by resistance to change. A kaizen event is typically one week long and begins with training in the tools of Lean, followed by analysis and measurement of the current process and generation of possible ideas for improvement. By midweek, a proposal for changes to improve the process should be completed. The proposal includes the improved process flow and metrics for determining the impacts of the changes. The proposed changes are implemented and tested during the remainder of the week. At the end of the week, a team reports the results on an A3 reporting form (A3 refers to the dimensions of the paper used for the form: 29.7 cm × 42 cm).

A kaizen event can be a powerful way to quickly and inexpensively improve processes. The results are usually a significantly enhanced process and increased employee pride and satisfaction.

Vincent Valley Hospital and Health System Kaizen Event

The value stream map developed for the VVH birthing center highlights the fact that nursing staff spend a significant amount of time on activities not related to actual patient care. This situation has resulted not only in dissatisfied patients, physicians, and nurses but also in increased staffing costs to the hospital. A kaizen blitz is planned to address this problem in the postpartum area of the birthing center.

The nursing administrator is charged with leading the kaizen event. She forms a team consisting of a physician, a housekeeper, two nurses' assistants, and two nurses. On Monday morning, the team begins the kaizen event with four hours of Lean training. That afternoon, team members develop a spaghetti diagram for a typical nurse and begin collecting data related to the amount of time nursing staff spend on various activities. They also collect historical data on patient load and staffing levels.

On Tuesday morning, the team continues to collect data. In the afternoon, its members analyze the data and note that nursing staff spend only 50 percent of their time in actual patient care. A significant amount of time—one hour per eight-hour shift—is spent locating equipment, supplies, and information. The team decides that a 50 percent reduction in this time measure is a reasonable goal for the kaizen event.

On Wednesday morning, the team performs a root-cause analysis to determine the reasons nursing staff spend so much time locating and moving equipment and supplies. They find that one of the major causes is general disorder in the supply and equipment room and in patient rooms.

On Wednesday afternoon, the team organizes the supply and equipment room. Team members begin by determining what supplies and equipment are necessary to performing their work, then removing those that are unnecessary. Next, they organize the supply and equipment room by identifying which items are needed most frequently and locating those items together. All storage areas are labeled, and specific locations for equipment are designated visually. White boards are installed to enable the tracking and location of equipment. The team also develops and posts a map of the room so that the location of equipment and supplies can be easily viewed.

On Thursday, the team works on reorganizing all of the patient rooms, standardizing the layout and location of items in each one. First, team members observe the activity taking place in one of the patient rooms and determine the equipment and supply needs of physicians and nurses. All nonessential items are removed, creating more space. Additionally, rooms are stocked with supplies used on a routine basis to reduce trips to the central supply room. A procedure is also established to restock supplies daily.

On Friday morning, the kaizen team again collects data on the amount of time nursing staff spend on various activities. It finds that after implementing the changes, the time nursing staff spent locating and moving supplies

and equipment has been reduced to approximately 20 minutes in an eight-hour shift, a 66 percent reduction. Friday afternoon is spent documenting the kaizen event and putting systems in place to ensure that the new procedures and organizational approach are maintained.

The kaizen philosophy is supported by the various tools and techniques of Lean.

The Merging of Lean and Six Sigma Programs

Many organizations now combine the philosophies and tools of Lean and Six Sigma into Lean Six Sigma. Although proponents of Lean or Six Sigma might tout their differences and champion one over the other, the two methods are complementary, and combining them can be an effective approach to improvement.

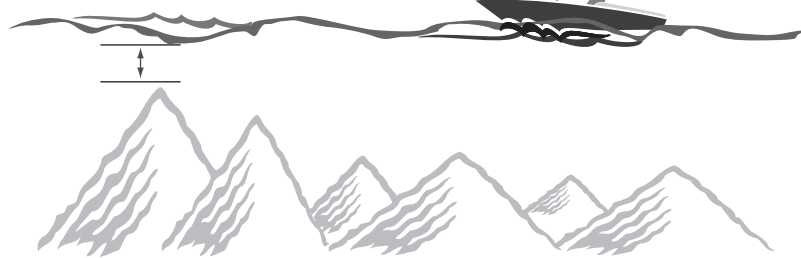
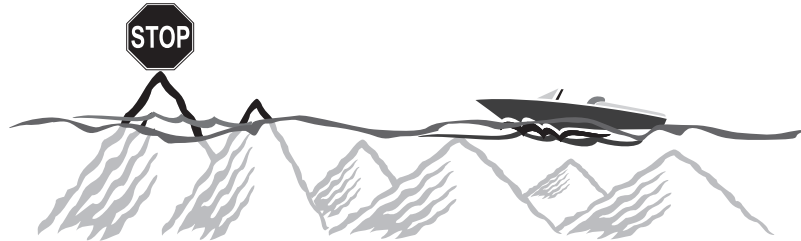
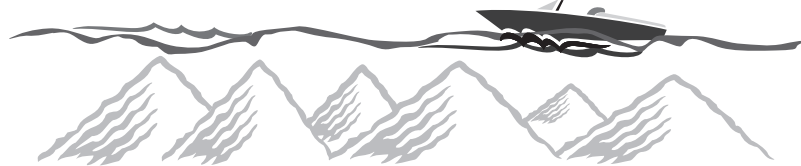
Exhibit 10.8 provides a classic illustration of how the two continuous improvement programs may be used together. Here, the water represents waste in the system. The high water (waste) buffers the rocks so the boat can move downstream without encountering any issues. In healthcare systems, this waste often shows up in one of two forms: excess supplies and inventory or too much demand on the system. This buffering might seem helpful, because once the water is removed, the rocks become exposed, making travel dangerous. But the rocks represent major issues in our systems, such as sentinel events and excessive overtime paid to nurses and other staff. To sail the boat without crashing (encountering issues), the rocks (problems) must be eliminated (by removing variance in the system). Perhaps too much overtime is being paid to the staff in the surgical suite of a hospital. Analysis finds that staff are spending excess time looking for equipment, which delays surgeries and forces the overtime. To get the boat to sail smoothly, the problems of looking for equipment must be reduced and removed.

The Lean system focuses on eliminating waste and streamlining flow. In the previous example, the waste in the system was identified as excessive idle time as a result of waiting for the equipment, which may lead to hiring extra people to make sure the equipment reaches the OR suite on time. The Six Sigma program focuses on creating value to the customer, eliminating defects, and reducing variation. It identifies the reasons that equipment arrives late to the OR and systematically reduces and removes those sources of variance. Both Lean and Six Sigma are ultimately focused on continuous improvement of any system.

The Six Sigma process, featuring the define-measure-analyze-improve-control structure, always begins with defining the issues or problems as they relate to the customer. The focus on reducing variance in the eyes of the customer allows Six Sigma programs to create customer value.

EXHIBIT 10.8
Lean Six Sigma
Approach

Excess hides problems

Reducing excess makes
problem visibleReduce problems/
remove variation

The kaizen philosophy of Lean begins with determining what customers value, followed by mapping and improving the process to achieve flow and pull. Lean thinking enables identification of the areas causing inefficiencies. However, to truly achieve Lean, variation in the processes must be eliminated—Six Sigma helps achieve its elimination. Focusing on the customer and eliminating waste not only results in increased customer satisfaction but also reduces costs and increases the profitability of the organization.

Together, Lean and Six Sigma can provide the philosophies and tools needed to ensure that the organization is continuously improving.

Conclusion

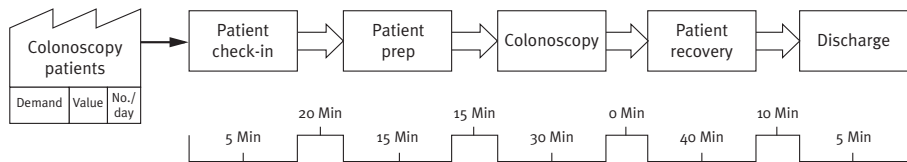
Lean systems have been used in many industries to remove inefficiencies and waste related to production of goods and services. Healthcare systems have also adopted Lean to enhance safety and improve the quality of care. The removal of outdated medicines, expired supplies, and clutter makes the environment safer for patients. These simple concepts related to waste reduction work well for most healthcare systems. Lean will continue to be a focal point in health-care as the pressure mounts to reduce cost. The waste reduction approaches will allow the US healthcare system to be increasingly cost-effective and safe for patients.

Discussion Questions

1. What are the drivers of the healthcare industry's focus on patient satisfaction and on employing resources in an effective manner?
2. What are the differences between Lean and Six Sigma? The similarities? Would you like to see both applied in your organization? Why or why not?
3. From your own experiences, discuss a specific example of each of the seven types of waste.
4. From your own experiences, describe a specific instance in which standardized work, kanban, jidoka and andon, and rapid changeover would enable an organization to improve its effectiveness or efficiency.
5. Does your primary care clinic have advanced-access scheduling? Should it? To determine supply and demand and track progress, what measures would you recommend to your clinic?
6. Are any drawbacks inherent in Lean Six Sigma? Explain.

Exercises

1. A simple value stream map for patients requiring a colonoscopy at an endoscopy clinic is shown in the following graphic. Assume that patients recover in the same room where the colonoscopy is performed and the clinic has two colonoscopy rooms. What is the cycle time for the process? What is the throughput time? What is the percent value added in this process? If the clinic operates 10 hours a day and demand is 12 patients per day, what is the takt time? If demand is 20 patients per day, what is the takt time? What would you do in the second situation?



Note: Created with eVSM software from GumshoeKI, Inc., a Microsoft Visio add-on.

2. Draw a high-level value stream map for your organization (or a part of your organization). Pick a part of this map and draw a more detailed value stream map for it. On each map, be sure to identify the information you would need to complete the map and exactly how you might obtain that information. What are the takt and throughput times of your process? Identify at least three kaizen opportunities on your map.
3. For one of the kaizen opportunities listed in exercise 2, describe the kaizen event you would plan if you were the kaizen leader.

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APPLICATIONS TO CONTEMPORARY HEALTHCARE OPERATIONS ISSUES

PROCESS IMPROVEMENT AND PATIENT FLOW

Operations Management in Action

Valley Health Clinic

Valley Health Clinic, part of Southern Indiana Community Health Care (a nonprofit community health center) is a small rural clinic with limited resources whose staff had a goal to improve the management of its type 2 diabetes patient population.

The clinic staff felt they needed to revise their workflow to reach the Centers for Medicare & Medicaid Services' Healthy People 2020 goals for patients with uncontrolled-rate diabetes (hemoglobin A1c levels >9%). With assistance from Purdue Healthcare Advisors (PHA), they began to make small, daily, coordinated changes to processes without disrupting the work environment.

Specific actions by the center to address this population included

- offering an additional 10 to 15 minutes with the medical assistant for support after their appointment with their provider,
- contacting patients to schedule future appointments and to remind them to come in,
- calling every two weeks for a wellness check,
- adding GLP-1 (a glucagon-like peptide-1 agonist) to their prescribing protocol to increase insulin levels,
- working with insurance companies to obtain prior approvals for medications, and

OVERVIEW

At the core of all organizations are their operating systems. Excellent organizations continuously measure, study, and make improvements to these systems. This chapter provides a methodology for measuring and improving systems using a select set of the tools presented in the preceding chapters.

The terminology associated with process improvement can be confusing. Typically, tasks combine to form subprocesses, subprocesses combine to form processes, and processes combine to form a system. The boundaries of a particular system are defined by the activity of interest. For example, the boundaries of a supply chain system are more encompassing than those of a hospital system that is part of that supply chain.

The term *process improvement* refers to improvement at any of these levels, from the task level to the systems level. This chapter focuses on process and systems improvement.

In general, process improvement follows the classic plan-do-check-act (PDCA) cycle with the following, more specific, key steps:

- *Plan:* Define the entire process to be improved using process mapping. Collect and analyze appropriate data for each element of the process.
- *Do:* Use a process improvement tool(s) to improve the process.
- *Check:* Measure the results of the process improvement.

(continued)

- calling the patient several days later to make sure they had obtained the medication from the pharmacy.

The six-month project, using daily PDCA improvement without disrupting the work environment, reduced the percentage of Valley Health's patients with uncontrolled-rate type 2 diabetes from 45 percent to 16 percent.

Source: PHA (2021).

OVERVIEW (*continued*)

- *Act to hold the gains:* If the process improvement results are satisfactory, hold the gains (chapter 16).

If the results are not satisfactory, repeat the PDCA cycle.

This chapter discusses the types of problems or issues healthcare organizations have with process improvement, reviews many of the operations tools discussed in earlier chapters, and illustrates how these tools can be applied. Relevant tools include the following:

- Basic process improvement tools
- Quality/Six Sigma and Lean tools
- Simulation software

Problem Types

Continuous process improvement is essential for organizations to meet the challenges of today's healthcare environment. The theory of swift and even flow (Schmenner 2001, 2004; Schmenner and Swink 1998) asserts that a process is more productive as the stream of materials (customers or information) flows more quickly and evenly. Productivity rises as the speed of flow through the process increases and the variability associated with that process decreases.

Note that these phenomena are not independent. Often, decreasing system variability increases flow, and increasing flow decreases variability. For example, advanced-access (same day) scheduling increases flow by decreasing the elapsed time between when a patient schedules an appointment and when she has completed her visit with the provider. Applying this concept of interdependence to patient no-shows, advanced-access scheduling can decrease variability by decreasing the number of no-shows.

Solutions to many of the problems facing healthcare organizations can be found in increasing flow or decreasing variability. For example, a key operating challenge in most healthcare environments is the efficient movement of patients in a hospital or clinic, commonly called *patient flow*. Various approaches to process improvement can be illustrated using the patient flow problem. Optimizing patient flow through EDs has become a top priority of many

hospitals; therefore, the Vincent Valley Hospital and Health System (VVH) example at the end of this chapter focuses on improving patient flow through that organization's ED.

Another key issue facing healthcare organizations is the need to increase the level of quality and eliminate errors in systems and processes. In other words, variation must be decreased. Finally, increasing cost pressures compel healthcare organizations to improve processes while also reducing costs.

The tools and techniques presented in this book are aimed at enabling cost-effective process improvement. Although this chapter focuses on patient flow and eliminating errors related to patient outcomes, the discussion is equally applicable to other types of flow problems (e.g., information, paperwork) and other types of errors (e.g., billing). Some tools are more applicable to increasing flow and others to decreasing variation, eliminating errors, or improving quality, but all of the tools can be used for process improvement.

Patient Flow

Efficient patient movement in healthcare facilities can significantly improve the quality of care patients receive and substantially improve financial performance. A patient receiving timely diagnosis and treatment has a higher likelihood of obtaining a desired clinical outcome than a patient whose diagnosis and treatment are delayed. Because most current payment systems are based on fixed payments per episode of treatment (i.e., capitation), a patient moving more quickly through a system tends to generate lower costs and, therefore, higher margins.

Patient flow optimization opportunities occur in many healthcare settings. Examples include operating suites, imaging departments, urgent care centers, and immunization clinics.

Poor patient flow has several causes; one culprit discovered by many investigators is variability of scheduled demand. For example, if an operating room is scheduled for a surgery but the procedure does not take place at the scheduled time, or it takes longer than scheduled to complete, the rest of the surgery schedule becomes delayed. These delays ripple through the entire hospital, including the ED.

As explained by Eugene Litvak, PhD (2003):

You have two patient flows competing for hospital beds—ICU or patient floor beds. The first flow is scheduled admissions. Most of them are surgical. The second flow is medical, usually patients through the emergency department. So when you have a peak in elective surgical demand, all of a sudden your resources are being consumed by those patients. You don't have enough beds to accommodate medical demand.

If scheduled surgical demand varies unpredictably, the likelihood of inpatient overcrowding, ED backlogs, and ambulance diversions increases dramatically.

The Agency for Healthcare Research and Quality provides a comprehensive resource for improving patient flow in EDs (McHugh et al. 2012). A New York hospital illustrates how the theory of constraints and load balancing (see sections hereafter) can be used to improve patient flow.

Good Samaritan Hospital in Long Island, NY, had a rate of left-without-being-seen (LWBS) patients that was close to the national average of 2 percent. After reviewing its data, ED leaders found that 87 percent of LWBS patients were triaged as Emergency Severity Index (ESI) Level 3, and the highest LWBS rates occurred among a subset of ESI 3 patients presenting with one of the following six chief complaints: abdominal pain, flank pain, headache, pregnancy complication, vaginal bleeding, or vomiting. The average LWBS rate among that group was 12.5 percent. Further, this subset of ESI 3 patients had an average length of stay of 426 minutes, compared with an average of 294 minutes for all ED patients.

In addition to having the highest LWBS rates, this subset also had the longest physician wait times—the median time was 78 minutes, compared with 48 minutes for all ESI 3 patients. Part of the reason for these higher LWBS rates and longer waits was that these patients fell in the middle: they had complaints too complex for fast track yet not serious enough for direct admission to the ED. However, the potential for these conditions to become life threatening while the patient waits to be seen is a major patient-safety and quality-of-care concern.

To address this identified problem, Good Samaritan implemented a strategy to immediately direct a subset of ESI 3 patients to a dedicated physician and nurse practitioner. Following a physician evaluation in triage, patients are received by a nurse practitioner who coordinates their care with the triage physician (McHugh et al. 2012, section 4).

For patient flow to be carefully managed and improved, the formal methods of process improvement outlined in the next section need to be widely employed.

Process Improvement Approaches

Process improvement projects can use a variety of approaches and tools. Typically, they begin with process mapping and measurement. Some simple tools can be initially applied to identify opportunities for improvements. Identifying and eliminating or alleviating bottlenecks in a system (theory of constraints) can quickly improve overall system performance. In addition, the Six Sigma

tools described in chapter 9 can be used to reduce variability in process output, and the Lean tools discussed in chapter 10 can identify and eliminate waste. Finally, simulation (discussed later in this chapter) is a powerful tool that enables understanding and optimization of flow in a system.

All major process improvement projects should use the formal project management methodology outlined in chapter 6. An important first step is to identify a system's owner: For a system to be managed effectively over time, it must have a designated individual who monitors the system as it operates, collects performance data, and leads teams to improve the system.

Many systems in healthcare do not have an owner and, therefore, operate inefficiently. For example, a patient may enter an ED, be assessed by the triage nurse, move to the admitting department, take a chair in the waiting area, be moved to an exam room, be seen by a floor nurse, have his blood drawn, and finally be examined by a physician. From the patient's point of view, this is one system, but these various hospital departments may be operating autonomously. System ownership problems can be remedied by multidepartment teams with one individual designated as the overall system or process owner.

Problem Definition and Process Mapping

Once the process owner is identified, the first step in improving a system is generally considered to be problem description and mapping of that process. However, the team should first ensure that the correct problem is being addressed. Mind mapping or root-cause analysis should be employed to ensure that the problem is identified and framed correctly; much time and money can be wasted in finding an optimal solution to a process that is not problematic.

For example, suppose a project team is given the task of improving customer satisfaction with the ED. The team assumes that customer satisfaction is low because of high throughput time. It proceeds to optimize patient flow in the ED. Patient satisfaction does not improve.

Now, imagine that a second project team is assigned to improve customer satisfaction. It conducts an analysis of customer satisfaction, which reveals that customers are dissatisfied because of a lack of parking. The team solves the problem by following a different path from the first team because it has clearly understood and defined the issue, allowing team members to determine what process to map.

Processes can be described in several ways. The most common is the written procedure or protocol, typically constructed in the "directions" style. This type of process is sufficient for simple procedures—for example, "Turn right at Elm Street, go two blocks, and turn left at Vine Avenue." Clearly written procedures are an important part of defining standardized work, as described in chapter 10.

However, when processes are linked to form systems, they become complex. These linked processes benefit from process mapping because process maps

- provide a visual representation that allows process improvement through inspection,
- enable branching in a process,
- provide the ability to assign and measure the resources in each task in a process, and
- are the basis for modeling the process via computer simulation software.

Chapter 7 provides an introduction to process mapping. To review, the steps in process mapping are as follows:

1. Assemble and train the team.
2. Determine the boundaries of the process (where it starts and ends) and the level of detail desired.
3. Brainstorm the major process tasks, and list them in order. (Sticky notes are often helpful here.)
4. Generate an initial process map (also called a flowchart).
5. Draw the formal flowchart using standard symbols for process mapping.
6. Check the formal flowchart for accuracy by all relevant personnel.
7. Depending on the purpose of the flowchart, collect data needed or include additional information.

Process Mapping Example

A basic process map illustrating patient flow in VVH's emergency department is displayed in exhibit 11.1.

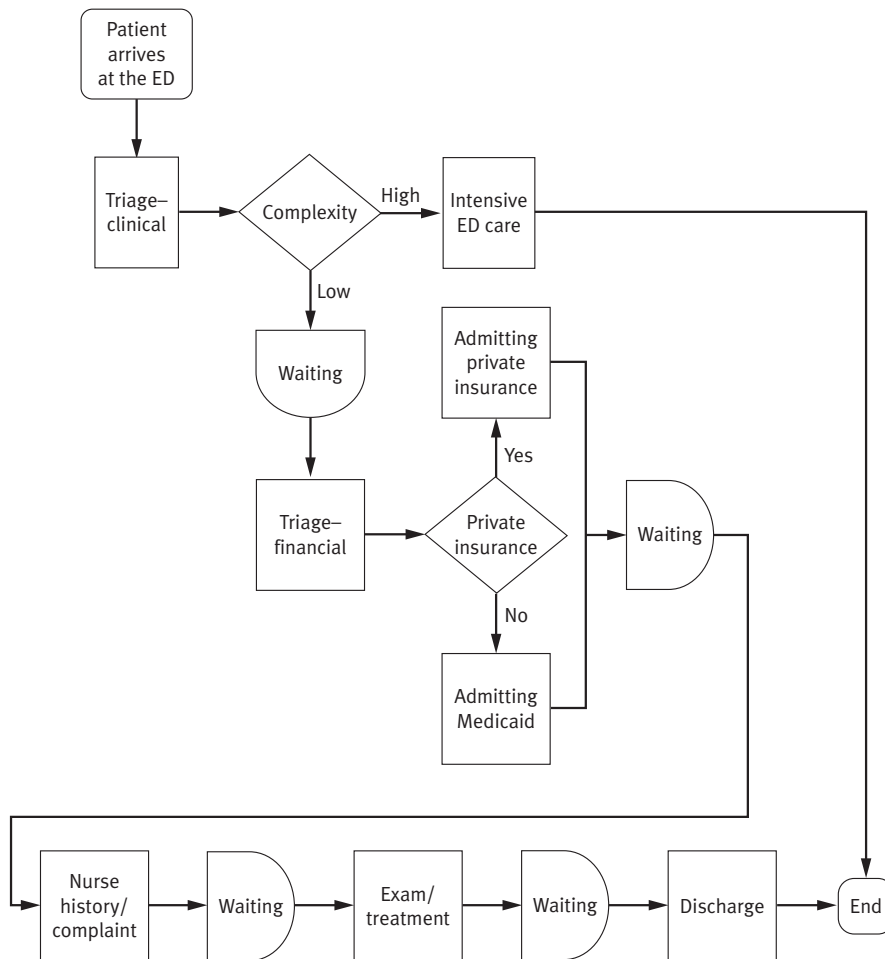
Here, the patient arrives at the ED and is examined by the triage nurse. If the patient is very ill (high complexity level), she is immediately sent to the intensive care section of the ED. If not, she is sent to admitting and then to the routine care section of the ED.

The simple process map shown in exhibit 11.1 ends with the routine care step. In actuality, other processes now begin, such as admission into an inpatient bed or discharge from the ED to home with a scheduled clinical follow-up. The VVH emergency department process improvement project is detailed at the end of this chapter.

Process Measurements

Once a process map is developed, relevant data are collected and analyzed. The situation at hand dictates which specific data and measures should be employed.

EXHIBIT 11.1
VVH Emergency
Department
(ED) Patient
Flow Process
Map



Note: Created with Microsoft Visio.

Ideally, demand and capacity are perfectly matched. If demand exceeds capacity, some customers will not be served. If capacity exceeds demand, resources will be underutilized. In reality, matching demand and capacity perfectly can be difficult because of fluctuations in demand. In a manufacturing environment, inventory can be used to compensate for demand fluctuations. In a service environment, this type of trade-off is not possible; therefore, excess capacity or a flexible workforce is often required to meet demand fluctuations. Advanced-access scheduling (chapters 10 and 12) is one way for healthcare operations to more closely match capacity to demand.

Capacity utilization is defined as the percentage of time that a resource (worker, equipment, space, etc.) or process is actually busy producing or

capacity utilization
 The percentage of time that a resource (worker, equipment, space, etc.) or process is actually busy producing or transforming output.

transforming output. If the hospital's food service can provide 1,000 meals per day but only provides 800 meals per day, the capacity utilization is 80 percent. If the magnetic resonance imaging (MRI) machine operates 18 hours per day, the capacity utilization is 75 percent $[(18 \div 24) \times 100]$.

Generally, higher-capacity utilization is better, but caution must be used in this evaluation. If the hospital's food service has a goal of 95 percent capacity utilization, it can meet that goal by producing 950 meals per day, even if only 800 meals per day are actually consumed and 150 meals are discarded. Obviously, this solution would not result in the effective use of resources, but food service would have met its goal.

Typically, the more costly the resource, the greater the importance of maximizing capacity utilization. For example, in a hospital emergency department, the most costly resource is often the physician. In this case, with other resources (e.g., nurses, housekeeping staff, clerical staff) being less expensive, maximizing the utilization of the physicians is more important than maximizing the utilization of the other resources. In fact, underutilizing less expensive resources in an effort to maximize the utilization of more expensive resources is more economical. Simulation (discussed later in this chapter) can help determine the most effective use of various types of resources.

Other Useful Process Measures

Important measures and data for possible collection and analysis include the following:

- *Throughput time* is the average time a unit spends in the process. Throughput time includes both processing time and waiting time and is determined by the critical (longest) path through the process.
- *Throughput rate*, sometimes referred to as drip rate, is the average number of units that can be processed per unit of time.
- *Service time* or *cycle time* is the time to process one unit. The cycle time of a process is equal to the longest task cycle time in that process. The probability distribution of service times may also be of interest.
- *Idle time* or *wait time* is the time a unit spends waiting to be processed.
- *Arrival rate* is the rate at which units arrive to the process. The probability distribution of arrival rates may also be of interest.
- *Work-in-process*, *things-in-process*, *patients-in-process*, or *inventory* describes the total number of units in the process.
- *Setup time* is the amount of time spent getting ready to process the next unit.
- *Value-added time* is the time a unit spends in the process where value is being added to the unit.

- *Non-value-added time* is the time a unit spends in the process where no value is being added. Wait time is non-value-added time.
- *Number of defects or errors.*

The art in process mapping is to provide enough detail to be able to measure overall system performance, determine areas for improvement, and measure the impact of these changes.

Basic Tools for Process Improvement

Once a system has been mapped, several techniques can be considered for improving the process. These improvements should result in a reduction in the duration, cost, or waste in a system.

Eliminate Non-Value-Added Activities

The first step after a system has been mapped is to evaluate every element to ascertain whether each is necessary and provides value (to the customer or patient). If a system has been in place for a long period and has not been evaluated through a formal process improvement project, elements of the system can likely be easily eliminated. This step is sometimes referred to as “harvesting the low-hanging fruit.”

Eliminate Duplicate Activities

Many processes in systems have been added on top of existing systems without formally evaluating the total system, frequently resulting in duplicate activities. The most infamous redundant process step in healthcare is asking patients repeatedly for their contact information. Duplicate activities increase both time and cost in a system and should be eliminated whenever possible.

Combine Related Activities

Process improvement teams should examine both the process map and the activity and swim lane map. If a patient moves back and forth between departments, the movement should be reduced by combining these activities so he only needs to be in each department once.

Process in Parallel

Although a patient can only be in one place at one time, other aspects of her care can be completed simultaneously. For example, medication preparation, physician review of tests, and chart documentation can all be performed at the same time. As more tasks are executed simultaneously, the total time a patient spends in the process is reduced. Similar to a chef who has a number of dishes on the stove synchronized to be completed at the same time, much of the patient care process can be completed simultaneously.

Another element of parallel processing is the relationship of subprocesses to the main flow. For example, a lab result may need to be obtained before a patient enters the operating suite. Many of these subprocesses can be synchronized through the analysis and use of takt time (chapter 10). This synchronization enables efficient process flow, thereby optimizing the process.

Balance Workloads

If similar workers perform the same task, a well-tuned system can be designed to balance the work among them. For example, a mass-immunization clinic should develop its system so that all immunization stations are active at all times. This aim can be accomplished by using a single queue that feeds into multiple immunization stations.

Load balancing (or load leveling, *heijunka*) is difficult when employees can only perform a limited set of specific tasks (a consequence of the superspecialization of the healthcare professions). Load balancing is easier in environments that feature cross-training of employees than in those that limit employee tasks to singular functions.

Develop Alternative Process Flow Paths and Contingency Plans

The number and placement of decision points in the process should be evaluated and optimized. A system with few decision points has few alternative paths and, therefore, does not respond well to unexpected events. Alternative paths or contingency plans should be developed for these types of events. For example, a standard clinic patient rooming system should designate alternative paths for when an emergency occurs, a patient is late, a provider is delayed, or medical records are absent.

Establish the Critical Path

For complex pathways in a system, identifying the critical pathway with tools described in chapter 6 can be helpful. If a critical path can be identified, execution of processes on the pathway can be improved (e.g., reduce average service time). In some cases, the process can be moved off the critical path and be performed in parallel to it. Either technique decreases the total time on the critical pathway. In the case of patient flow, moving this process off the critical pathway decreases the patient's total time spent in the system.

Embed Information Feedback and Real-Time Control

Some systems have a high level of variability in their operations because they experience variability in the arrival of jobs or customers (patients) into the process and variability of the cycle time of each process in the system. High variability in the system can lead to poor performance. One tool to reduce variability is the control loop. Information can be obtained from one process

and used to drive change in another. For example, the number of patients in the ED waiting area can be continuously monitored, and if it reaches a certain level, contingency plans—such as floating in additional staff from other portions of the hospital—can be initiated.

Ensure Quality at the Source

Many systems contain multiple reviews, approvals, and inspections. A system in which the task is performed correctly the first time should not require these redundancies. Deming (1998) first identified this problem in the process design of manufacturing lines that had inspectors throughout the assembly process. This expensive and ineffective system was one of the factors that gave rise to the quality movement in Japan and, later, the United States.

Systems should be designed to embed quality at their source or beginning to eliminate inspections. For example, a billing system that requires a clerk to inspect a bill before it is released does not have quality built into the process.

Match Capacity to Demand

A common problem in 24-hour healthcare operations is having too few or too many staff for patient care demand. This problem is exacerbated if an organization only allows set shifts (e.g., eight hours).

To solve this problem, first graph and analyze demand on an hourly and daily basis. Then develop staffing patterns that match this demand. For example, a five-hour or seven-hour shift might be needed to correctly meet the demand.

Using the tools in chapter 7, you should be able to identify patterns of demand (e.g., high ED demand on Friday and Saturday evenings). Chapter 12 also provides details on capacity planning.

Let the Patient Do the Work

The internet and other advanced information technologies have allowed for increased self-service in service industries. Individuals are now comfortable booking their own airline reservations, buying goods online, and checking themselves out at retailers. This trend can be exploited in healthcare with tools that enable patients to be part of the process. For example, online tools are now available that allow patients to make their own clinic appointments. Letting the patient do the work reduces the work of staff and provides an opportunity for quality at the source—the data are more likely to be correct if the patients input them than if a staff member does so.

Embed Evidence-Based Medicine

When clinical processes are being improved, it is important to rely on evidence-based medicine (EBM) as a resource and frequently as the initial starting point for the improved process. Chapter 3 provides an overview of this resource and

its importance as a prime component of delivering high-quality, cost-effective care. Chapter 3 illustrates many of the approaches to using EBM to improve clinical processes.

Use Technology

The electronic health record (EHR) and other information technology tools provide a platform to automate many tasks that were once performed manually. A good rubric through which to identify these tasks is to examine every daily task and ask where it ranks in complexity on the basis of your professional training. For those tasks that are low on this list, consider ways to automate them.

Today, work is an activity—not a place. The widespread use of smartphones and tablets enables work to be performed outside the traditional workplace. The ability to work from home was expanded considerably during the COVID-19 pandemic, and these new technological tools should be applied widely to automate processes. Further, the capabilities of these tools should be considered in all process improvement projects; see Chapter 15 for more detailed information on these and other tools:

- *Health information technology*: Described in chapter 4, this technology provides a comprehensive platform for process improvements in both clinical and administrative systems.
- *Artificial intelligence and machine learning*: Machine learning enables systems to automatically learn and upgrade their algorithms using artificial intelligence (AI) to make process decisions and project outcomes. AI can also be used to process natural language into usable data for analysis and process control.
- *Digital therapeutics*: A common example of digital therapeutics are mobile apps that connect with wearable devices to track patient health data and provide them with recommendations on their behavior.
- *Internet of Medical Things*: A system of connected medical devices, sensors, and software.
- *Virtual and augmented reality*: Augmented reality enhances the existing environment of the individual using a mobile device or headset, whereas virtual reality provides a completely immersive experience by generating an entire environment within a headset.
- *Computer vision and image processing*: Computer vision relies on AI and machine learning to train computers in analyzing and identifying patterns in images for clinical diagnosis and treatment recommendations.
- *Facial recognition*: An application of computer vision to identify faces and expressions.

- *Natural language processing—medical chatbots:* These chatbots are software programs that use machine learning and language algorithms to provide real-time assistance to patients.
- *Robotic process automation:* A software-enabled process automation enabling automatic execution of tasks like moving files, filling forms, or sending notifications to streamline processes.
- *Cobots:* Whereas robots are used in heavy-duty production settings involving rapid movements and often work in isolated environments, cobots move more slowly and are designed to work directly with people.
- *3D printing:* Enables printing of three-dimensional objects from commercially available printers and is used in applications such as localized printing of medical equipment, bioprinting, and precision medicine.
- *Autonomous vehicles and drones:* Autonomous vehicles and drones are unpiloted transportation devices that can be used to transport patients, medical supplies, and samples.

Apply the Theory of Constraints

Chapter 7 discusses the underlying principles and applications of the theory of constraints, which can be used as a powerful process improvement tool. First, the bottleneck in a system is identified, often through the observation of queues forming in front of it. Once a bottleneck is identified, it should be exploited and everything else in the system subordinated to it. Specifically, other nonbottleneck resources (or steps in the process) should be synchronized to match the output of the constraint. Idleness at a nonbottleneck resource costs nothing, and nonbottlenecks should never produce more than can be consumed by the bottleneck resource. Often, this synchronization causes the bottleneck to shift and a new bottleneck is identified. However, if the original bottleneck remains, the possibility of elevating the bottleneck needs to be considered. Elevating bottlenecks requires additional resources (e.g., staff, equipment), so a comprehensive financial and outcomes analysis needs to be undertaken to determine the trade-offs among process improvement, quality, and costs.

Identify Best Practices and Replicate

Although this tip does not describe a formal operations management tool, it must be mentioned as a highly recommended management approach. As health systems expand, they are likely to have many similar activities replicated in separate geographic sites. Good management practice is to identify high-performing sites (e.g., the best primary care clinic in a system) and replicate their core processes throughout the organization.

A similar approach can be taken with individual employees. For example, study the best billing clerk in a hospital to understand her processes and then replicate them with all the billers in a department.

For more complex processes, Six Sigma and Lean methodologies can be used. Chapters 9 and 10 provide detailed descriptions of the use of these tools.

The Science of Lines: Queuing Theory

queuing theory
The mathematical study of wait lines.

Although most people are familiar with waiting in line, few are familiar with, or even aware of, **queuing theory**, or the theory of waiting lines. Most people's experience with waiting lines is when they are actually part of those lines, for example, when waiting to check out in a retail environment. In a manufacturing environment, items wait in line to be worked on. In a service environment, customers wait for a service to be performed.

Queues, or lines, form because the resources needed to serve them (servers) are limited—deploying unlimited resources is economically unfeasible. Queuing theory is used to study systems to determine the best balance between service to customers (short or no waiting lines, implying many resources or servers) and economic considerations (few servers, implying long lines). A simple queuing system is illustrated in exhibit 11.2.

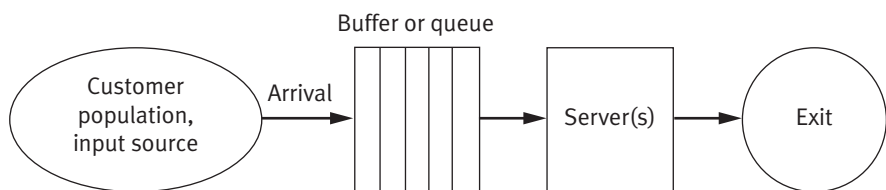
Customers (often referred to as entities) arrive and either are served (if there is no line) or enter the queue (if others are waiting to be served). Once they are served, customers exit the system.

The customer population, or input source, can be either finite or infinite. If the source is effectively infinite, the analysis of the system is easier than if it is finite because simplifying assumptions can be made.

The arrival process is characterized by the arrival pattern—the rate at which customers arrive (number of customers divided by unit of time)—or by the interarrival time (time between arrivals) and the distribution in time of those arrivals. The distribution of arrivals can be constant or variable. A constant arrival distribution has a fixed interarrival time. A variable, or random, arrival pattern is described by a probability distribution. The **queue discipline**

queue discipline
In queuing theory, the method by which customers are selected from the queue to be served.

EXHIBIT 11.2 Simple Queuing System



is the method by which customers are selected from the queue to be served. Often, customers are served in the order in which they arrived—first come, first served. However, many other queue disciplines are possible, and choice of a particular discipline can greatly affect system performance. For example, choosing the customer whose service can be completed most quickly (shortest processing time) usually minimizes the average time customers spend waiting in line. This result is one reason urgent care centers are often located near an ED—urgent issues can usually be handled more quickly than true emergencies can.

The service process is characterized by the number of servers and service time. Like arrivals, the distribution of service times can be constant or variable. Often, the exponential distribution (M) is used to model variable service times, μ is the mean service rate, λ is the mean arrival rate, and ρ is capacity utilization. (An exponential distribution creates data points that simulate a purely random process.)

Queuing Notation

The type of queuing system is identified with a specific notation in the form of A/B/c/D/E. The A represents the interarrival time distribution, and B represents the service time distribution. A and B together are represented as either a deterministic or a constant rate. The c represents the number of servers, D is the maximum queue size, and E is the size of the input population. When queue and input population are assumed to be infinite, D and E are typically omitted. An M/M/1 queuing system, therefore, has an exponential service time distribution, a single server, an infinite possible queue length, and an infinite input population; it assumes only one queue. An M/M/1 queue for VVH is used as an example throughout the remainder of the chapter.

Queuing Solutions

Analytic solutions for some simple queuing systems at equilibrium or steady state (after the system has been running for some time and is unchanging, often referred to as a stable system) have been determined; however, the derivation of these results is outside the scope of this text. Refer to Cooper (1981) for a complete derivation and results for many other types of queuing systems.

Here, we focus primarily on the M/M/1 queuing system by presenting the results for an M/M/1 queue where $\lambda < \mu$ —the arrival rate is less than the service rate. Note that if $\lambda \geq \mu$ (customers arrive faster than they are served), the queue becomes infinitely long, the number of customers in the system becomes infinite, waiting time becomes infinite, and the server experiences 100 percent capacity utilization (percentage of time the server is busy). The

following formulas can be used to determine some characteristics of the queuing system at steady state.

Capacity utilization:

$$\rho = \frac{\lambda}{\mu} = \frac{\text{Mean arrival rate}}{\text{Mean service rate}} = \frac{1/\text{Mean time between arrivals}}{1/\text{Mean service time}} = \frac{\text{Mean service time}}{\text{Mean time between arrivals}}$$

Average waiting time in queue:

$$W_q = \frac{\lambda}{\mu(\mu - \lambda)}$$

Average length of queue (average number in queue):

$$L_q = \frac{\lambda^2}{\mu(\mu - \lambda)} = \left(\frac{\lambda}{\mu}\right) \left(\frac{\lambda}{\mu - \lambda}\right)$$

Average total number of customers in the system:

$$L_s = \frac{\lambda}{\mu - \lambda} = \lambda W_s = \text{Arrival rate} \times \text{Time in the system}$$

Little's law

The relationship between the arrival rate to a system, the time an item (e.g., a patient) spends in the system, and the number of items in a system.

This last result is called **Little's law** and applies to all types of queuing systems and subsystems. To summarize this result in plain language, in a stable system or process, the number of things in the system is equal to the rate at which things arrive to the system multiplied by the time they spend in the system. In a stable system, the average rate at which things arrive to the system is equal to the average rate at which things leave the system. If this were not true, the system would not be stable.

Little's law can also be restated using other terminology:

$$\text{Inventory (things in the system)} = \text{Arrival rate (or departure rate)} \times \text{Throughput time (flow time)}$$

or

$$\text{Throughput time} = \text{Inventory} \div \text{Arrival rate}$$

Knowledge of two of the variables in Little's law allows calculation of the third variable. Consider a clinic that serves 200 patients in an eight-hour

day, or an average of 25 patients an hour. The average number of patients in the clinic (waiting room, exams rooms, etc.) is 15. Therefore, the average throughput time is

$$\begin{aligned} T &= I/\lambda \\ &= \frac{15 \text{ patients}}{25 \text{ patients/hour}} \\ &= 0.6 \text{ hour,} \end{aligned}$$

where T is throughput time, λ is patients per hour, and I is number of patients. Hence, each patient spends an average of 36 minutes in the clinic.

Little's law has important implications for process improvement and can be seen as the basis of many improvement techniques. Throughput time can be decreased by decreasing inventory or increasing departure rate. Lean initiatives often focus on decreasing throughput time (or increasing throughput rate) by decreasing inventory. The theory of constraints (chapter 7) focuses on identifying and eliminating system bottlenecks. The departure rate in any system is equal to $1 \div$ task cycle time of the slowest task in the system or process (the bottleneck). Decreasing the amount of time an object spends at the bottleneck task therefore increases the departure rate of the system and decreases throughput time.

Vincent Valley Hospital and Health System M/M/1 Queue

VVH began receiving complaints from patients related to crowded conditions in the waiting area for MRI procedures. The organization has determined a goal to average just one patient waiting in line for the MRI. It has collected data on arrival and service rates and sees that, for MRIs, the mean service rate (μ) is four patients per hour, exponentially distributed. VVH also finds that the mean arrival rate (λ) is three patients per hour. To find the capacity utilization of MRI (percentage of time the MRI is busy), VVH uses the following formula:

$$\rho = \frac{\lambda}{\mu} = \frac{3}{4} = 75\% \quad \text{or} \quad \rho = \frac{1/\mu}{1/\lambda} = \frac{15 \text{ minutes}}{20 \text{ minutes}} = 75\%.$$

Assuming each MRI takes 15 minutes to complete, if one customer arrives every 20 minutes, the MRI is busy 75 percent of the time.

Next, VVH calculates patients' average time waiting in line,

$$W_q = \frac{\lambda}{\mu(\mu - \lambda)} = \frac{3}{4(4 - 3)} = \frac{3}{4} = 0.75 \text{ hour,}$$

and average time spent in the system,

$$W_s = \frac{1}{\mu - \lambda} = \frac{1}{4 - 3} = 1 \text{ hour.}$$

Finally, it determines average total number of patients in the system,

$$L_s = \frac{\lambda}{\mu - \lambda} = \frac{3}{4 - 3} = 3 \text{ patients.}$$

or

$L_s = \lambda W_s = \text{Arrival rate} \times \text{Time in the system} = 3 \text{ patients/hour} \times 1 \text{ hour} = 3$ patients, and average number of patients in the waiting line,

$$\begin{aligned} L_q &= \frac{\lambda^2}{\mu(\mu - \lambda)} = \left(\frac{\lambda}{\mu}\right) \left(\frac{\lambda}{\mu - \lambda}\right) = \left(\frac{3}{4}\right) \left(\frac{3}{4 - 3}\right) \\ &= \frac{3^2}{4(4 - 3)} = \frac{9}{4} = 2.25 \text{ patients.} \end{aligned}$$

To decrease the average number of patients waiting, VVH needs to decrease the utilization, $\rho = \lambda \div \mu$, of the MRI process. In other words, the service rate must be increased or the arrival rate decreased. VVH may increase the service rate by making the MRI process more efficient so that the average time to perform the procedure is decreased and MRIs can be performed on a greater number of patients in an hour. Alternatively, the organization may decrease the arrival rate by scheduling fewer patients per hour.

To achieve its goal (assuming that the service rate is not increased), VVH needs to decrease the arrival rate to

$$\begin{aligned} L_q &= \frac{\lambda^2}{\mu(\mu - \lambda)} = \frac{\lambda^2}{4(4 - \lambda)} = 1 \\ \lambda^2 &= 4 \times (4 - \lambda) = 16 - 4\lambda \\ \lambda^2 + 4\lambda - 16 &= 0 \\ \lambda &= 2.47. \end{aligned}$$

Alternatively (assuming that the arrival rate is not decreased), VVH may increase the service rate to

$$\begin{aligned} L_q &= \frac{3^2}{\mu(\mu - 3)} = \frac{3^2}{\mu(\mu - 3)} = 1 \\ \mu(\mu - 3) &= \mu^2 - 3\mu = 3^2 = 9 \\ \mu^2 - 3\mu - 9 &= 0 \\ \mu &= 4.85. \end{aligned}$$

VVH may also implement some combination of decreasing arrival rate and increasing service rate. In all cases, utilization of the MRI will be reduced to $\rho = \lambda \div \mu = 2.47 \div 4.00$, or $3.00 \div 4.85 = 0.62$.

Real systems are seldom as simple as an M/M/1 queuing system and rarely reach equilibrium. Often, simulation is needed to study these more complicated systems.

Discrete Event Simulation

Discrete event simulation (DES) is typically performed using commercially available software packages. As with Monte Carlo simulation, performing DES by hand is an option, albeit a tedious one. Two popular simulation software packages are Arena (Rockwell Automation 2021) and Simul8 (Simul8 Corporation 2021).

The terminology and general logic of DES are built on queuing theory. A basic simulation model consists of entities, queues, and resources, all of which can have various attributes. Entities are the objects that flow through the system; in healthcare, entities typically are patients, but they can be any object on which some service or task will be performed. For example, blood samples in the hematology lab are entities. Queues are the waiting lines that hold the entities while they await service. Resources (previously referred to as servers) can be people, equipment, or space for which entities compete.

The specific operation of a simulation model is based on states (variables that describe the system at a point in time) and events (variables that change the state of the system). Events are controlled by the simulation executive, and data are collected on the state of the system as events occur. The simulation jumps through time from event to event.

A simple example from the Vincent Valley Hospital and Health System M/M/1 MRI queuing discussion helps show the logic behind DES software. Exhibit 11.3 contains a list of the events as they happen in the simulation. The arrival rate is three patients per hour, and the service rate is four patients per hour. Random interarrival times are generated using an exponential distribution with a mean of 0.33 hours. Random service times are generated using an exponential distribution with a mean of 0.25 hours (shown at the bottom of exhibit 11.10 later in this chapter).

The simulation starts at time 0.00. The first event is the arrival of the first patient (entity); there is no line (queue), so this patient enters service. Upcoming events are the arrival of the next patient at 0.17 hours (the interarrival between patients 1 and 2 is 0.17 hours) and the completion of the first patient's service at 0.21 hours.

The next event is the arrival of patient 2 at 0.17 hours. Because the MRI on patient 1 is not complete, patient 2 enters the queue. The MRI has been busy since the start of the simulation, so the utilization of the MRI

EXHIBIT 11.3
Simulation Event List

Just Finished			Variables		Attributes		Statistics				Upcoming Events		
Entity No.	Time	Event Type	Length of Queue	Server Busy	Arrival Time in Queue	Arrival Time in Service	Number of			Utilization	Entity No.	Time	Event
							Complete	Waits in Queue	Total Wait Time in Queue				
1	0.00	Arr	0	1	0.00	0.00	0	0	0	0	2	0.17	Arr
2	0.17	Arr	1	1	0.17		0	0	0	1.00	1	0.21	Dep
1	0.21	Dep	0	1	0.00	0.00	1	0.04	0.19	1.00	3	0.54	Arr
3	0.54	Arr	1	1	0.54		1	0.04	0.07	1.00	3	0.54	Arr
2	0.77	Dep	0	1	0.17	0.21	2	0.27	0.35	1.00	2	0.77	Dep
3	0.79	Dep	0	0		0.77	3	0.27	0.34	1.00	4	0.90	Arr
4	0.90	Arr	0	1		0.90	3	0.27	0.30	0.88	4	0.90	Arr
											5	1.49	Arr
						1	2	3	4	5	6	7	8
Interarrival time			Expon (0.33)			0.17	0.37	0.36	0.59	0.14	0.17	0.24	0.06
Time of arrival					0.00	0.17	0.54	0.90	1.49	1.63	1.80	2.04	2.10
Service time			Expon (0.25)		0.21	0.56	0.02	0.37	0.34	0.11	1.02	0.01	0.20

Note: Arr = arrival; Dep = departure; Expon = exponent.

is 100 percent. Upcoming events are the completion of the first patient's service at 0.21 hours and the arrival of patient 3 at 0.54 hours (the interarrival between patients 2 and 3 is 0.37 hours).

When the first patient's MRI is completed at 0.21 hours, no one is waiting in the queue because once patient 1 has completed service, patient 2 can enter service. The total waiting time in the queue for all patients is 0.04 hours (the difference between when patient 2 entered the queue and entered service). The average queue length is 0.19 patients. No people were in line for hours, and one person was in line for 0.04 hours:

$$\frac{0 \text{ people} \times 0.17 \text{ hours} + 1 \text{ person} \times 0.04 \text{ hours}}{0.21 \text{ hours}} = 0.19 \text{ people.}$$

Upcoming events are the arrival of patient 3 at 0.54 hours and the departure of patient 2 at 0.77 hours (patient 2 entered service at 0.21 hours, and service takes 0.56 hours).

Patient 3 arrives at 0.54 hours and joins the queue because the MRI is still busy with patient 2. The average queue length has decreased from the previous event because more time has passed with no one in the queue—only one person has been in the queue for 0.04 hours, but total time in the simulation is 0.54 hours. Upcoming events are the departure of patient 2 at 0.77 hours and the arrival of patient 4 at 0.90 hours.

Patient 2 departs at 0.77 hours. No one is waiting in the queue at this point because patient 3 has entered service. Two people have departed the system. The total wait time in the queue for all patients is 0.04 hours for patient 2 plus 0.17 hours for patient 3 (0.77 hours – 0.54 hours) for a total of 0.21 hours. The average queue length is

$$\frac{0 \text{ people} \times 0.50 \text{ hours} + 1 \text{ person} \times 0.21 \text{ hours}}{0.77 \text{ hours}} = 0.35 \text{ people.}$$

The MRI utilization is still at 100 percent because the MRI has been busy constantly since the start of the simulation. Upcoming events are the departure of patient 3 at 0.79 hours (patient 3 arrived at 0.54 hours, and service takes 0.25 hours) and the arrival of patient 4 at 0.90 hours.

Patient 3 departs at 0.79 hours. Because no patients are waiting for the MRI, it becomes idle. Upcoming events are the arrival of patient 4 at 0.90 hours and the departure of patient 4 at 1.27 hours.

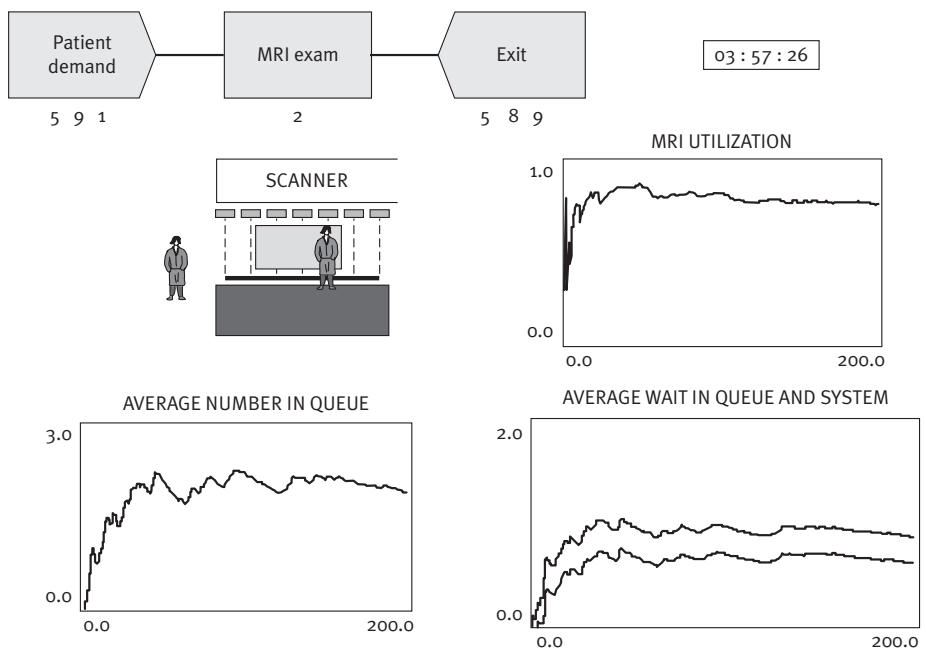
With patient 4 arriving at 0.90 hours and entering service, the utilization of the MRI has decreased to 88 percent because it was idle for 0.11 hours of the 0.90 hours the simulation has run. Upcoming events are the departure of

patient 4 at 1.27 hours and the arrival of patient 5 at 1.49 hours. The simulation continues in this manner until the desired stop time is reached.

Even for this simple model, performing these calculations by hand takes a long time. Additionally, an advantage of simulation is that it uses process mapping; many simulation software packages are able to import and use Microsoft Visio process and value stream maps. DES software allows process improvement teams to build, run, and analyze simple models in limited time; Arena software was used to build and simulate the present model (exhibit 11.4).

As before, the arrival rate is three patients per hour, the service rate is four patients per hour, and both rates are exponentially distributed. Averages over time for queue length, wait time, and utilization for a single replication are shown in the plots in exhibit 11.12 later in the chapter. Each of 30 replications of the simulation is run for 200 hours. Replications are needed to determine confidence intervals for the reported values. Some of the output from this simulation is shown in exhibit 11.5. The sample mean plus or minus the half-width gives the 95 percent confidence interval for the mean. Increasing the number of replications reduces the half-width. The results of this simulation agree fairly closely with the calculated steady-state results because the process was assumed to run continuously for a significant period, 200 hours. A more realistic assumption might be that MRI

EXHIBIT 11.4
Arena
Simulation
of VVH MRI
M/M/1 Queuing
Example



Note: Created with Arena simulation software. M = exponential distribution; MRI = magnetic resonance imaging.

procedures are only performed 10 hours every day. The Arena simulation was rerun with this assumption, and the results are shown in exhibit 11.6. The average wait times, queue length, and utilization are lower than the steady-state values.

Vincent Valley Hospital and Health System M/M/1 Queue

VVH has determined that a steady-state analysis is not appropriate for its situation because MRIs are only offered 10 hours a day. The process improvement team assigned to this system decides to analyze the situation using simulation. Once the model is built and run, the model and simulation results are compared with actual data and evaluated by relevant staff to ensure that the model accurately reflects reality. All staff agree that the model is valid and can be used

EXHIBIT 11.5 **Arena Output** **for VVH MRI** **M/M/1 Queuing** **Example: 200** **Hours**

Category Overview						
8:22:36 AM			July 26, 2021			
Values across all replications						
MRI Example						
Replications: 30 Time unit: Hours						
Key Performance Indicators						
System		Average				
Number out		601				
Entity						
Time						
Wait Time	Average	Half-Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	0.7241	0.08	0.5009	1.3496	0.00	7.3900
Total Time	Average	Half-Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	0.9734	0.08	0.7427	1.6174	0.00001961	7.4140
Queue						
Other						
Number Waiting	Average	Half-Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
MRI exam queue	2.1944	0.25	1.4326	4.2851	0.00	29.0000
Resource						
Usage						
Instantaneous Utilization	Average	Half-Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
MRI	0.7488	0.01	0.6767	0.8513	0.00	1.0000
Arrival rate = 3 patients/hour; service rate = 4 patients/hour.						

Note: Created with Arena simulation software. M = exponential distribution; MRI = magnetic resonance imaging.

EXHIBIT 11.6
Arena Output
for VVH MRI
M/M/1 Queuing
Example: 10
Hours

Category Overview						
12:19:03 PM			July 26, 2021			
Values across all replications						
MRI Example						
Replications: 30 Time unit: Hours						
Key Performance Indicators						
System		Average				
Number out		28				
Entity						
Time						
Wait Time	Average	Half-Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	0.4778	0.15	0.02803444	1.4312	0.00	2.9818
Total Time	Average	Half-Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	0.7304	0.16	0.2407	1.7611	0.00082680	3.3129
Queue						
Other						
Number Waiting	Average	Half-Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
MRI exam queue	1.5265	0.46	0.2219	4.5799	0.00	10.0000
Resource						
Usage						
Instantaneous Utilization	Average	Half-Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
MRI	0.7167	0.05	0.4088	0.9780	0.00	1.0000
Arrival rate = 3 patients/hour; service rate = 4 patients/hour.						

Note: Created with Arena simulation software. M = exponential distribution; MRI = magnetic resonance imaging.

to determine how to achieve the stated goal. If the model had not been considered valid, the team would have needed to build and validate a new model.

The results of the simulation (refer to exhibit 11.14 later in the chapter) indicate that VVH has an average of 1.5 patients in the queue. To reach the desired goal of only one patient waiting on average, VVH needs to decrease the arrival rate or increase the service rate. Using trial and error in the simulation, the organization finds that decreasing the arrival rate to 2.7 or increasing the service rate to 4.4 will allow the goal to be achieved.

However, even using the improvement tools in this text, the team believes that the organization will only be able to increase the service rate of the MRI to 4.2 patients per hour. Therefore, to reach the goal, the arrival rate must also be decreased. Again using the simulation, VVH finds that it needs

to decrease the arrival rate to 2.8 patients per hour. Exhibit 11.7 shows the results of this simulation.

The team recommends that (1) a kaizen event be held for the MRI process to increase service rate and (2) appointments for the MRI be reduced to decrease the arrival rate. However, the team also notes that implementing these changes will reduce the average number of patients served from 28 to 26 and reduce the utilization of the MRI from 0.72 to 0.69. More positively, average patient wait time will be reduced from 0.48 hours to 0.35 hours.

VVH is able to increase the service rate to 4.2 patients per hour and decrease the arrival rate to 2.8 patients per hour, and the results are as predicted by the simulation. The team now begins to investigate other solutions enabling VVH to increase MRI utilization while maintaining wait times and queue length.

EXHIBIT 11.7
Arena Output
for VVH MRI
M/M/1 Queuing
Example:
Decreased
Arrival Rate,
Increased
Service Rate

Category Overview						
8:24:44 AM			July 26, 2021			
Values across all replications						
MRI Example						
Replications: 30		Time unit: Hours				
Key Performance Indicators						
System	Average					
Number out	26					
Entity						
Wait Time	Average	Half-Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	0.3507	0.12	0.02449931	1.4202	0.00	3.4973
Total Time	Average	Half-Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	0.6008	0.14	0.1899	1.7825	0.00097591	4.2210
Queue						
Other						
Number Waiting	Average	Half-Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
MRI exam queue	1.0342	0.36	0.0928	4.2272	0.00	9.0000
Resource						
Usage						
Instantaneous Utilization	Average	Half-Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
MRI	0.6682	0.06	0.3314	0.9456	0.00	1.0000
Arrival rate = 2.8 patients/hour; service rate = 4.2 patients/hour; 10 hours simulated.						

Arrival rate = 2.8 patients/hour; service rate = 4.2 patients/hour; 10 hours simulated.

Note: Created with Arena simulation software. M = exponential distribution; MRI = magnetic resonance imaging.

Simulation and Queuing Theory Findings

Simulation is a powerful tool for modeling processes and systems to evaluate choices and opportunities. As is true of all of the tools and techniques presented in this text, simulation can be used in conjunction with other initiatives, such as Lean or Six Sigma, to enable continuous improvement of systems and processes.

Process Improvement in Practice

When confronting process improvement projects, start by using the basic process improvement tools just discussed. However, for more comprehensive or challenging projects, more structured methodologies are appropriate. In this section, we review methods and tools that, in addition to simulation, are key approaches to complex process improvement challenges, and we apply them to an emergency department scenario at VVH.

Review of Methodologies

Quality and Six Sigma

If the primary goal of a process improvement project is to improve quality (reduce the variability in outcomes), the quality improvement tools using Six Sigma described in chapter 9 yield the best results. As discussed, the methodology uses seven basic tools: fishbone diagrams, check sheets, histograms, Pareto charts, flowcharts, scatter plots, and run charts. It also includes statistical process control to provide an ongoing measurement of process output characteristics to ensure quality and enable the identification of a problem situation before an error occurs.

This approach also includes measuring process capability—whether a process is capable of producing the desired output—and benchmarking it against other similar processes in other organizations. Quality function deployment is used to match customer requirements (voice of the customer) with process capabilities given that trade-offs must be made. Poka-yoke is employed selectively to mistake-proof parts of a process.

A primary function of Quality/Six Sigma programs is to eliminate sources of artificial variance in processes and systems. Natural variance occurs in any system, such as heat, temperature, and patients getting sick or breaking a leg. Artificial variance is created by the people in the system and is completely in their control; the quality tools are used to identify and eliminate those sources of artificial variance. For example, scheduling systems, overtime allocations, and business office processing systems can all be changed by people in the system. The secret to a successful Six Sigma program is removing all the artificial variance and focusing on creating

value for customers. Effective Six Sigma systems strategically employ Lean concepts to achieve this goal.

Lean

Process improvement projects focused on eliminating waste and improving flow in the system or process can use many of the tools that are part of the Lean approach (chapter 10). The kaizen philosophy, which is the basis for Lean, includes the following steps:

1. *Specify value.* Identify activities that provide value from the customer's perspective.
2. *Map and improve the value stream.* Determine the sequence of activities or the current state of the process and the desired future state.
Eliminate non-value-added steps and other waste.
3. *Enable flow.* Allow the process to flow as smoothly and quickly as possible.
4. *Enable pull.* Allow the customer to pull products or services.
5. *Perfect.* Repeat the cycle to ensure a focus on continuous improvement.

An important part of Lean is value stream mapping, which is used to define the process and determine where waste is occurring. Takt time measures the time needed for the process to occur, given customer demand, and can be used to synchronize flow in a process. Standardized work, an important part of the Lean approach, is written documentation of the precise way in which every step in a process should be performed and helps ensure that activities are completed the same way every time in an efficient manner.

Other Lean tools include the five Ss (a technique to organize the workplace) and spaghetti diagrams (a mapping technique to show the movement of customers, patients, workers, equipment, jobs, etc.). Leveling workload (heijunka) so that the system or process flows without interruption can be used to improve the value stream. Kaizen blitzes or events are Lean tools used to improve the process quickly when project management is not needed (chapter 10).

Process Improvement Project: Vincent Valley Hospital and Health System Emergency Department

To demonstrate the power of many of the process improvement tools described in this book, an extensive patient flow process improvement project at VVH is examined.

VVH has identified patient flow in the ED as an important area on which to focus process improvement efforts. The goal of the project is to reduce total patient time in the ED (both waiting and care delivery) while maintaining or improving financial performance.

The first step for VVH leadership is to charter a multi-departmental team using the project management methods described in chapter 6. The head nurse for emergency services has been appointed project leader. The team feels VVH should take a number of steps to improve patient flow in the ED and splits the systems improvement project into three major phases. First, team members will perform simple data collection and basic process improvement to identify low-hanging fruit and make obvious, straightforward changes.

Once the team feels comfortable with its understanding of the basics of patient flow in the department, it will work to understand the elements of the system more fully by collecting detailed data. Then, value stream mapping and the theory of constraints will be used to identify opportunities for improvement. Root-cause analysis will be employed on poorly performing processes and tasks; resulting changes will be adopted and their effects measured.

The third phase of the project will be the use of simulation. Because the team, by this stage in the improvement effort, will have complete knowledge of patient flow in the system, it will be able to develop and test a simulation model with confidence. Once the simulation is validated, the team will continuously test process improvements in the simulation model and implement them in the ED.

The specific high-level tasks in this project are as follows.

Phase I

1. Observe patient flow and develop a detailed process map.
2. Measure high-level patient flow metrics for one week:
 - Patients arriving per hour
 - Patients departing per hour to inpatient
 - Patients departing per hour to home
 - Number of patients in the ED, including the waiting area and exam rooms
3. With the process map and data in hand, use simple process improvement techniques to make changes in the process, then measure the results.

Phase II

4. Set up a measurement system for each individual process, and take measurements over one week.

5. Use value stream mapping and the theory of constraints to analyze patient flow and make improvements, then measure the effects of the changes.

Phase III

6. Collect data needed to build a realistic simulation model.
7. Develop the simulation model and validate it against real data.
8. Use the simulation model to conduct virtual experiments on process improvements. Implement promising improvements, and measure the results of the changes.

Phase I

VVH process improvement project team members observe patient flow and record the needed data. With the information collected, the team creates a detailed process map. Team members measure the following high-level operating statistics related to patient flow:

- Patients arriving per hour = 10
- Patients departing per hour to inpatient = 2
- Patients triaged to routine emergency care per hour = 8
- Patients departing per hour to home = 8
- Average number of patients in various parts of the system (sampled every 10 minutes) = 20
- Average number of patients in ED exam rooms = 4

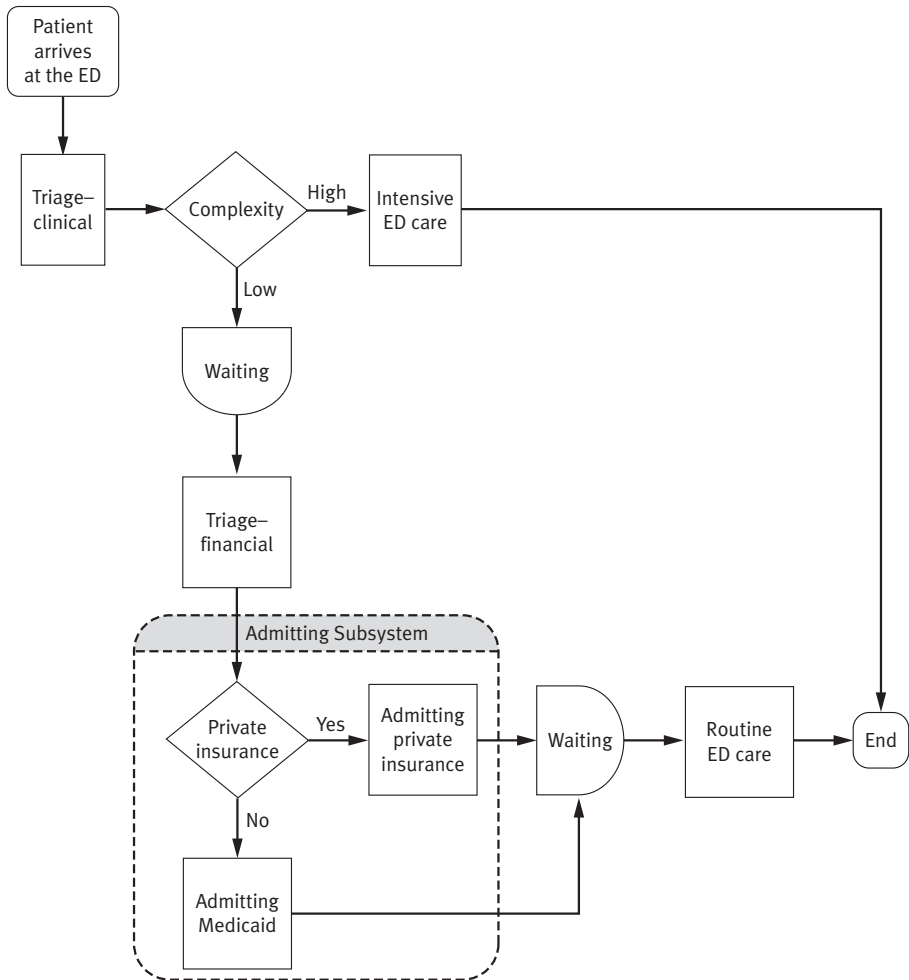
Using Little's law, the average time in the ED (throughput time) is calculated as

$$\begin{aligned}
 \text{Throughput time} &= T \\
 &= I/\lambda \\
 &= \frac{24 \text{ patients}}{8 \text{ patients/hour}} \\
 &= 3 \text{ hours.}
 \end{aligned}$$

Hence, each patient spends an average of 3 hours, or 180 minutes, in the ED.

However, Little's law only gives the average time in the department at steady state. Therefore, the team measures total time in the system for a sample of routine patients and determines an average of 165 minutes. It also observes that the number of patients in the waiting room varies from 0 to 20, and the actual time to move through the process varies from 1 hour to more than 5 hours.

EXHIBIT 11.8
VVH Emergency
Department
(ED) Admitting
Subsystem



Note: Created with Microsoft Visio.

Initially, the team focuses on the ED admitting subsystem as an opportunity for immediate improvement. Exhibit 11.8 shows the complete ED system, with the admitting subsystem highlighted.

The team develops the following description of the admitting process from its documentation of patient flow:

Patients who did not have an acute clinical problem were asked if they had health insurance. If they did not have health insurance, they were sent to the admitting clerk who specializes in Medicaid (to enroll them in a Medicaid program). If they had health insurance, they were sent to the other clerk, who specializes in private insurance. If a patient had been sent to the wrong clerk by triage, he was sent to the other clerk.

The team determines that one process improvement change could be to cross-train the admitting clerks on both private insurance and Medicaid eligibility. This training would provide for load balancing, as patients would automatically go to the free clerk. In addition, this system improvement would eliminate triage staff errors in sending patients to the wrong clerk, hence providing quality at the source.

Phase II

Phase I produced some gains in reducing patient time in the ED. However, the team feels more detailed data are needed for further improvement. As a first step in collecting these data, the team measures various parameters of the department's processes. Initially, it focuses on the period from 2:00 p.m. to 2:00 a.m., Monday through Thursday, as this is the busy period in the ED and demand seems relatively stable during these times.

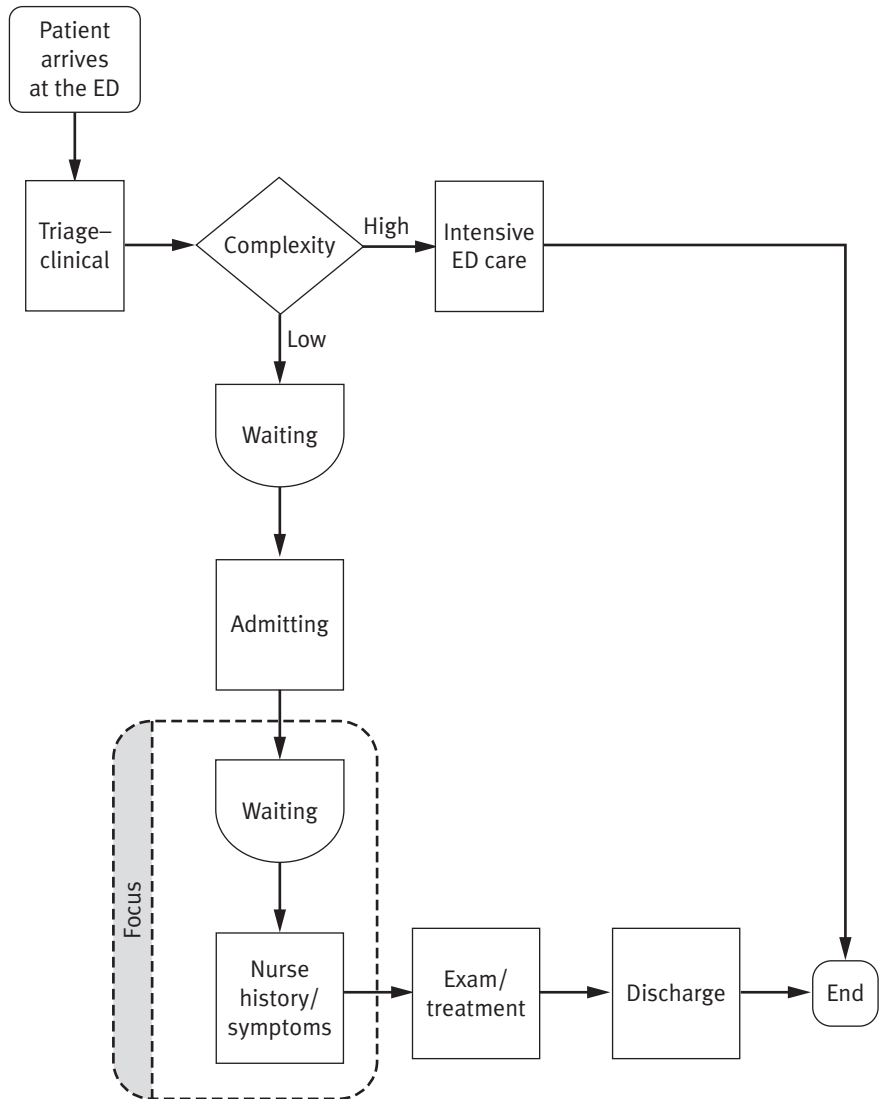
The team draws a more detailed process map (exhibit 11.9) and performs value stream mapping of this process (exhibit 11.10). First, team members evaluate each step in the process to determine if it is value-added, non-value-added, or non-value-added but necessary. Then, they measure the time a patient spends at each step in the process. The team finds that after a patient has given his insurance information, he spends an average of 30 minutes of non-value-added time in the waiting room before a nurse is available to take his history and record the presenting complaint, a process that takes an average of 20 minutes to complete. The percentage of value-added time for these two steps is

$$\begin{aligned} & (\text{Value-added time} \div \text{Total time}) \times 100 = [20 \text{ minutes} \div \\ & (30 \text{ minutes} + 20 \text{ minutes})] \times 100 = 40\%. \end{aligned}$$

The team believes the waiting room process can be improved through automation. Patients are handed a tablet personal computer in the waiting area and asked to enter their symptoms and history via a series of branched questions. The results are sent via a wireless network to VVH's EHR. This step takes patients an average of 20 minutes to complete. Staff know which patients have completed the electronic interview by checking the EHR and can prioritize which patient is to be seen next. This new procedure also reduces the time the nurse spends with the patient to 10 minutes because it enables the nurse to verify, rather than record, presenting symptoms and patient history. The percentage of value-added time for the new procedure is

$$\begin{aligned} & (\text{Value-added time} \div \text{Total time}) \times 100 \\ & = [(\text{Patient history time} + \text{Nurse history time}) \div (\text{Patient history time} \\ & \quad + \text{Wait time} \\ & \quad + \text{Nurse history time})] \times 100 \\ & = [(20 \text{ minutes} + 10 \text{ minutes}) \div (20 \text{ minutes} + 10 \text{ minutes} + 10 \text{ minutes})] \times 100 \\ & = 75\%. \end{aligned}$$

EXHIBIT 11.9
VVH Emergency
Department
(ED) Process
Map: Focus on
Waiting and
History



Note: Created with Microsoft Visio.

The average throughput time for a patient in the ED is reduced by 10 minutes. The average time for patients to flow through the department (throughput time) prior to this improvement was 155 minutes. Because this step is on the critical path of the complete routine care ED process, throughput time for noncomplex patients is reduced to 145 minutes, a 7 percent productivity gain. An analyst from the VVH finance department (a member of the project team) is able to demonstrate that the capital and software costs for the

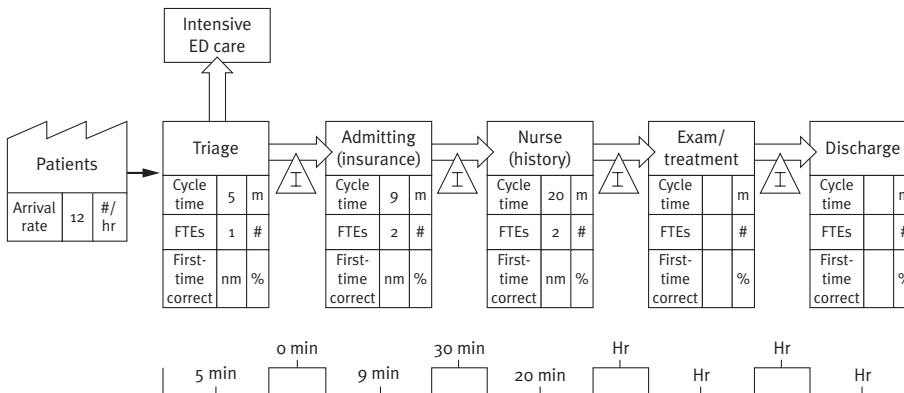


EXHIBIT 11.10
VVH Emergency
Department
(ED) Value
Stream Map:
Focus on
Waiting and
History

Note: Created with eVSM software, a Microsoft Visio add-on from GumshoeKI, Inc. FTE = full-time equivalent; nm = number of patients in this step of the process.

tablet computers will be recovered within 12 months by the improvement in patient flow.

This phase of the project used three of the basic process improvement tools discussed in this chapter:

- Have the customer (patient) do it.
- Provide quality at the source.
- Gain information feedback and real-time control.

Although the process improvements already undertaken have had a visible impact on flow in the ED, the team believes more improvements are possible. Bottlenecks plague the process, as evidenced by two waiting lines, or queues: (1) the waiting room queue, where patients wait before being moved to an exam room, and (2) the most visible queue for routine patients, the discharge area, where patients occasionally must stand because all of the area's chairs are occupied. In the discharge area, patients wait a significant amount of time for final instructions and prescriptions.

The theory of constraints suggests that the bottleneck be identified and optimized. However, alleviating or eliminating the patient examination and treatment or discharge bottlenecks would require significant changes in a long-standing process. Because this process improvement step seems to have the probability of a high payoff but would be a significant departure from existing practice, the team moves to phase III of the project and uses simulation to model different options to improve patient flow in the examination/treatment and discharge processes.

Phase III

First, the team reviews the basic terminology of simulation.

- An *entity* is what flows through a system. Here, the entity is the patient. However, in other systems, the entity can be materials (e.g., blood sample, drug) or information (e.g., diagnosis, billing code). Entities usually have attributes that affect their flow through the system (e.g., male/female, acute/chronic condition).
- Each individual *process* in the system transforms (adds value to) the entity being processed. Each process takes time and consumes resources, such as staff, equipment, supplies, and information.
- *Time* and *resource* use can be defined as an exact value (e.g., 10 minutes) or a probability distribution (e.g., normal—mean, standard deviation). Most healthcare tasks and processes do not require the same amount of time each time they are performed—they require a variable amount of time. These variable usage rates are best described as probability distributions. (A probability distribution is a statistical calculation that describes the possible values and likelihoods that a value can take within a given range.)
- The geographic location of a process is called a *station*. Entities flow from one process to the next via *routes*. The routes can branch out on the basis of *decision points* in the process map.
- Finally, because a process may not be able to handle all incoming entities in a timely fashion, *queues* occur at each process and can be measured and modeled.

The team next develops a process map and simulation model for routine patient flow (exhibit 11.11) in the ED using Arena simulation software (see the companion website for links to videos detailing this model and its operation). The team focuses on routine patients rather than those requiring intensive emergency care because of the high proportion of routine patients seen in the department. Routine patients are checked in and their self-recorded history and presenting complaint(s) verified by a nurse. Then, patients move to an

exam/treatment room and, finally, to the discharge area. Of the 10 patients who arrive at the ED per hour, 8 follow this process.



On the web at
ache.org/books/OpsManagement4

Next, to build a simulation model that accurately reflects this process, the team needs to determine the probability distributions of treatment time, admitting time, nurse history time, discharge time, and arrival rate for routine patients. To determine these probability distributions, team members collect data on time of arrival in the department and time to perform each step in the routine patient care process.

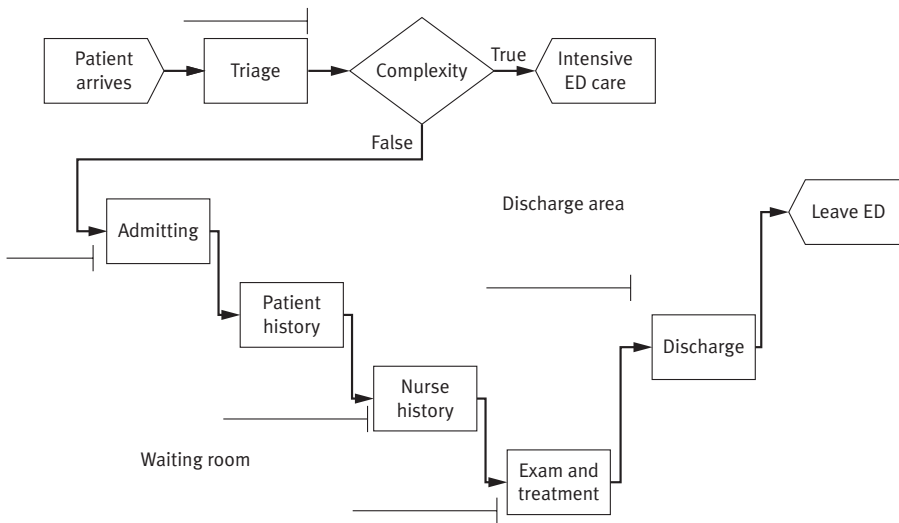


EXHIBIT 11.11
VVH Emergency
Department
(ED) Initial State
Simulation
Model

Note: Created with Arena simulation software.

Probability distributions are determined using the input analyzer function in Arena. Input Analyzer takes raw input data and finds the best-fitting probability distribution for them. Exhibit 11.12 shows the output of Input Analyzer for 500 observations of treatment time for ED patients requiring routine care. Input Analyzer suggests that the best-fitting probability distribution for these data is triangular, with a minimum of 9 minutes, mode of 33 minutes, and maximum of 51 minutes.

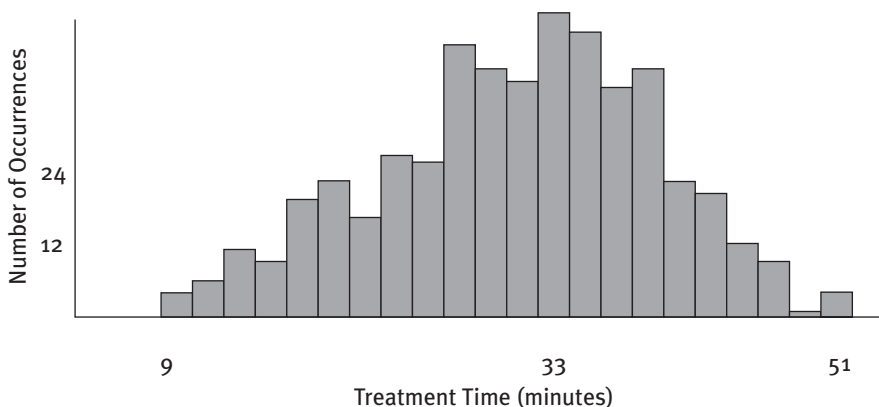


EXHIBIT 11.12
Examination
and Treatment
Time Probability
Distribution:
Routine
Emergency
Department
Patients

The remaining data are analyzed in the same manner, and the following best-fitting probability distributions are determined:

- Emergency routine patient arrival rate—exponential (7.5 minutes between arrivals)
- Triage time—triangular (2, 5, 7 minutes)
- Admitting time—triangular (3, 8, 15 minutes)
- Patient history time—triangular (15, 20, 25 minutes)
- Nurse history time—triangular (5, 11, 15 minutes)
- Exam/treatment time—triangular (14, 36, 56 minutes)
- Discharge time—triangular (9, 19, 32 minutes)

The Arena model simulation is based on 12-hour intervals (2:00 p.m. to 2:00 a.m.) and replicated 100 times. Note that increasing the number of replications decreases the half-width and, therefore, gives tighter confidence intervals. The number of replications needed depends on the desired confidence interval for the outcome variables. However, as the model becomes more complicated, more replications take more simulation time; this model is fairly simple, so 100 replications take little time and are sufficient for this purpose.

Most simulation software, including Arena, is capable of using different arrival rate probability distributions for different times of the day and days of the week, allowing for varying demand patterns. However, the team believes that this simple model using only one arrival rate probability distribution represents the busiest time for the ED, having observed that by 2:00 p.m. on weekdays no queues are created in either the waiting room or the discharge area.

The results of the simulation are reviewed by the team and compared with actual data and observations to ensure that the model is, in fact, simulating the reality of the ED. The team is satisfied that the model accurately reflects reality.

The focus of this simulation is the queuing that occurs in both the waiting room and the discharge area and the total time in the system. Exhibit 11.13 shows the results of this base (current status) model. On average, a patient spends 2.4 hours in the ED.

The team next examines the discharge process in depth because patient waiting time is greatest there. The ED has two rooms devoted to discharge and uses two nurses to handle all discharge tasks, such as making sure prescriptions are given and home care instructions are understood. However, because of the limited number of nurses and exam rooms, queuing is inevitable. In addition, the patient treatment information must be handed off from the treatment team to the discharge nurse. The process improvement team simulates having the discharge process carried out by the examination and treatment team. Because the examination and treatment team knows the patient information, the handoff task can be eliminated. The team estimates that this change will save about five

EXHIBIT 11.13
VVH Emergency
Department
Initial State
Simulation
Model Output

Replications: 100 Time Unit: Hours

Total Time	Average	Half-Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Routine patient	2.4207	0.08	1.7953	3.4082	1.2004	5.2448

Queue

Time

Waiting Time	Average	Half-Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Admitting queue	0.00526930	0.00	0.00048553	0.01668610	0.00	0.2235
Discharge queue	0.3972	0.26	0.06416692	0.8865	0.00	2.0531
Exam and treatment queue	0.3382	0.38	0.04167122	1.1956	0.00	2.5777
Nurse history queue	0.01764541	0.01	0.00272715	0.05309733	0.00	0.3694
Triage queue	0.06437939	0.05	0.01703829	0.1402	0.00	0.6506

Other

Waiting Time	Average	Half-Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Admitting queue	0.03458032	0.00	0.00267040	0.1001	0.00	2.0000
Discharge queue	2.2481	0.26	0.2888	5.1713	0.00	13.0000
Exam and treatment queue	2.1930	0.38	0.2062	9.4408	0.00	22.0000
Nurse history queue	0.1136	0.01	0.01298461	0.4069	0.00	5.0000
Triage queue	0.5394	0.05	0.1145	1.7216	0.00	10.0000

Resource

Usage

Instantaneous Utilization	Average	Half-Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Discharge nurse 1	0.8285	0.01	0.6715	0.8972	0.00	1.0000
Discharge nurse 2	0.8360	0.01	0.6673	0.9105	0.00	1.0000
Exam room 1	0.8441	0.01	0.6253	0.9497	0.00	1.0000
Exam room 2	0.8329	0.01	0.6548	0.9297	0.00	1.0000
Exam room 3	0.8182	0.02	0.5358	0.9200	0.00	1.0000
Exam room 4	0.8075	0.02	0.6135	0.9156	0.00	1.0000
Financial clerk 1	0.4615	0.01	0.3320	0.5636	0.00	1.0000
Financial clerk 2	0.4580	0.01	0.3286	0.5823	0.00	1.0000
History nurse 1	0.5294	0.01	0.3886	0.6796	0.00	1.0000
History nurse 2	0.5240	0.01	0.3937	0.7107	0.00	1.0000
Triage nurse	0.6267	0.01	0.4861	0.8373	0.00	1.0000

Note: Created with Arena simulation software.

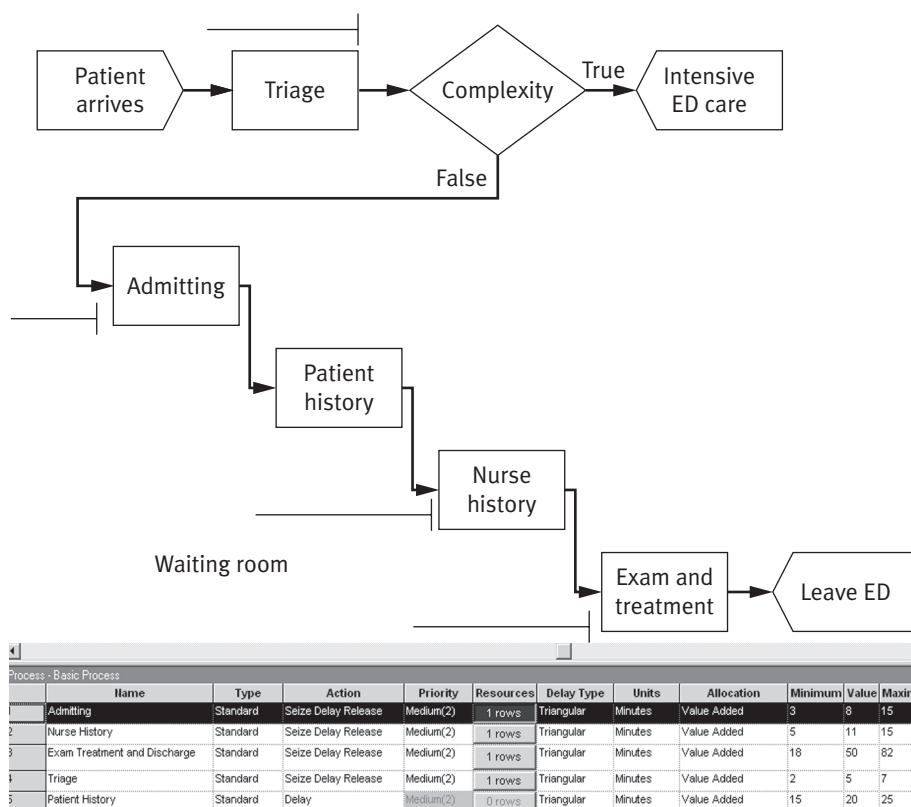
minutes. To ensure that this is the correct outcome, team members simulate the new system by eliminating discharge as a separate process.

Team members estimate the probability distribution of the combined exam/treatment/discharge task by first estimating the probability distribution for handoff as triangular (4, 5, 7 minutes). The team uses Input Analyzer to simulate 1,000 observations of exam/treatment time, discharge time, and handoff time using the previously determined probability distributions for each. For each observation, it adds exam/treatment time to discharge time and

subtracts handoff time to find total time. Input Analyzer finds the best-fitting probability distribution for the total time for the new process as triangular (18, 50, 82 minutes).

The team simulates the new process and finds that, under the new system, patients will spend an average of 2.95 hours in the ED—increasing the time spent there. However, it will eliminate the need for discharge rooms. The team decides to investigate the impact of converting the former discharge rooms to exam rooms and runs a new simulation incorporating this change (exhibit 11.14). The result of this simulation is shown in exhibit 11.15. Both the number of patients in the waiting room (examination and treatment queue) and the amount of time they wait are reduced substantially. The staffing levels are not changed, as the discharge nurses are now treatment nurses. Physician staffing also is not increased, as some delay inside the treatment process itself has always existed because of the need to wait for lab results, resulting in a delayed final physician diagnosis. Having more patients available for treatment fills this lab delay time for physicians to perform patient care.

EXHIBIT 11.14
VVH Emergency
Department
(ED) Proposed
Change
Simulation
Model



Note: Created with Arena simulation software.

EXHIBIT 11.15
VVH Emergency
Department
(ED) Proposed
Change
Simulation
Model Output

4:11:35 PM

February 8, 2022

Category Overview

Values Across All Replications

VVH Emergency

Replications: 100 Time Unit: Hours

Entity

Time

Total Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Routine patient	1.8376	0.05	1.5459	2.8729	1.0063	4.5989

Queue

Time

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Admitting queue	0.00519434	0.00	0.00041085	0.01364095	0.00	0.2235
Exam and treatment and discharge queue	0.2039	0.04	0.00197293	1.1105	0.00	2.2943
Nurse history queue	0.01791752	0.00	0.00244500	0.07537764	0.00	0.3417
Triage queue	0.06635691	0.01	0.01863876	0.2547	0.00	0.8065

Other

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Admitting queue	0.03400433	0.00	0.00218978	0.0946	0.00	3.0000
Exam and treatment and discharge queue	1.3571	0.31	0.00838496	7.8288	0.00	19.0000
Nurse history queue	0.1098	0.01	0.01120623	0.5716	0.00	4.0000
Triage queue	0.5629	0.08	0.1227	2.5046	0.00	11.0000

Resource

Usage

Instantaneous Utilization	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Exam room 1	0.7827	0.02	0.5405	0.9303	0.00	1.0000
Exam room 2	0.7644	0.02	0.5468	0.9103	0.00	1.0000
Exam room 3	0.7626	0.02	0.5577	0.9052	0.00	1.0000
Exam room 4	0.7478	0.02	0.4984	0.8993	0.00	1.0000
Exam room 5	0.7859	0.02	0.5420	0.9313	0.00	1.0000
Exam room 6	0.8030	0.02	0.4990	0.9472	0.00	1.0000
Financial clerk 1	0.4606	0.01	0.3250	0.5985	0.00	1.0000
Financial clerk 2	0.4529	0.01	0.2968	0.6119	0.00	1.0000
History nurse 1	0.5236	0.01	0.3642	0.6766	0.00	1.0000
History nurse 2	0.5154	0.01	0.3403	0.6982	0.00	1.0000
Triage nurse	0.6226	0.02	0.4742	0.8185	0.00	1.0000

Note: Created with Arena simulation software.

EXHIBIT 11.16
Summary of
VVH Emergency
Department
Throughput
Improvement
Project

Process Improvement Change	Throughput Time, Routine Patients
Baseline, before any improvement	165 minutes
Combine admitting functions	155 minutes
Patients enter their own history into computer	145 minutes
Combine discharge tasks into examination and treatment process, and convert discharge rooms to treatment rooms	110 minutes

The most significant improvement resulting from the process improvement initiative is that total patient throughput time now averages 1.84 hours (110 minutes). This 33 percent reduction in throughput time exceeds the team’s goal and is celebrated by VVH’s senior leadership. The summary of process improvement steps is displayed in exhibit 11.16.

Conclusion

The theory of swift, even flow provides a framework for process improvement and increased productivity. The efficiency and effectiveness of a process increase as the speed of flow through the process increases and the variability associated with that process decreases.

The movement of patients in a healthcare facility is one of the most critical and visible processes in healthcare delivery. Reducing flow time and variation in processes results in a number of benefits, including the following:

- Patient satisfaction increases.
- Quality of clinical care improves as patients have reduced waits for diagnosis and treatment.
- Financial performance improves.

This chapter demonstrates many approaches to the challenges of reducing flow time and process variation. Starting with the straightforward process map, many improvements can be found immediately by inspection. In other cases, the powerful tool of computer-based discrete event simulation can provide a road map to sophisticated process improvements.

Ensuring quality of care is another critical focus of healthcare organizations. The process improvement tools and approaches in this chapter may be

used to reduce process variation and eliminate errors. Healthcare organizations must employ the disciplined approach described in this chapter to achieve the needed improvements in flow and quality.

Discussion Questions

1. How do you determine which process improvement tools should be used in a given situation? What is the cost and return of each approach?
2. Which process improvement tool can have the most powerful impact, and why?
3. How can barriers to process improvement, such as staff reluctance to change, lack of capital, technological barriers, or clinical practice guidelines, be overcome?
4. How can the electronic health record or other digital technologies be used to make significant process improvements for both efficiency and quality increases?
5. Describe several places or times in your organization where people or objects (paperwork, tests, etc.) wait in line. How do the characteristics of each example differ?

Exercises

1. Access the National Guideline Clearinghouse (<https://www.ahrq.gov/gam/index.html>) and translate one of the guidelines described into a process map. Add decision points and alternative paths to account for unusual issues that might occur in the process. (Hint: Use Microsoft Visio or another similar application to complete this exercise.)
2. Access the following process maps on the companion website:
 - Operating Suite
 - Cancer Treatment ClinicUse basic improvement tools, theory of constraints, Six Sigma, or Lean tools to determine possible process improvements.
3. The hematology lab manager has received complaints that the turnaround time for blood tests is too long. Data from the past month show that the arrival rate of blood samples to one technician in the lab is five per hour and the service rate is six per hour. Using queuing theory, and assuming that (a) both rates are

On the web at
[ache.org/books/OpsManagement4](https://www.ache.org/books/OpsManagement4) 

exponentially distributed and (b) the lab is at steady state, determine the following measures:

- Capacity utilization of the lab
- Average number of blood samples in the lab
- Average time that a sample waits in the queue
- Average number of blood samples waiting for testing
- Average time that a blood sample spends in the lab

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SCHEDULING AND CAPACITY MANAGEMENT

**Operations Management
in Action**

What impact has the COVID-19 pandemic had on digital healthcare transformation? For scheduling and capacity management, the shift to digital in the healthcare system has had both immediate and long-term effects on the system's ability to deliver high-quality care. Physicians saw telehealth visits increase during the pandemic by more than 50-fold, which has completely changed how healthcare systems plan patient capacity.

In reaction to increased demand for virtual and telehealth medicine, healthcare systems are building online portals referred to as *digital front doors*. Such portals give patients a guided process for customizing their healthcare experience and choosing the right level of care for their clinical and financial needs. Because the virtual care environment vastly increases flexibility, patient satisfaction has risen tremendously. Same-day appointments and instant access to care through these portals have created a new normal for healthcare systems.

At the same time, the health system can align clinical need with payment to balance their capacity with demand. According to the *Harvard Business Review*, "Acceleration has been the

OVERVIEW

Matching the supply of goods or services to the demand for those goods or services is a basic operational problem. In a manufacturing environment, inventory can be used to respond to fluctuations in demand. In the healthcare environment, safety stock can be used to respond to fluctuations in demand for supplies (see chapter 13), but stocking healthcare services is not possible. Therefore, capacity must be matched to demand. If capacity is greater than demand, resources are underutilized and costs are high. Idle staff, equipment, or facilities increase organizational costs without increasing revenues. If capacity is lower than demand, patients endure long waits or find another provider.

To match capacity to demand, organizations can use demand-influencing strategies or capacity management strategies. Pricing and promotions are often deployed to influence demand and demand timing; however, this strategy typically is not viable for healthcare organizations. In the past, many clinics, hospitals, and health systems used the demand-leveling strategy of appointment scheduling; more recently, many have moved to advanced-access scheduling. Capacity management strategies allow the organization to adjust capacity to meet fluctuating demand; they include using part-time or on-call employees, cross-training staff, and assigning overtime. Effective and efficient scheduling of patients, staff, equipment, facilities, or jobs can help leaders match capacity to demand and ensure that scarce healthcare resources are used to their fullest extent.

This chapter outlines issues and problems faced in scheduling and discusses tools and techniques that can be employed in scheduling patients, staff, equipment, facilities, or jobs. Topics covered here related to scheduling tools and approaches include

- hospital census and resource loading,
- staff scheduling,
- job and operation scheduling and sequencing rules,

(continued)

pandemic's most notable impact on health systems' digital strategy. Prior to the pandemic, most health systems had initiatives to pursue telehealth, implement applications that support value-based care, increase integration across care settings, improve the patient experience through the implementation of a 'digital front door,' and reduce the cost of delivering care. The timeframe for accomplishing these initiatives will now be significantly compressed; what might have taken 10 years to accomplish will now take three years" (Glaser et al. 2020). For example, Gozio Health, a mobile platform provider of digital front doors, has seen a 700 percent increase in sales from 2019 to 2021 (Street-Insider.com 2021), indicating the expanding use of such portals.

One of the risks associated with digital front doors is physician burnout, not unlike that seen after electronic health

records were implemented. Careful implementation of patient portals to ensure doctors are onboard is critical to the success of telehealth systems. The technology has great potential to advance patient care while lessening financial and capacity burdens on healthcare systems (Zenoos 2020).

OVERVIEW (*continued*)

- patient appointment scheduling models, and
- advanced-access patient scheduling.

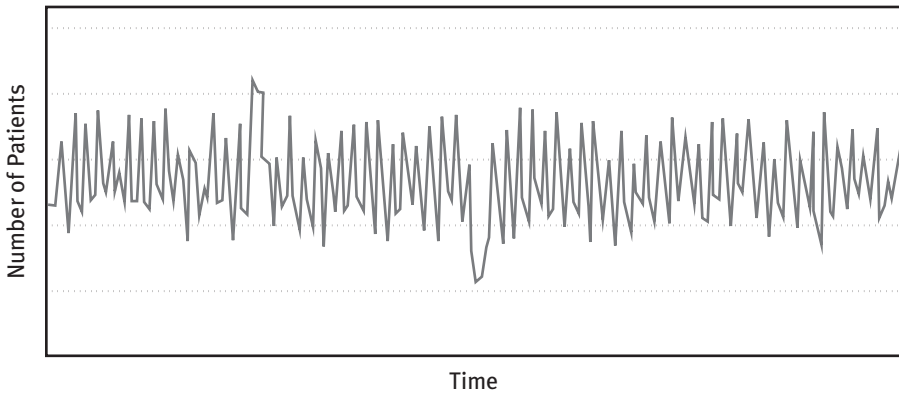
The scheduling of patients is a unique, but important, subproblem of patient flow. Since the mid-twentieth century, much patient care delivery has moved from the inpatient setting to the ambulatory clinic. Because this trend is likely to continue, matching clinic capacity to patient demand becomes an even more critical operating skill. Beyond operational considerations, if capacity management can be deployed to meet a patient's desired schedule, marketplace advantage can be gained. Therefore, this chapter focuses on advanced access (same-day scheduling) for ambulatory patients. Related topics covered in this chapter include

- advantages of advanced access,
- implementation steps, and
- metrics for tracking the operations of advanced-access scheduling systems.

Many of the operations tools and strategies detailed in earlier chapters are demonstrated here to show how to optimize the operations of an advanced-access clinic.

Hospital Census and Rough-Cut Capacity Planning

For many healthcare organizations, the admittance rate and number of occupied beds provide a good indication of the demands being placed on the system. For hospitals, these numbers often can be measured on the basis of the total patient census. Most hospitals report their census daily and hourly to manage the available beds in the system. However, what many healthcare organizations fail to understand is that the census also provides a view into the resources needed to appropriately staff a system. Exhibit 12.1 shows a three-month view of a census

EXHIBIT 12.1
Daily Census at
VVH

for Vincent Valley Hospital and Health System (VVH). The pattern is remarkably similar to most hospitals in that the patient population shows considerable daily variance. Observing the census hourly can further magnify this variance.

Rough-cut capacity planning is the process of converting the overall production plan into capacity needs for key resources. For a hospital, it means planning key resources for the demand schedule. Although the day-to-day demand in healthcare systems is highly variable, the aggregate month-to-month demand can be predicted more precisely. When planning resources, hospital leaders generally consider two types of labor resources: full-time staff and contractors. By examining the census, an administrator should be able to determine, on an aggregate basis, the number of contractors needed during high-volume months. This approach is an example of rough-cut capacity planning. But many healthcare systems leave this planning until the need for additional resources arises. Because they have not paid enough attention to the staffing levels required to meet aggregate demand, these systems are forced to spend unnecessarily.

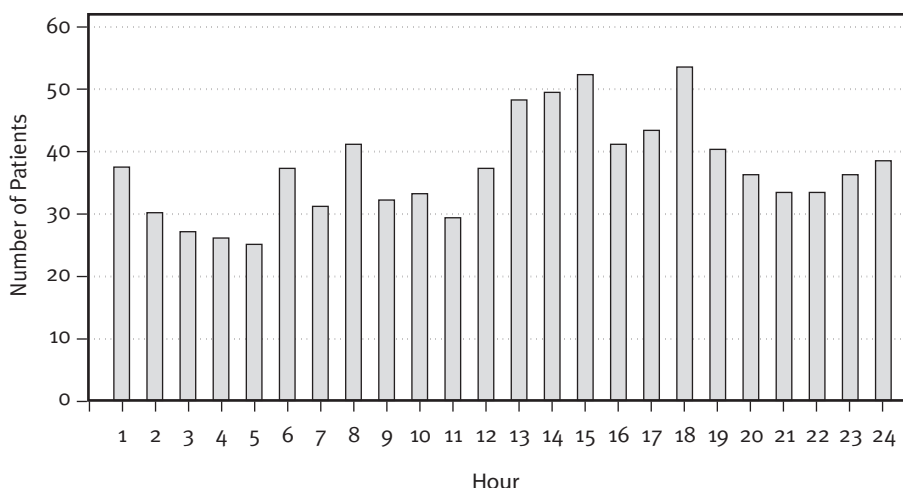
A hospital administrator may also use the daily census to assist in preparing workforce schedules on a weekly or daily basis. Exhibit 12.2 shows a spike in the system at VVH occurring from hour 13 to hour 19, which in most situations is the middle of the day. Many hospitals still schedule staff using standard morning, evening, and night shifts. Under that staffing model, VVH doctors and nurses are ending their shifts at the time of maximum demand on the system, resulting in increased potential for errors in handing off patients to new doctors, long patient wait times, and untimely completion of medical records.

A major cost savings can be gained for hospitals and clinics by simply matching the resources to the demand patterns in the system. In this case, staffing many doctors and nurses to overlap the peak times in the middle of the day is ideal.

rough-cut capacity planning

The process of converting the overall production plan into capacity needs for key resources.

EXHIBIT 12.2
Hourly Census
at VVH in One
Patient Care
Unit



From an operations perspective, this problematic issue is easy to fix. However, in practice, several obstacles may emerge, such as contractual terms agreed to by unions and conflicting physician block scheduling.

Staff Scheduling

For minor schedule-optimization problems, where demand is reasonably known and staffing requirements can be estimated with certainty, mathematical programming may be used to optimize staffing levels and schedules. As these problems increase in complexity, however, developing and applying a mathematical programming model becomes time and cost prohibitive. In those cases, simulation can be used to answer what-if scheduling questions, such as “What if we added a nurse?” or “What if we cross-trained employees?” See chapter 11 and the advanced-access section of this chapter for examples of these types of applications.

A simple example of this type of issue, and how to solve it using linear programming, is illustrated in the paragraphs that follow.

Solving Riverview Clinic Urgent Care Staffing

Nurses who staff Riverview Urgent Care Clinic (UCC), the after-hours urgent care facility of VVH’s Riverview Clinic, have been complaining about their schedules. They would like to work five consecutive days and have two consecutive days off every seven days. Different nurses prefer different days off and believe that their preferences should be accommodated on the basis of seniority, whereby the most senior nurses are granted their desired days off first.

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Nurses needed per day	5	4	3	3	3	3	6
Salary and benefits per nurse-day	\$320	\$240	\$240	\$240	\$240	\$240	\$320

EXHIBIT 12.3
Riverview UCC
Target Staffing
Level and Salary
Expense

Riverview UCC collects patient demand data by day of the week and knows how many nurses should be on staff each day to meet demand. Riverview UCC managers want to minimize nurse payroll while reducing the nurses' complaints about their schedules. They decide to apply **linear programming** to help determine a solution for this two-pronged problem. Target staffing levels and salary expense are shown in exhibit 12.3.

First, Riverview UCC needs to determine how many nurses should be assigned to each of the seven possible schedules (Monday and Tuesday off, Tuesday and Wednesday off, etc.).

The goal is to minimize weekly salary expense, and the objective function is set up as follows.

Minimize:

$$(\$320 \times Su) + (\$240 \times M) + (\$240 \times Tu) + (\$240 \times W) \\ + (\$240 \times Th) + (\$240 \times F) + (\$320 \times Sa),$$

where Su is the number of nurses required on staff for Sundays, M is nurses needed Mondays, Tu is nurses needed Tuesdays, W is nurses needed Wednesdays, Th is nurses needed Thursdays, F is nurses needed Fridays, and Sa is nurses needed Saturdays.

The constraints are the following:

- The number of nurses scheduled each day must be greater than or equal to the number of nurses needed each day.

$$Su \geq 5$$

$$M \geq 4$$

$$Tu \geq 3$$

$$W \geq 3$$

$$Th \geq 3$$

$$F \geq 4$$

$$Sa \geq 6$$

linear programming
A mathematical technique used to find the optimal solution to a linear problem given a set of constrained resources.

- The number of nurses assigned to each schedule, where the schedules are denoted by a letter of the alphabet from A to G, must be greater than zero and an integer.

Number of nurses for schedule A (B, C, D, E, F, or G) ≥ 0

Number of nurses for schedule A (B, C, D, E, F, or G) = integer

Exhibit 12.4 shows the Excel Solver setup of this problem.

As illustrated in exhibit 12.5, Solver finds that the Riverview UCC needs to employ six full-time equivalent nurses and should assign one nurse to schedules A, B, C, and D; two nurses to schedule E; and no nurses to schedules F and G. The total salary expense with this optimal schedule is calculated as follows.

Minimize:

$$(\$320 \times 5) + (\$240 \times 4) + (\$240 \times 4) + (\$240 \times 4) + (\$240 \times 3) + (\$240 \times 4) + (\$320 \times 6) = \$8,080 \text{ per week.}$$

Next, Riverview UCC needs to determine which nurses to assign to which schedule on the basis of their preferences and seniority. Each nurse is asked to rank schedules A through E in order of preference. The nurses' preferences on a scale of 1 to 5, with 5 being the most preferred schedule, are then weighted by a seniority factor. Riverview UCC uses as the weighting factor the number of years a particular nurse has worked at the facility compared with the number of years the most senior nurse has worked there.

The goal is to maximize the nurses' total weighted preference scores (WPSs), and the objective function is set up as follows.

EXHIBIT 12.4

Initial Excel Solver Setup of Riverview UCC Optimization

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1																				
2	Schedule	Days off	Employees		Sun	Mon	Tue	Wed	Thu	Fri	Sat		Sun	Mon	Tue	Wed	Thu	Fri	Sat	
3	A	Sun, Mon	0		0	0	1	1	1	1	1		0	0	0	0	0	0	0	
4	B	Mon, Tues	0		1	0	0	1	1	1	1		0	0	0	0	0	0	0	
5	C	Tues, Wed	0		1	1	0	0	1	1	1		0	0	0	0	0	0	0	
6	D	Wed, Thurs	0		1	1	1	0	0	1	1		0	0	0	0	0	0	0	
7	E	Thurs, Fri	0		1	1	1	1	0	0	1		0	0	0	0	0	0	0	
8	F	Fri, Sat	0		1	1	1	1	1	0	0		0	0	0	0	0	0	0	
9	G	Sat, Sun	0		0	1	1	1	1	1	0		0	0	0	0	0	0	0	
10																				Total
11																				0
12																				28
13																				
14																				
15																				
16																				
17																				
18																				
19																				
20																				
21																				
22																				
23																				
24																				
25																				
26																				
27																				
28																				
29																				
30																				
31																				
32																				

Nurses Scheduled/Day:	0	0	0	0	0	0	0	0	0	0	0	0
Nurses Needed/Day:	5	4	3	3	3	4	6	28				
Salary & Benefits/Nurse/Day:	320	240	240	240	240	240	320					
Total Salary & Benefits/Day:	0	0	0	0	0	0	0					
Salary & Benefits/Week:	\$0											

Solver Parameters	
Set Target Cell:	\$M\$17
Equal To:	Max ☐ Min ☒ Value of: 0
By Changing Variable Cells:	\$C\$3:\$C\$9
Subject to the Constraints:	\$C\$3:\$C\$9 = integer \$C\$3:\$C\$9 >= 0 \$M\$11 >= \$M\$12 \$O\$11 >= \$O\$12 \$P\$11 >= \$P\$12
	Solve Options Reset All Help

Maximize:

$$\text{Mary's WPS} + \text{Anne's WPS} + \text{Susan's WPS} + \text{Tom's WPS} + \text{Cathy's WPS} \\ + \text{Jane's WPS}$$

The constraints are the following:

- The assignment is binary, meaning that each nurse must be either assigned or not assigned to a particular schedule.
 - Mary assigned to schedule A (B, C, D, or E) = 0 or 1
 - Anne assigned to schedule A (B, C, D, or E) = 0 or 1
 - Susan assigned to schedule A (B, C, D, or E) = 0 or 1
 - Tom assigned to schedule A (B, C, D, or E) = 0 or 1
 - Cathy assigned to schedule A (B, C, D, or E) = 0 or 1
 - Jane assigned to schedule A (B, C, D, or E) = 0 or 1
- The number of nurses assigned to each schedule must adhere to the requirements established earlier.
 - Number of nurses assigned to schedule A (B, C, or D) = 1
 - Number of nurses assigned to schedule E = 2
- Each nurse can only be assigned to one schedule.
 - Mary (Anne, Susan, Tom, Cathy, or Jane) $A + B + C + D + E = 1$

Exhibit 12.5 shows the Excel setup of this problem.

As shown in exhibit 12.6, Solver finds that Mary should be assigned to schedule D (her second choice), Anne to schedule E (her first choice), Susan to schedule C (her first choice), Tom to schedule E (his first choice), Cathy to schedule B (her second choice), and Jane to schedule A (her first choice).

EXHIBIT 12.5
Riverview UCC
Initial Solver
Solution and
Schedule
Preference
Setup

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W												
1																																			
2	Schedule	Days off	Employees	Daily Schedule								Number of Employees/Day																							
3	A	Sun, Mon	1	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat																		
4	B	Mon, Tues	1	1	0	0	1	1	1	1	1	0	0	1	1	1	1																		
5	C	Tues, Wed	1	1	1	0	0	1	1	1	1	1	0	0	1	1	1																		
6	D	Wed, Thurs	1	1	1	1	0	0	1	1	1	1	1	0	0	1	1																		
7	E	Thurs, Fri	2	1	1	1	1	0	0	1	2	2	2	2	0	0	2																		
8	F	Fri, Sat	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0																		
9	G	Sat, Sun	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0																		
10																																			
11													Nurses Scheduled/Day:						Total																
12													Nurses Needed/Day:						30																
13																			28																
14													Salary&Benefits/Nurse-Day:																						
15													Total Salary & Benefits/Day:						320 240 240 240 240 320																
16																			1600 960 960 960 720 1920																
17													Salary & Benefits/Week:						\$8,080																
18																																			
19			Seniority		Seniority factor		Preference of employees					Weighted preference of employees					Schedule assigned to					Preference score													
20	Employee	(years)					A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	Total	score												
21	Mary	5	0.71	3	1	2	4	5	2.14	0.71	1.43	2.86	3.57	0	0	0	0	0	0	0	0	0	0.00												
22	Anne	6	0.86	3	2	1	4	5	2.57	1.71	0.86	3.43	4.29	0	0	0	0	0	0	0	0	0	0.00												
23	Susan	4	0.57	2	3	5	1	4	1.14	1.71	2.86	0.57	2.29	0	0	0	0	0	0	0	0	0	0.00												
24	Tom	7	1.00	3	2	4	1	5	3.00	2.00	4.00	1.00	5.00	0	0	0	0	0	0	0	0	0	0.00												
25	Cathy	3	0.43	3	4	5	2	1	1.29	1.71	2.14	0.86	0.43	0	0	0	0	0	0	0	0	0	0.00												
26	Jane	2	0.29	5	4	3	2	1	1.43	1.14	0.86	0.57	0.29	0	0	0	0	0	0	0	0	0	0.00												
27																																			
28	Maximum	7											Actual:		0	0	0	0	0	0	0														
29															Needed:		1	1	1	1	2														
30																																			

EXHIBIT 12.6
Riverview UCC
Final Solver
Solution for
Individual
Schedules

18	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
19				Preference of employees						Weighted preference of employees					Schedule assigned to								
20	Employee	Seniority (years)	Seniority factor	A	B	C	D	E		A	B	C	D	E		A	B	C	D	E	Total	Preference score	
21	Mary	5	0.71	3	1	2	4	5		2.14	0.71	1.43	2.86	3.57		0	0	0	1	0	1	2.86	
22	Anne	6	0.86	3	2	1	4	5		2.57	1.71	0.86	3.43	4.29		0	0	0	0	1	1	4.29	
23	Susan	4	0.57	2	3	5	1	4		1.14	1.71	2.86	0.57	2.29		0	0	1	0	0	1	2.86	
24	Tom	7	1.00	3	2	4	1	5		3.00	2.00	4.00	1.00	5.00		0	0	0	0	1	1	5.00	
25	Cathy	3	0.43	3	4	5	2	1		1.29	1.71	2.14	0.86	0.43		0	1	0	0	0	1	1.71	
26	Jane	2	0.29	5	4	3	2	1		1.43	1.14	0.86	0.57	0.29		1	0	0	0	0	1	1.43	
27																							
28	Maximum	7																					
29																							
30																							
31																							
32																							
33																							
34																							
35																							
36																							
37																							
38																							
39																							
40																							

Solver Parameters

Set Target Cell:

Equal To: ☒ Max ☐ Min ☐ Value of:

By Changing Variable Cells:

Subject to the Constraints:

\$Q\$28 = \$Q\$29

\$R\$28 = \$R\$29

\$S\$28 = \$S\$29

\$T\$28 = \$T\$29

\$U\$28 = \$U\$29

\$V\$21:\$V\$26 = 1

Add

Change

Delete

Solve

Options

Reset All

Help

Actual: 1 1 1 1 2
Needed: 1 1 1 1 2

18 14,285,591

All of the nurses now have two consecutive days off every seven days and are assigned to either their first or their second choice of schedule. Note that even this simple problem has 20 decision variables and 41 constraints.

Job and Operation Scheduling and Sequencing Rules

Master production scheduling (MPS) is a technique used in most production-oriented environments that has direct application to the healthcare operations space. The concept behind MPS is to forecast needs for the future and build a schedule to fit those needs.

When building a master production schedule, time fences are set up to help avoid disruptions in the schedule. Typically, time fences depicted as “frozen,” “slushy,” or “liquid” are established to give the scheduling department information as to when a schedule can be adjusted. For example, a surgery center may aim for a frozen schedule for surgeries scheduled during the following week; a slushy schedule, where up to 20 percent may be adjusted, for surgeries scheduled two to three weeks in advance; and a liquid, or open, schedule for surgeries scheduled one month or more into the future. By freezing a schedule for a set period, the surgery center is able to avoid unnecessary interruptions. Interruptions in scheduling eventually lead to fewer surgeries for a variety of reasons, including the variance in time related to surgeries, extra setup time of surgery rooms, and general impact of changing surgeries at the last minute. To handle urgent surgeries when using MPS, a hospital should keep some capacity available for these situations. The net effect of this approach is increased output from the surgery because the variability associated with urgent surgeries does not affect the MPS.

Job and operation scheduling views the problem of how to sequence a pool of jobs (or patients) through a particular operational activity. For example, a

clinic laboratory constantly receives patient blood samples that need to be tested, and it must determine in what order it should conduct those tests. Similarly, a hospital typically has many patients waiting for their surgery to be performed, and it needs to decide the order in which those surgeries should occur.

The simplest sequencing problems consist of a pool of jobs waiting for only one resource to become available. Sequencing of those jobs is usually based on a desire to meet due dates (time at which the job is expected to be complete) by minimizing the number of jobs that are late, minimizing the average amount of time by which jobs are late, or minimizing the maximum late time of any job. Also desirable is to minimize the time jobs spend in the system or average completion time.

Various **sequencing rules**, also known as the queuing priority, may be used to schedule jobs through the system. Commonly used rules include the following:

- *First come, first served (FCFS)*—Jobs are sequenced in the same order in which they arrive.
- *Shortest processing time (SPT)*—The job that takes the least amount of time to complete is first, followed by the job that takes the next least amount time, and so on.
- *Earliest due date (EDD)*—The job with the earliest due date is first, followed by the job with the next earliest due date, and so on.
- *Slack time remaining*—The job with the least amount of slack (time until due date or processing time) is first, followed by the job with the next least amount of slack time, and so on.
- *Critical ratio*—The job with the smallest critical ratio (time until due date or processing time) is first, followed by the job with the next smallest critical ratio, and so on.

sequencing rules
Heuristic rules that indicate the order in which jobs are processed from a queue. Also known as *queuing priority*.

When only one resource or operation is available through which the jobs may be processed, the SPT rule minimizes average completion time, and the EDD rule minimizes average lateness and maximum lateness. However, no single rule accomplishes both objectives. When jobs (or patients) must be processed via a series of resources or operations, with different possible sequencing at each, the situation becomes complex and applying a particular rule does not result in the same outcome for the entire system as for the single resource. Simulation may be used to evaluate these complex systems and helps determine optimum sequencing.

For a busy resource, the SPT rule is often applied. It allows completion of a greater number of jobs in a shorter amount of time than do the other rules, but it may result in some jobs with long completion times never being finished. To alleviate this problem, the SPT rule may be used in combination

with other rules. For example, in some emergency departments (EDs), less severe cases (those with a shorter processing time) are separated from more severe cases and fast-tracked to free up examination rooms quickly.

For time-sensitive operational activities, in which lateness is not tolerated, the EDD rule is appropriate. Because it is the easiest to apply, the FCFS rule is typically used when the resource has excess capacity and no jobs will be late. In a Lean environment, sequencing rules become irrelevant because the ideal size of the pool of jobs is reduced to one and a kanban system (a form of FCFS) can be used to pull jobs through the system (chapter 10).

Vincent Valley Hospital and Health System Laboratory Sequencing Rules

A technician recently has left the laboratory at VVH, and the lab manager, Jessica Simmons, does not believe she can find a qualified replacement for at least one month. This situation has greatly increased the workload in the lab, and physicians have been complaining that their requested blood work is not being completed in a timely manner.

In the past, Jessica has divided the blood testing among the technicians and requested they complete the tests on an FCFS basis. She is now considering a different sequencing rule to satisfy the physicians. In anticipation of this change, she has asked each physician to enter a desired completion time on each request for blood testing. To investigate the effects of changing the sequencing rules, she analyzes, under various scheduling rules, the first five requests completed by one of the technicians. For five jobs, 120 sequences are possible for their completion. Exhibit 12.7 shows the time to complete each blood work sample and the time of completion requested by the physician.

Exhibit 12.8 indicates the order in which jobs will be processed and results under different sequencing rules, and exhibit 12.9 compares different sequencing rules. The FCFS rule performs poorly on all measures. The SPT rule minimizes average completion time, and the EDD rule minimizes average

EXHIBIT 12.7
VVH Laboratory
Blood Test
Information

Sample	Processing Time (minutes)	Due Time (minutes from now)	Slack	CR
A	50	100	$100 - 50 = 50$	$100 \div 50 = 2.00$
B	100	160	$160 - 100 = 60$	$160 \div 100 = 1.60$
C	20	50	$50 - 20 = 30$	$50 \div 20 = 2.50$
D	80	120	$120 - 80 = 40$	$120 \div 180 = 1.50$
E	60	80	$80 - 60 = 20$	$80 \div 60 = 1.33$

Note: CR = critical ratio.

EXHIBIT 12.8
VVH Laboratory
Blood Test
Sequencing
Rules

Sequence	Start Time	Processing Time	Completion Time	Due Time	Tardiness
FCFS					
A	0	50	50	100	
B	50	100	150	160	
C	150	20	170	50	$170 - 50 = 120$
D	170	80	250	120	$250 - 120 = 130$
E	250	60	310	80	$310 - 80 = 230$
		Average	186		$(120 + 130 + 230) \div 3$ $= 96$
SPT					
C	0	20	20	50	
A	20	50	70	100	
E	70	60	130	80	$130 - 80 = 50$
D	130	80	210	120	$210 - 120 = 90$
B	210	100	310	160	$310 - 160 = 150$
		Average	148		$(50 + 90 + 150) \div 3$ $= 58$
EDD					
C	0	20	20	50	
E	20	60	80	80	
A	80	50	130	100	$130 - 100 = 30$
D	130	80	210	120	$210 - 120 = 90$
B	210	100	310	160	$310 - 160 = 150$
		Average	150		$(30 + 90 + 150) \div 3$ $= 54$
STR					
E	0	60	60	80	
C	60	20	80	50	$80 - 50 = 30$
D	80	80	160	120	$160 - 120 = 40$
A	160	50	210	100	$210 - 100 = 110$
B	210	100	310	160	$310 - 160 = 150$
		Average	164		$(30 + 40 + 110 + 150) \div 4$ $= 66$
CR					
E	0	60	60	80	
D	60	80	140	120	$140 - 120 = 20$
B	140	100	240	160	$240 - 160 = 80$
A	240	50	290	100	$290 - 100 = 190$
C	290	20	310	50	$310 - 50 = 260$
		Average	208		$(20 + 80 + 190 + 260) \div 4$ $= 110$

Note: All times shown in exhibit are in minutes. CR = critical ratio; EDD = earliest due date; FCFS = first come, first served; SPT = shortest processing time; STR = slack time remaining.

EXHIBIT 12.9
Comparison of
VVH Blood Test
Sequencing
Rules

Sequencing Rule	Average Completion Time	Average Tardiness	Number of Tardy Jobs	Maximum Tardiness
FCFS	186	96	3*	230
SPT	148*	58	3*	150*
EDD	150	54*	3*	150*
STR	164	66	4	150*
CR	208	110	4	260

*Best values.

Note: All times shown in exhibit are in minutes. CR = critical ratio; EDD = earliest due date; FCFS = first come, first served; SPT = shortest processing time; STR = slack time remaining.

tardiness. Under these two rules, three jobs are tardy and the maximum tardiness is 150 minutes. After considering these results, Jessica implements the EDD rule for laboratory blood tests to minimize the number of tardy jobs and the average tardiness of jobs. She hopes adopting this rule reduces physician complaints until a new technician can be hired.

Patient Appointment Scheduling Models

Appointment scheduling models attempt to minimize patient waiting time while maximizing utilization of the resource (clinician, machine, etc.) the patients are waiting to access. Soriano (1966) classifies appointment scheduling systems into four basic types: block appointment, individual appointment, mixed block-individual appointment, and other.

A block appointment scheme schedules the arrival of all patients at the start of a clinic session. Patients are usually seen FCFS, but other sequencing rules can be used in block appointment scheduling. This type of scheduling system maximizes utilization of the clinician, but patients may experience long wait times.

An individual appointment scheme assigns different, equally spaced appointment times to each patient. In a common modification of this type of system, different appointment lengths are available and assigned on the basis of the type of patient. This system reduces patient waiting time but decreases utilization of the clinician; in other words, increasing the interval between arrivals results in a reduction of both waiting time and utilization.

A mixed block-individual appointment scheme schedules a group of patients to arrive at the start of the clinic session, followed by equally spaced

appointment times for the remainder of the session. This type of system can be used to balance the competing goals of increased utilization and decreased waiting time.

Finally, other appointment schemes are modifications of the first three types.

Simulation has been used to study the performance of different appointment scheduling models and rules. Although no scheduling rule or scheme has been found to be universally superior, the Bailey-Welch rule (Bailey and Welch 1952) performs well under most conditions. This rule schedules two patients at the beginning of a clinic session, followed by equally spaced appointment times for the remainder of the session.

Chow and colleagues (2011) demonstrate how to reduce the number of surgery cancellations by using an advanced computer simulation model to improve the allocation of open surgical slots in the appointment system. Using Monte Carlo simulation techniques, they increased surgical volume by more than 5 percent and reduced the number of overcapacity bed days by more than 9 percent.

Kaandorp and Koole (2007a, 2007b) developed a mathematic model, called the Optimal Outpatient Scheduling tool, to determine an optimal schedule using a weighted average of expected waiting times of patients, idle time of the clinician, and tardiness (the probability that the clinician has to work later than scheduled multiplied by the average amount of added time). This tool uses simulation to compare the optimal schedule found using the model to a user-defined schedule.

Riverview Clinic Appointment Schedule

Physicians at VVH's Riverview Clinic typically see patients for six consecutive hours each day. Each appointment takes an average of 20 minutes; therefore, each clinician is scheduled to see 18 patients per day. The patient no-show rate is 2 percent. Currently, Riverview uses an individual appointment scheme with appointments scheduled every 20 minutes. However, clinicians have been complaining that they often have to work late but are idle at various points during the day. Riverview decides to use the Optimal Outpatient Scheduling tool (Kaandorp and Koole 2007b) to determine if another scheduling model can alleviate these complaints without increasing patient waiting time to an unacceptable level.

Exhibit 12.10 shows the results of this analysis when waiting time weight is 1.5, idle time weight is 0.2, and tardiness weight is 1.0. The optimal schedule follows the Bailey-Welch rule. Under this rule, patient waiting is increased by five minutes, but both idleness and tardiness are decreased. Riverview Clinic leaders do not believe that the additional waiting time is unacceptable and decide to implement this new appointment scheduling scheme.

EXHIBIT 12.10

Riverview Clinic

Appointment Scheduling

Optimal outpatient appointment scheduling tool			
Average service time	20	minutes	
Number of intervals	18		
Length of interval	20	minutes	
Total number of arrivals	18		
Percentage no-shows	2	%	
alpha waiting	1.5		
alpha idle time	0.2		
alpha tardiness	1		
			Press the button to compute the solutions
			Finished searching
☒ ☐ Small Neighborhood <i>(Suboptimal, calc time: several minutes)</i> ☐ Full Neighborhood <i>(Optimal, calc time: several hours)</i>			
Interval	Time	☒ Number of patients of your choice <i>(calc time: several seconds)</i>	
1	0:00	1	2
2	0:20	1	1
3	0:40	1	1
4	1:00	1	1
5	1:20	1	1
6	1:40	1	1
7	2:00	1	1
8	2:20	1	1
9	2:40	1	1
10	3:00	1	1
11	3:20	1	1
12	3:40	1	1
13	4:00	1	1
14	4:20	1	1
15	4:40	1	1
16	5:00	1	1
17	5:20	1	1
18	5:40	1	0
Waiting time		31 minutes	35.85 minutes
Idle time		57.53 minutes	40.53 minutes
Tardiness		52.47	40.96
Fraction of excess		79.82 %	53.75 %
Makespan		410.33 minutes	393.33 minutes
Lateness		50.33 minutes	33.33 minutes
Object Value		110.47	102.84

Source: Kaandorp and Koole (2007b). Copyright © 2007 Guido Kaandorp and Ger Koole.

Advanced-Access Patient Scheduling

Advanced Access for an Operating and Market Advantage

In the early 1990s, Mark Murray, MD, and Catherine Tantau, RN, were among the early adopters of **advanced-access scheduling** (or *open-access scheduling*) at Kaiser Permanente in Northern California. Advanced access scheduling helps to eliminate long patient waits for appointments and bottlenecks in clinic operations.

The increased capability of technology has allowed clinics and hospitals to revolutionize the use of advanced-access scheduling. During the pandemic, many healthcare systems built user interface apps that allowed patients to schedule their vaccinations: Available appointments were slotted in the system, and users chose their desired times. This gave patients some ability to control their healthcare experience while allowing the system to maximize capacity usage, because all available slots were accessible to the patients. The end result was increased access to care and more efficient use of capacity.

Because most clinics today use traditional scheduling systems, long wait times are prevalent and appointments may only be available weeks, or even months, into the future. The further in advance that visits are scheduled, the greater the fail (no-show) rate becomes. To compensate, providers double-book or even triple-book appointment slots. Long delays and queues occur when all the patients scheduled actually appear for the same appointment slot. This problem is compounded by patients who have urgent needs requiring that they be seen immediately. These patients are either worked into the schedule or sent to an ED, decreasing both continuity of care for the patient and revenue to the clinic. At the ED, patients are frequently told to see their primary care physician (PCP) in one to three days, further complicating the scheduling problem at the physician office.

Advanced access is implemented by beginning each day with a large portion of each provider's schedule open for urgent, routine, and follow-up appointments. Patients are seen when they want to be seen. This scheme dramatically reduces the fail rate, as patients do not have to remember clinic visits they booked long ago. Because no double or triple booking occurs, patients are seen on time and schedules run smoothly. Clinics using advanced access can provide patients with the convenience of walk-in or urgent care, with the added advantage of maintaining continuity of care with their own doctors and clinics.

Implementing Advanced Access

Changing from a long-standing—albeit flawed—scheduling system to advanced access is challenging. However, an organization can increase its probability of success by following a few well-prescribed steps. In a study of large urban public

advanced-access scheduling

A method of scheduling outpatient appointments that provides open time slots every day for seeing patients on the same day they request an appointment. Also known as *open-access scheduling*.

hospitals, Singer (2001) developed the following methodology to implement advanced access.

Obtain Buy-In

Leadership is key to making this major change. The advanced-access system must be supported by senior leaders as well as providers. Touring other clinics that have implemented advanced access may help these groups understand how this system can work successfully.

For large systems, starting small in one or two clinical settings is best. Once initial operating problems are resolved and clinic staff are expressing positive feelings about the change, advanced access can be carefully implemented in additional clinics in the system.

Predict Demand

The first quantitative step in implementation is to measure and predict patient demand. For each day during a study period, demand is calculated as the number of patients requesting appointments (today or in the future), walk-in patients, patients referred from urgent care clinics or EDs, and calls deflected to other providers. After initial demand calculations are performed, additional factors may be included, such as day of the week, seasonality, demand for same-day versus scheduled appointments, and even clinical characteristics of patients.

Predict Capacity

The capacity of the clinic needs to be determined once demand is calculated. In general, capacity is the sum of appointment slots available each day. Capacity can vary dramatically from day to day, as providers usually have obligations for their time in addition to seeing patients in the clinic. Determining whether a clinic's capacity can meet expected demand is relatively easy using Little's law (described in detail in chapter 11).

That said, true capacity may not be readily apparent. Singer (2001) reports that, prior to close examination, leaders at many public hospital clinics felt that demand exceeded capacity in their operations. However, several of these clinics were able to find hidden capacity in their systems by using providers effectively (e.g., by minimizing their paperwork) and converting storage space to examination areas.

Another opportunity to improve the capacity of a clinic is to standardize and minimize the length of visit times. A clinic with high variability in appointment times may find that it has many small blocks of unused time.

Assess Operations

The implementation of advanced access provides the opportunity to review and improve the core patient flow and operations in a clinic. The tools and techniques of process mapping and process improvement, particularly value stream

mapping and the theory of constraints, should be applied before advanced access is implemented.

Work Down the Backlog

Working down the backlog is one of the most challenging tasks in implementing advanced access, as providers are required to see more patients per day than usual until they have caught up to same-day access. For example, each provider may need to work one extra hour per day and see three additional patients until the backlog is eliminated.

The number of days needed to work down a backlog can be determined using this equation:

$$\text{Days to work down backlog} = \text{Current backlog} \div \text{Increase in capacity},$$

where current backlog equals the number of appointments on the books divided by the average number of patients seen per day, and increase in capacity is the new service rate (patients per day) divided by the old service rate minus 1.

Go Live

Once a clinic has completed these steps, it is almost ready to go live with its advanced-access scheduling system. However, it must first determine how many appointment slots to reserve for same-day access. Singer and Regenstein (2003) report that public hospital clinics leave 40 percent to 60 percent of their slots available for same-day access, whereas other types of clinics leave up to 75 percent of slots available.

Educating patients in anticipation of the shift to advanced access is important, as many will be surprised by the ability to see a provider the day they request an appointment. Many elderly patients may actually decline this option, as they may need more time to prepare for the appointment or arrange transportation to it.

No clinic operates in a completely stable environment, so prospectively developing contingency plans is useful. Contingencies can range from the unexpected, such as a provider being ill or called away on an emergency, to the predictable, such as increases in demand, as for routine physicals in the weeks preceding the start of school. Good contingency planning ensures the smooth and efficient operation of an advanced-access system.

Metrics for Evaluating Advanced Access

Gupta and colleagues (2006) developed the following set of key indicators that can be used to evaluate the performance of advanced-access scheduling systems:

- *PCP match*—percentage of same-day patients who see their own PCP
- *PCP coverage*—percentage of same-day patients seen by any physician

- *Wait time for next appointment* (or third next available appointment)—for example, if you are calling on Monday and an appointment is available on Tuesday, Thursday, and Friday, the wait time for the third next available appointment is five days (Friday)
- *Good backlog*—appointments scheduled in advance because of patient preference
- *Bad backlog*—appointments waiting because of lack of slots

Most well-functioning advanced-access systems have high PCP match and PCP coverage. Depending on patient mix and preferences, the good backlog may be relatively large and still not be problematic, but a large or growing bad backlog can signal that capacity or operating systems in the clinic need to be improved.

Fears About Advanced Access and Their Resolution

Pointing out the realities of same-day scheduling can help reduce physicians' fears about change and help them make an effective adjustment to the new system. Gregg Broffman, MD, medical director of the 110-physician Lifetime Health Medical Group in Rochester and Buffalo, New York, whose group adopted same-day scheduling in the late 1990s, reported the following three common fears that physicians experience but that actually are unjustified (Olsen 2007):

- *Insatiable demand.* Physicians worry that opening their schedule will leave them swamped with work, but this is a false expectation. By carefully measuring and predicting supply and demand, advanced access ensures adequate coverage and can help determine the need to hire new clinicians to handle the workload.
- *Fewer encounters.* Use of same-day scheduling has been shown to decrease the number of annual encounters with individual patients. At the same time, it boosts the likelihood that patients will see their personal physician, rather than be worked in with the first available clinician. As a result, patients are more satisfied with their visits than they would be without advanced access. Furthermore, clinical outcomes improve while costs decrease, because a person's regular practitioner is less likely to order unnecessary tests or prescribe medication than is a clinician who is unfamiliar with the patient's history.
- *Lower revenue.* Decreased volume might suggest a dip in practice revenue, but the opposite has proven true. Clinicians who initially saw a 10 percent to 15 percent drop in encounters experienced about an 8 percent increase in relative value units, which are used to measure the robustness (or "dollar value") of an office visit. For example, when an

individual with diabetes makes an unplanned visit, physicians can look ahead to her next scheduled appointment and “max pack” the initial visit by performing the future checkup that day. The visit can be coded at the higher level allowed by a more complicated encounter, and the max packing leaves an appointment open in two weeks to see a new patient.

Conclusion

Advanced-access scheduling is an efficient and patient-friendly method of scheduling the delivery of ambulatory care. However, implementing and maintaining this and other capacity management techniques are difficult unless leadership and staff are committed to their success.

Discussion Questions

1. What job sequencing rule do you see most often in healthcare? Why? Can you think of any additional job sequencing rules not described in this text?
2. How could advanced-access techniques be used for the following types of facilities?
 - a. An ambulatory surgery center
 - b. A freestanding imaging center
3. What are the consequences of using advanced access in a multispecialty clinic? How might these tools be applied to provide same-day scheduling?
4. Can advanced-access techniques be used with appointment scheduling schemes? Why or why not?

Exercises

1. Two of the nurses (Mary and Tom) at Riverview UCC have decided to work part time rather than their previous full-time schedule. Each prefers to work only two (consecutive) days per week. Once they become part-time employees, salary and benefits per nurse-day for these nurses will be reduced to \$160 on weekdays and \$220 on weekend days. Considering this savings, Riverview UCC can hire an additional full-time nurse if needed. Should Riverview UCC agree to the two

nurses' request? If the clinic agrees, will additional nurses need to be hired? Assuming that part-time nurses and any new hires accept any schedule offered by Riverview UCC and that preferences for the remainder of the nurses are the same as stated in the chapter, what new schedule would you recommend for each nurse?

2. The VVH radiology department currently uses FCFS to determine how to sequence patient X-rays. On a typical day, the department collects patient X-ray data, and these data are available on the book's



On the web at

ache.org/books/OpsManagement4

companion website. Use the data to compare various sequencing rules. Assuming these data are representative, what rule should the radiology department adopt for sequencing, and why?

3. Use the Optimal Outpatient Scheduling tool (Kaandorp and Koole 2007b), provided on the companion website, to compare two appointment scheduling schemes—individual appointments and optimal scheduling—under the following assumptions. For the individual scheduling scheme, assume an 8-hour day that can be divided into 10-minute time blocks (48 time intervals), a 15-minute service time for patients, 24 patients seen according to the individual appointment scheme (a patient is scheduled to be seen every 20 minutes), and 5 percent no-shows. For the small neighborhood optimal schedule, assume a waiting time weight of 1, an idle time weight of 1, and a tardiness weight of 1. What are the differences in the two schedules? Which would you choose? Why? Now, increase the waiting time weight to 3 and recompute the small neighborhood optimal schedule. How is this optimal schedule different from the previous one? Finally, change the service time to 20 minutes and compare the individual appointment



On the web at

ache.org/books/OpsManagement4

schedule scheme to the small neighborhood optimal schedule with waiting time weights of 1 and 3. Which schedule would you choose, and why?

4. A clinic wants to work down its backlog to implement advanced access. The clinic currently has 1,200 booked appointments and sees 100 patients a day. The physician staff have agreed to extend their schedules and can now see 110 patients per day. What is their current backlog, and how many days will it take to reduce it to zero?

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SUPPLY CHAIN MANAGEMENT

Operations Management in Action

Trinity Health, a multisite healthcare system based in Livonia, Michigan, reports that recently adopted aggressive supply chain management techniques will save the organization \$20 million in costs. This cost decrease is being achieved largely through a relentless reduction of redundant inventory across the system and consolidation of many of its practices into efficiently streamlined services.

The central focus of the efforts at Trinity was to reduce the inventory in the supply chain. Previously, fulfilling the supply preferences of physicians and nurses led to increased SKUs [stock keeping units] (representing individual products) and total dollars of inventory in the system. “As we’re bringing more organizations together, we naturally want to take advantage of economies of scale,” says Lou Fierens, senior vice president overseeing supply chain at Trinity. “We had to rigorously reduce the amount of SKUs that we use inside the hospital” and centralize procurement of the medical goods, he says. This centralization gives the system better insights into inventory usage patterns across the entire system and the ability to adjust purchasing practices to take advantage of economies of scale and improve availability of inventory throughout the system.

The healthcare system is able to increase cash flow and reduce costs by

OVERVIEW

In the current world of healthcare and healthcare reform, the supply chain is rarely discussed as a source of improvement and cost savings. However, health spending related to the supply chain represents a substantial opportunity to save capital. A groundbreaking study indicates that an effective supply chain for tangible goods in hospitals and health systems can bring potential savings of 2 percent to 8 percent of overall operating costs (McKone-Sweet, Hamilton, and Willis 2005). Johnson and Teplitz (2009) demonstrated that procurement costs can be reduced by more than 10 percent and quantity of items purchased by more than 20 percent. With many hospital budgets exceeding \$500 million, these savings represent an enormous impact on an organization’s bottom line.

As a result, efficient and effective supply chain management (SCM) is increasingly important in healthcare. This chapter introduces the concept of SCM and the various tools, techniques, and theories that can enable supply chain optimization. The major topics covered include the following:

- SCM basics
- Tools for tracking and managing inventory
- Forecasting
- Inventory models
- Inventory systems
- Procurement and vendor relationship management
- Strategic SCM

After completing this chapter, readers should have a basic understanding of SCM. This knowledge will help them determine how to apply SCM in their organizations and enable them to employ SCM-related tools, techniques, and theories to optimize supply chains.

increasing the inventory turnover in the system. The increase in inventory turnover reduces the amount of time between paying for inventory and receiving revenue from that inventory. These supply chain practices make a tremendous impact on the profitability of the healthcare systems.

Source: Adapted and excerpted from Chao (2016).

Supply Chain Management

supply chain management

The management of all supplier, vendor, and distribution activities related to the production of value to end consumers.

The supply chain includes all of the processes involved in moving supplies and equipment from the manufacturer to patient care areas. **Supply chain management** is the handling and oversight of all activities and processes related to both upstream vendors and downstream customers in the value chain. Because SCM requires the effective management of relationships outside as well as inside an organization, this discipline constitutes a broad field of thought.

SCM aims to reduce costs and increase efficiencies associated with the supply chain. This effort carries substantial implications: Duffy (2009) indicates that the average hospital can assume its expenditure on supplies, and on labor to manage supplies, is approximately 25 percent of its total operating budget.

Effective SCM is enabled by new technologies and “old” methodologies for reducing supply-associated costs and effort and improving the efficiency of supply processes. Many techniques used to improve supply chain performance in other industries are applicable to healthcare. They may include technology-enabled solutions, such as electronic procurement, radio-frequency identification (RFID), bar coding, point-of-use data entry and retrieval, and data warehousing and management. Healthcare organizations increasingly find that they, too, can reduce costs and increase safety by using these technologies.

A systems view of the supply chain can lead to an enhanced understanding of processes and how best to improve and optimize them. SCM is focused on managing relationships with vendors and customers to render the entire chain (rather than just pieces of it) as efficient as possible, which benefits all members of the chain. For SCM to be effective, reliable and accurate data are required to determine where the greatest improvements and gains can be made by improving the supply chain.

Tracking and Managing Inventory

Inventory is the stock of items held by the organization either for sale or to support the delivery of a service. In healthcare organizations, inventory typically includes supplies and pharmaceuticals. This stock allows organizations

to cope with variations in supply and demand while making cost-effective ordering decisions.

Inventory management helps determine how much inventory to hold, when to order, and how much to order. Effective and efficient inventory management requires a classification system; an inventory tracking system; a reliable forecast of demand; knowledge of lead times; and reasonable estimates of holding, ordering, and shortage costs.

Inventory Classification Systems

Not all inventory is equal: Some items may be critical for the organization's operations, some may be costly or relatively inexpensive, and some may be used in large volumes while others are seldom needed. A classification system can enable organizations to manage inventory effectively by allowing them to focus on the most important inventory items and place less emphasis on those items of low importance.

The ABC classification system divides inventory items into three categories on the basis of the Pareto principle. Vilfredo Pareto studied the distribution of wealth in nineteenth-century Milan and found that 80 percent of the wealth was controlled by 20 percent of the people (Femia and Marshall 2012). This same idea of the vital few and the trivial many is found in quality management (chapter 9) and sales (80 percent of sales come from 20 percent of customers).

In ABC classification, the A items have a high-dollar volume (70%–80%) but account for a minority of items (5%–20%), B items have moderate dollar (30%) and item (15%) volume, and C items are low-dollar (5%–15%) and high-item (50%–65%) volume. The classification of items is not related to their unit cost; an A item may have high-dollar volume because of high usage and low cost or because of high cost and low usage. Items vital to the organization should be assigned to the A category even if their dollar volume is low to moderate.

The A items are the most important and, therefore, the most closely managed. The B and C items are less important and less closely managed. In a hospital setting, pacemakers are an example of A items and facial tissue might be a C item. The A items are likely ordered more often than B and C items, and their inventory accuracy is checked more often. These items are good candidates for bar coding and point-of-use systems. The C items do not need to be as closely managed, and often, a two-bin system (discussed later in this chapter) is used for their management and control.

Inventory Tracking Systems

An effective inventory management system requires a means of determining how much of a particular item is available. In the past, inventory records were updated manually and typically were not very accurate. Bar coding and point-of-use systems have eliminated much of the data input inaccuracy, but inventory

records are still imperfect. A physical count must usually be performed to ensure that the actual and recorded amounts are the same.

Although many organizations perform periodic (e.g., once a month) inventory counts, cycle counting is a more helpful technique in ensuring accuracy and eliminating errors. Highly accurate inventory records not only enable efficient inventory management but also help eliminate the hoarding that occurs when providers are concerned an item will be unavailable when needed. In a typical cycle counting system, a physical inventory is performed on a rotating schedule on the basis of item classification. The A items might be counted every day, whereas C items are counted once a month.

Electronic medication orders and matching allow an organization to track demand and improve patient safety—the patient and order are matched at the time of administration. Rules can be set up in the system to alert providers to adverse drug interactions and thus eliminate errors. Systems are being developed that bring complete, current patient records to the bedside; the ready availability of patient and drug history can improve the quality and safety of the care delivered.

Radio-Frequency Identification

RFID is a tool for identifying objects, collecting data about them, and storing those data in a computer system with little human involvement. RFID tags are similar to bar codes, but they emit a data signal that can be read without actually scanning the tag. RFID tags can also be used to determine the location of the object to which they are attached. However, using RFID tags is more expensive than bar coding.

BJC HealthCare, with hospitals in Illinois and Missouri, uses RFID to keep track of expensive equipment and supplies in the system. The RFID technology allows the organization to collect and use data to build increasingly effective inventory control systems. BJC has reported a 23 percent reduction in its inventory as a result of using the RFID technology (Chao 2015).

PinnacleHealth Harrisburg (Pennsylvania) Hospital has also successfully implemented RFID technology to track and locate expensive medical equipment (Wright 2007). The system can be queried to locate a particular piece of equipment rather than staff having to search the hospital for it. The hospital's real-time asset-tracking program saved PinnacleHealth \$900,000 in its first 12 months of deployment (Radianse 2016).

Warehouse Management

Warehouse management systems enable healthcare organizations to optimize operations, thereby decreasing their storage and facility costs. Functions such as bar coding and point-of-use systems help reduce the labor needed by automating data entry in the receiving area; such automations also reduce errors, allowing for more accurate determination of the inventory held. Information

about demand trends at the organization, if available at the warehouse or storage facility, can be used to organize inventory so that the heavily demanded items are easily accessible. This process can significantly reduce labor costs associated with the storage facility.

Demand Forecasting

Knowledge of demand and demand variation in the system enables improved demand forecasting, which, in turn, can allow inventory reductions and enhance the probability that an item is available when needed. Bar coding and point-of-use systems allow organizations to track when and how many supplies are consumed, to use that information to forecast demand organization-wide, and to plan how to meet that demand effectively in the future.

Forecasting, or time series analysis, is used to predict what will happen in the future on the basis of data obtained at set intervals in the past. For example, forecasting can be used to predict the number of patients who will be seen in the emergency department in the next year (or month or day) based on the number of patients seen there in the past. Time series analysis accounts for the fact that data points collected over time may be related to one another and, therefore, violate the assumptions of linear regression. Forecasting methods range from simple to complex. Here, we describe the simpler methods; only a brief discussion of the more complicated methods is provided.

Averaging Methods

All averaging methods assume that the variable of interest is stable or stationary—not growing or declining over time and not subject to seasonal or cyclical variation.

Simple Moving Average

A simple moving average (SMA) takes the last p values and averages them to forecast the value in the next period:

$$F_t = \frac{D_{t-1} + D_{t-2} + \dots + D_{t-p}}{p},$$

where F_t = forecast for period t (or the coming period), D_{t-1} = value in the previous time period, and p = number of time periods.

Weighted Moving Average

In contrast to SMA, where all values from the past are given equal weight, a weighted moving average (WMA) weights each previous time period. Typically,

the more recent periods are assumed to be more relevant and are assigned greater weight:

$$F_t = w_1 D_{t-1} + w_2 D_{t-2} + \dots + w_p D_{t-p},$$

where F_t = forecast for period t (or the coming period), D_{t-1} = value in the previous time period, w_p = weight for time period p , and $w_1 + w_2 + \dots + w_p = 1$.

Exponential Smoothing

single exponential smoothing (SES)

A simple forecasting model that smooths data in a time series to predict the future.

The problem with SMA and WMA is that a large amount of historical data is required to compute the solutions. With **single exponential smoothing (SES)**, the oldest data are eliminated once new data have been added. The forecast is calculated by using the previous forecast and the previous actual value with a weighting or smoothing factor, alpha (α). Alpha can never be greater than 1, and higher values of alpha put more weight on the most recent periods:

$$F_t = \alpha D_{t-1} + (1 - \alpha) F_{t-1},$$

where F_t = forecast for period t (or the coming period), D_{t-1} = value in the previous time period, and α = smoothing constant ≤ 1 .

Trend, Seasonal, and Cyclical Models

Holt's Trend-Adjusted Exponential Smoothing Technique

trend-adjusted exponential smoothing

An extension of a single exponential smoothing model that accounts for a trend when smoothing the data.

SES assumes that the data fluctuate around a reasonably stable mean; that is, no trend or consistent pattern of growth or decline is present. If the data contain a trend, Holt's **trend-adjusted exponential smoothing** model can be used.

Trend-adjusted exponential smoothing works much as simple smoothing, except that two components—level and trend—must be updated each period. The level is a smoothed estimate of the value of the data at the end of each period, and the trend is a smoothed estimate of average growth at the end of each period. Again, the weighting or smoothing factors, α and delta (δ), can never exceed 1, and higher values put more weight on more recent time periods:

$$FIT_t = F + T_t$$

and

$$\begin{aligned} F_t &= \alpha D_{t-1} + (1 - \alpha) FIT_{t-1} \\ T_t &= T_{t-1} + \delta (F_{t-1} - FIT_{t-1}), \end{aligned}$$

where FIT_t = forecast for period t including the trend, F_t = smoothed forecast for period t , T_t = smoothed trend for period t , D_{t-1} = value in the previous time period, $0 \leq \alpha$ = smoothing constant ≤ 1 , and $0 \leq \delta$ = smoothing constant ≤ 1 .

Linear Regression

Alternatively, when a trend exists in the data, regression analysis (chapter 8) is often used for forecasting. Demand is the dependent, or Y , variable, and the time period is the predictor, or X , variable. The regression equation

$$\hat{Y} = b(X) + a$$

can be restated using forecasting notation as

$$F_t = b(t) + a,$$

where F_t = forecast for period t , b = slope of the regression line, and a = Y intercept. To find b and a , $\bar{D}$ = actual demand, D = average of all actual demands, t = time period, and $\bar{t}$ = average of time periods, such that $b = \frac{\sum (t - \bar{t})(D - \bar{D})}{\sum (t - \bar{t})^2}$ and $a = \bar{D} - b\bar{t}$.

In time series forecasting, the predictor variable is time. Regression analysis is also used in forecasting when a causal relationship exists between a predictor variable (not time) and the demand variable of interest. For example, if the number of surgeries to be performed at some future date is known, that information can be used to forecast the number of surgical supplies needed.

Winter's Triple Exponential Smoothed Model

In addition to adjusting for a trend, Winter's triple exponential smoothed model adjusts for a cycle or seasonality.

Autoregressive Integrated Moving Average Models

Autoregressive integrated moving average (ARIMA) models, developed by Box and Jenkins (1976), model a wide variety of time series behavior. However, ARIMA is a complex technique; although it often produces appropriate models, it requires a great deal of expertise to use.

Model Development and Evaluation

Forecasting models are developed on the basis of historical time series data using the previously described techniques. Typically, the “best” model is the simplest one available by which to minimize the forecast error associated with that model. Mean absolute deviation (MAD), mean squared error (MSE), or both may be used to determine error levels:

$$\text{MAD} = \frac{\sum_{t=1}^n |D_t - F_t|}{n}$$

$$\text{MSE} = \frac{\sum_{t=1}^n (D_t - F_t)^2}{n},$$

where t = period number, F = forecast demand for the period, D = actual demand for the period, and n = total number of periods.



On the web at
ache.org/books/OpsManagement4

Many of these forecasting models are available as downloads on the companion website to this book.

Vincent Valley Hospital and Health System Diaper Demand Forecasting

Jessie Jones, purchasing agent for Vincent Valley Hospital and Health System (VVH), wants to forecast demand for diapers. She gathers information related to past demand for diapers (exhibit 13.1) and plots it on a graph (exhibit 13.2). The plot of weekly demand shows no cycles or trends, so Jessie believes that an averaging method is most appropriate for achieving the accuracy desired. She obtains a five-period SMA forecast; a WMA forecast with weights of 0.5, 0.3, and 0.2; and an exponentially smoothed forecast with an alpha of 0.25.

EXHIBIT 13.1
VVH Weekly
Diaper Demand

Period	Week of	Cases of Diapers
1	1-Jan	70
2	8-Jan	42
3	15-Jan	63
4	22-Jan	52
5	29-Jan	56
6	5-Feb	53
7	12-Feb	66
8	19-Feb	61
9	26-Feb	45
10	5-Mar	54
11	12-Mar	53
12	19-Mar	43
13	26-Mar	60

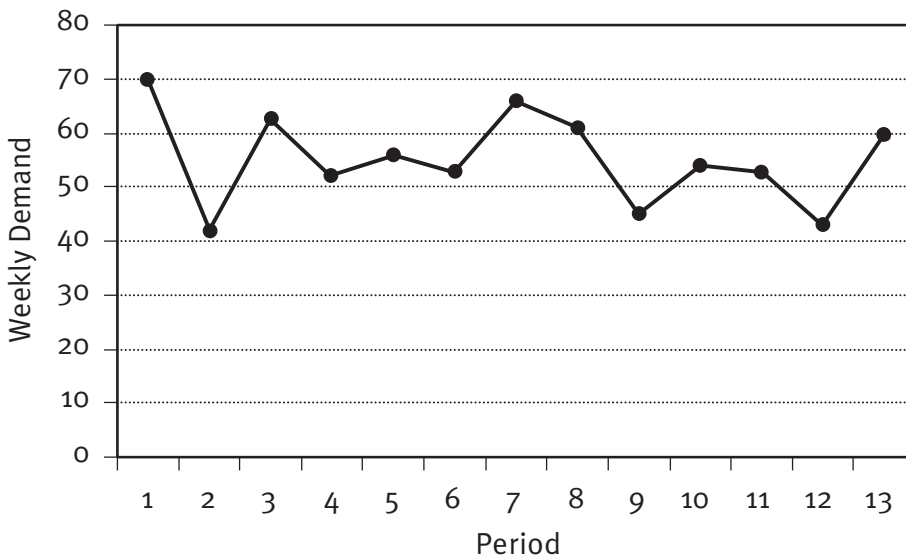


EXHIBIT 13.2
Plot of VVH
Weekly Diaper
Demand

SMA forecast:

$$F_t = \frac{A_{t-1} + A_{t-2} + \dots + A_{t-p}}{p}$$

$$F_{14} = \frac{A_{13} + A_{12} + A_{11} + A_{10} + A_9}{5} = \frac{60 + 43 + 53 + 54 + 45}{5} = 51$$

WMA forecast:

$$F_t = w_1 A_{t-1} + w_2 A_{t-2} + \dots + w_p A_{t-p}$$

$$F_{14} = (w_1 A_{13}) + (w_2 A_{12}) + (w_3 A_{11})$$

$$= (0.5 \times 60) + (0.3 \times 43) + (0.2 \times 53) = 53.5$$

Exponentially smoothed forecast:

$$F_t = \alpha A_{t-1} + (1 - \alpha) F_{t-1}$$

$$F_{14} = 0.25 \times A_{13} + (1 - 0.25) \times F_{13}$$

$$= 0.25 \times 60 + 0.75 \times 52 = 54$$

Because each method results in a different forecast, Jessie compares the methods to determine which is best. She uses the Excel forecasting template (found on

the companion website) to perform the calculations (exhibit 13.3). She finds that both MAD and MSE are lowest with the WMA method and decides to use that method for forecasting. Therefore, she forecasts that 53.5 cases of diapers will be demanded the week of April 2, period 14.



On the web at
ache.org/books/OpsManagement4

Order Amount and Timing

Inventory management is concerned with the following questions:

- How much inventory should the organization hold?
- When should an order be placed?
- How much should be ordered?

economic order quantity (EOQ)

An inventory model that indicates an optimal purchase quantity that will minimize total annual inventory costs.

To answer these questions, organizations need reasonable estimates of holding, ordering, and shortage costs. Knowledge of lead times and demand forecasts is also essential to determining the best answers to inventory questions.

Economic Order Quantity Model

In the early 1900s, F. W. Harris (1913) developed the **economic order quantity (EOQ)** model to answer inventory questions. Although the assumptions of

EXHIBIT 13.3

Excel
Forecasting
Template
Output: VVH
Diaper Demand

Simple Moving Average

Periods

MAD
MSE

Period	Actual	Forecast	Error
1	70		
2	42		
3	63		
4	52		
5	56		
6	53	57	4
7	66	53	13
8	61	58	3
9	45	58	13
10	54	56	2
11	53	56	3
12	43	56	13
13	60	51	9
14		51	

Weighted Moving Average (3 periods)

Least Recent Most Recent

MAD
MSE

Period	Actual	Forecast	Error
1	70		
2	42		
3	63		
4	52	58	6
5	56	53	3
6	53	56	3
7	66	54	12
8	61	60	1
9	45	61	16
10	54	54	0
11	53	53	0
12	43	52	9
13	60	48	12
14		53.5	

Single Exponential Smoothing

Most Recent α

MAD
MSE

Period	Actual	Forecast	Error
1	70		
2	42	70	28
3	63	63	0
4	52	63	11
5	56	60	4
6	53	59	6
7	66	58	8
8	61	60	1
9	45	60	15
10	54	56	2
11	53	56	3
12	43	55	12
13	60	52	8
14		54	

this model limit its usefulness in real situations, it provides important insights into effective and efficient inventory management.

To aid in understanding the model, definitions for some key inventory terms are provided.

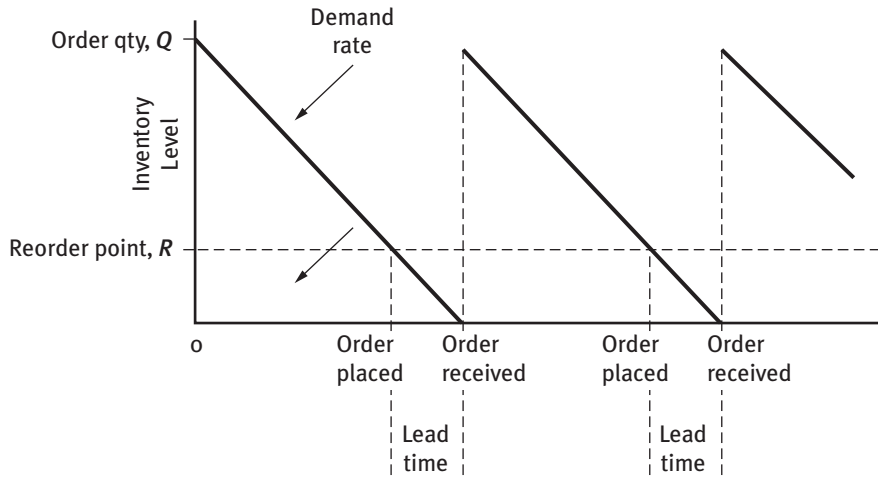
- *Lead time* is the interval between placing an order and receiving it.
- *Holding (carrying) costs* are associated with keeping goods in storage for a period of time, usually one year. The most obvious of these costs are the cost of the space and the cost of the labor and equipment needed to operate the space. Less obvious costs include the opportunity cost of capital and those costs associated with obsolescence, damage, and theft of the goods. These costs are often difficult to measure and are commonly estimated as one-third to one-half the value of the stored goods per year.
- *Ordering (setup) costs* are the costs of ordering and receiving goods. They may also be the costs associated with changing or setting up to produce another product.
- *Shortage costs* are the costs of not having an item in inventory when it is needed.
- *Independent demand* is generated by the customer and is not a result of demand for another good or service.
- *Dependent demand* results from another demand. For example, the demand for hernia surgical kits (dependent) is related to the demand for hernia surgeries (independent).
- *Back orders* are orders that cannot be filled when received but are placed because the customer is willing to wait for the order to be filled.
- *Stockouts* occur when the desired good is not available.

The basic EOQ model is based on the following assumptions:

- Demand for the item in question is independent.
- Demand is known and constant.
- Lead time is known and constant.
- Ordering costs are known and constant.
- Back orders, stockouts, and quantity discounts are not allowed.

The EOQ inventory order cycle (exhibit 13.4) consists of stock or inventory being received at a point in time. An order is placed when the amount of stock on hand is just enough to cover the demand that will be experienced during lead time. The new order arrives at the exact point when the stock is

EXHIBIT 13.4
EOQ Inventory
Order Cycle



completely depleted. The point at which new stock should be ordered, the reorder point (R), is the quantity of stock demanded during lead time:

$$R = \bar{d}L$$

where $\bar{d}$ = average demand per time period and L = lead time.

The EOQ inventory order cycle shows that the average amount of inventory held will be

$$\frac{\text{Order quantity}}{2} = \frac{Q}{2}$$

and the number of orders placed in one year will be

$$\frac{\text{Yearly demand}}{\text{Order quantity}} = \frac{D}{Q}.$$

Total costs are the sum of holding and ordering costs. Yearly holding costs are calculated as follows:

$$\text{Cost to hold one item one year} \times \text{Average inventory} = h \times \frac{Q}{2}.$$

Yearly ordering costs are

$$\text{Cost to place one order} \times \text{Yearly number of orders} = o \times \frac{Q}{2}.$$

Total yearly costs are then

$$h \times \frac{Q}{2} + o \times \frac{D}{Q}.$$

Exhibit 13.5 illustrates these relationships. An inspection of this graph shows that total cost is minimized when holding costs equal ordering costs. (This relationship can also be proven using calculus.) In equation form, the order quantity that will minimize total costs is found with

$$h \times \frac{Q^*}{2} + o \times \frac{D}{Q^*},$$

where Q^* is the EOQ.

Rearranging this equation, the optimal order quantity is

$$Q^2 = \frac{2 \times o \times D}{h}$$

$$Q^* = \sqrt{\frac{2 \times o \times D}{h}}.$$

A key insight into inventory management can be gained from an examination of this simple model. First, trade-offs are inherent between holding costs and ordering costs: As holding costs increase, optimal order quantity decreases, and as ordering costs increase, optimal order quantity increases. Many organizations, including those in the healthcare industry, believe that the costs of holding inventory are much higher than was previously thought. As a

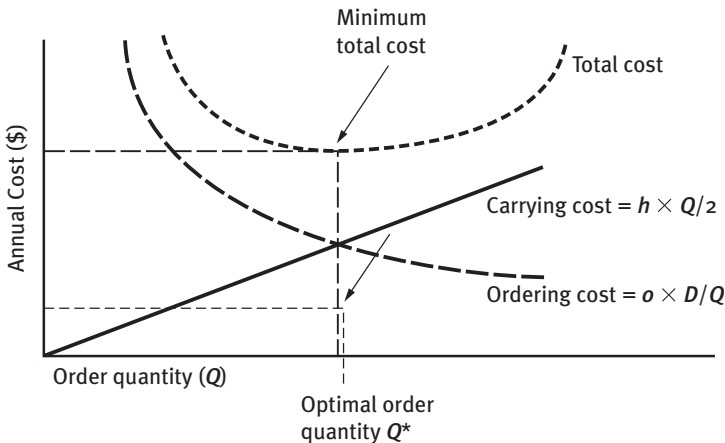


EXHIBIT 13.5
EOQ Model Cost
Curves

consequence, these organizations are decreasing order quantities and working to decrease order costs by streamlining procurement processes.

Vincent Valley Hospital and Health System Diaper Order Quantity

Jessie Jones, VVH's purchasing agent, now wants to determine the optimal order quantity for diapers. From her forecasting work, she knows that annual demand, D , for the item (in this case, diapers), is

$$\bar{d} \times \text{Time period} = \frac{53.5 \text{ cases}}{\text{week}} \times \frac{52 \text{ weeks}}{\text{year}} = \frac{2,782 \text{ cases}}{\text{year}}.$$

Each case of diapers costs \$5, and Jessie estimates holding costs at 33 percent. The transaction cost is \$100 to place an order. Lead time for diapers is one week. She calculates the EOQ, Q^* , as follows:

$$\begin{aligned} \sqrt{\frac{2 \times o \times D}{h}} &= \sqrt{\frac{2 \times \$100 \times 2,782 \text{ cases}}{\$1.67/\text{case}}} \\ &= \sqrt{333,174 \text{ cases}^2} = 577 \text{ cases.} \end{aligned}$$

She calculates the reorder point, R , as

$$\bar{d}L = \frac{53.5 \text{ cases}}{\text{week}} \times 1 \text{ week} = 53.5 \text{ cases.}$$

Jessie will need to place an order for 577 cases of diapers when the stock drops to 53.5 cases.

Fixed Order Quantity with Safety Stock Model

The basic EOQ model assumes that demand is constant and known. In other words, the amount of stock carried in inventory need only match demand. In reality, demand is seldom constant, and excess inventory must be held to meet variations in demand and avoid stockouts. This excess inventory, called safety stock (SS), is the amount of inventory carried over and above expected demand. Exhibit 13.6 illustrates this model.

The SS model assumes that demand varies and is normally distributed. It also assumes that a fixed quantity equal to EOQ will always be ordered. The EOQ remains the same as in the basic model, but the reorder point differs because of the need for SS:

$$R = \bar{d}L + SS.$$

service level

The probability of having an item on hand when needed.

The amount of SS to carry is determined by variation in demand and desired service level. **Service level** is defined as the probability of having

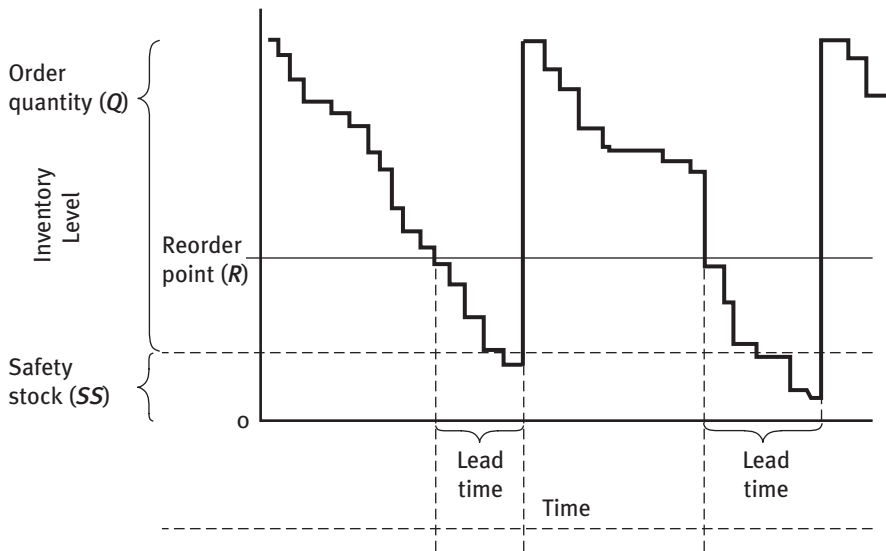


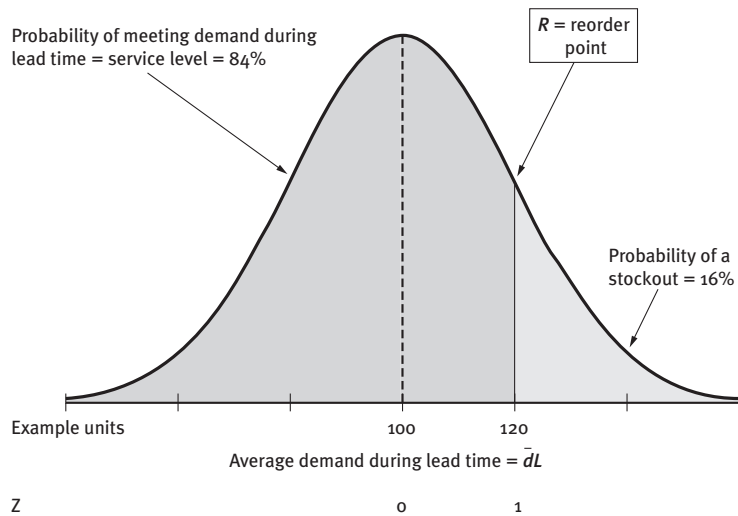
EXHIBIT 13.6
Variable
Demand
Inventory Order
Cycle with
Safety Stock

an item on hand when needed. For example, suppose orders are placed at the beginning of a time period and received at the end of that period. If demand is expected to be 100 units in the next time period with a standard deviation of 20 units and 100 units on hand at the start of the period, the probability of stocking out is 50 percent and the service level is 50 percent. If demand is normally distributed, there is a 50 percent probability of its being higher than the mean and a 50 percent probability of its being lower than the mean. Demand is then greater than the stock on hand in half of the time periods.

To increase the service level, SS is needed. For example, if the stock on hand at the start of the time period is 120 units (20 units of SS), the service level increases to 84 percent and the probability of a stockout is reduced to 16 percent. Because demand is assumed to follow a normal distribution, and 120 units is exactly one standard deviation higher than the mean of 100 units, the probability of being less than one standard deviation above the mean is 84 percent. There is a 16 percent probability of being more than one standard deviation above the mean (exhibit 13.7). A service level of 95 percent is typically used in industry. However, if one stockout every 20 time periods is unacceptable, a higher service level target is needed.

SS is the z -value associated with the desired service level (number of standard deviations above the mean) multiplied by the standard deviation of demand during lead time:

$$SS = z \times \sigma_L$$

EXHIBIT 13.7**Service Level
and Safety
Stock**

Note that with this model, the only occasion in which demand variability may be problematic is during lead time. Because an order is triggered when a certain level of stock is reached, any variation in demand prior to that time does not affect the reorder point.

This model also provides critical information about inventory management. Trade-offs exist between the amount of SS held and service level. As the desired service level increases, the amount of SS needed—and therefore the amount of inventory held—increases. As the variation in demand during lead time increases, the amount of SS increases. If demand variation or lead time can be decreased, the amount of SS needed to reach a desired service level also decreases. Many healthcare organizations continuously work with their suppliers to reduce lead time and, therefore, SS levels.

Vincent Valley Hospital and Health System Diaper Order Quantity

After learning more about inventory models, Jessie Jones has realized that the reorder point she chose earlier by using the basic EOQ model will cause the hospital to run out of diapers during 50 percent of the order cycles. Because diapers are ordered five times per year, the hospital will stock out of diapers at least twice a year. Jessie believes this is an unacceptable amount of stockouts and determines that SS is needed to avoid them. She sets a service level of 95 percent, or one stockout every four years, as an acceptable threshold.

Jessie gathers additional information related to demand for diapers over the past year and finds that the standard deviation of demand during lead time is 11.5 cases of diapers. She calculates the amount of SS needed as follows:

$$z \times \sigma_L = 1.64 \times 11.5 = 18.9 \text{ cases.}$$

Her new reorder point is

$$\bar{d}L + SS = \left(\frac{53.5 \text{ cases}}{\text{week}} \times 1 \text{ week} \right) + 18.9 \text{ cases} = 72.4 \text{ cases.}$$

Jessie needs to place an order for 577 cases of diapers when inventory drops to 72.4 cases. The forecasting template found on the companion web-site can be used to perform these calculations, and the output related to Jessie's problem is shown in exhibit 13.8.

On the web at

ache.org/books/OpsManagement4 

Additional Inventory Models

Many inventory models that address some of the limiting assumptions of the EOQ have been developed. One is known as the fixed time period with SS model, whereby the order quantity varies and the time at which the order is placed is fixed. This type of model is applicable when vendors deliver on a set schedule or if one supplier is used for many different products and orders are bundled and delivered together on a set schedule. Generally, this situation requires more SS because stockouts are possible during the entire time between orders, not just the lead time for the order. Another inventory model is the fixed order quantity with SS model, in which the order quantity is fixed and the time at which the order is placed varies.

Models that account for quantity discounts and price breaks have also been developed. Information on these high-level models can be found in most inventory management textbooks.

Inventory Systems

In practice, various types of systems are employed for management and control of inventory. They range from simple to complex, and organizations typically employ a mixture of these systems.

Reorder Point (ROP) with EOQ Ordering

Average daily demand	d =	7.64	Units
Average lead time	L =	7	Days
Std dev demand during lead time	σ _L =	11.5	Units
Service level	SL =	0.95	▲
increment	SL =		▼
Stockout risk		0.05	
z associated with service level		1.64	
Average demand during lead time	dL =	53.48	Units
Safety stock	SS =	18.9	Units
Reorder point	ROP =	72.4	Units

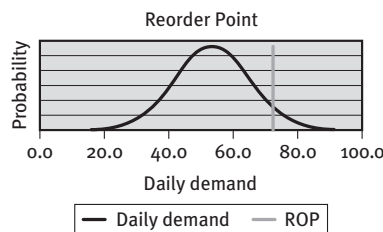


EXHIBIT 13.8
VVH 95 Percent
Service Level
Reorder Point

Two-Bin System

The two-bin system is a simple, easily managed approach often used for B- or C-type items. In this system, inventory is separated into two bins. These are not necessarily actual bins or containers; the idea is to have in place a means of identifying the items as being in the first or second bin.

In the two-bin system, inventory is taken from the first bin. When that bin is emptied, an order is placed, and inventory from the second bin is used during the lead time. The amount of inventory held in each bin can be determined from the fixed order quantity with the SS model. Inventory held in the first bin is ideally the EOQ minus the reorder point, and inventory in the second bin equals the reorder point.

Just-in-Time

Just-in-time (JIT) inventory systems are based on Lean concepts and employ a type of two-bin system called kanban. (See chapter 10 for a description of this type of system.) Because inventory levels are controlled by the number of kanbans in the system and inventory is “waste” in a Lean system, organizations try to decrease the number of kanbans as much as possible.

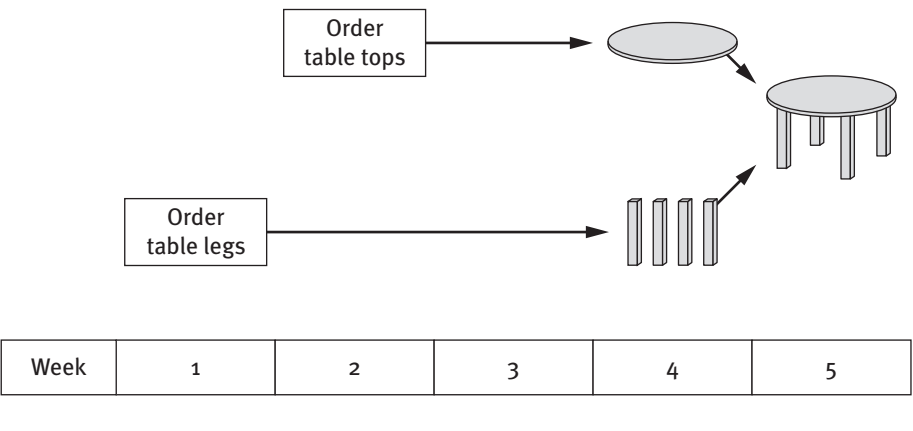
Material Requirements Planning and Enterprise Resources Planning

Material requirements planning (MRP) systems were first employed by manufacturing organizations in the 1960s when computers became commercially available. These systems were used to manage and control the purchase and production of dependent-demand items.

A simple example illustrates the logic of MRP (exhibit 13.9). A table manufacturer knows (or forecasts) that 50 tables, consisting of a top and four legs, will be demanded five weeks in the future. The manufacturer also knows

material requirements planning (MRP)
A computer system designed to manage the purchase and control of dependent-demand items.

EXHIBIT 13.9
Material Requirements Planning Logic



that producing a table takes one week if both the legs and the top are available. Lead time is two weeks for table legs and three weeks for tabletops. From this information, MRP helps the manufacturer determine that, to produce 50 tables in week 5, it needs to have on hand 50 tabletops and 200 table legs in week 4. The company also needs to order 200 table legs in week 2 and 50 tabletops in week 1.

The same type of logic can be applied in healthcare for dependent-demand items. For example, if the demand for a particular type of surgery is known or can be forecast, supplies related to this type of surgery can be ordered on the basis of MRP-type logic.

Enterprise resources planning (ERP) evolved from the relatively simple MRP systems as computing power grew and software applications became more sophisticated. ERP-type systems in healthcare today are found throughout the entire organization and include finance, accounting, human resources, patient records, and many more functions in addition to inventory management and control.

enterprise resources planning (ERP)
Global information systems that help individuals and groups manage the entire organization, including accounting, operations, and human resources.

Procurement and Vendor Relationship Management

Analyzing and improving the processes used for procurement can result in significant savings for an organization. Technology can be used to not only streamline processes but also improve data reliability, accuracy, and visibility. Streamlining procurement processes can also reduce associated labor costs. Electronic procurement (e-procurement) is one example of how technology can be used to increase procurement efficiency. The ease of obtaining product information, the reduced time associated with the procurement process, and the increased use of a limited number of suppliers can significantly reduce costs as well.

In addition to basic procurement data, information about supplier reliability can be maintained in e-procurement systems to allow organizations to make informed choices about vendors, assuming these entities track and regularly review supplier performance. For example, one vendor may be inexpensive but extremely unreliable, whereas another may be slightly more expensive but more reliable and faster. Conducting an analysis can help an organization determine that using the slightly more expensive vendor is prudent because the amount of SS held or the need to expedite shipments may be reduced.

Value-based standardization can be used to reduce both the number of different items and the quantity of those items held. Focusing on high-use or high-cost items can leverage the benefits of standardization and reduce the number of suppliers to the organization. Holding fewer supplies and engaging fewer suppliers can result in both labor and material cost savings.

One effective means of ensuring supply availability and reducing internal labor is outsourcing. Distributors can break orders down by point of use—for example, the emergency department, the dietary department—and deliver directly to that point as needed rather than having the organization's personnel perform that function. In addition, the use of prepackaged supply packs or surgical carts can reduce the amount of in-house labor needed to organize these supplies and ensure that the correct supplies are available when needed. Vendor-managed inventory is another way to outsource some of the work involved with procurement, with automated supply carts or cabinets and point-of-use systems enabling this type of inventory. Participation in group purchasing organizations (GPOs) leverages increased order quantities, thereby reducing costs.

Finally, disintermediation is a way to improve supply chain management. Reducing the number of organizations in the chain can result in reduced costs and improvements in speed and reliability.

Group Purchasing Organizations

GPOs are a critical part of healthcare supply chains. It is anticipated that between 90 percent to 98 percent of all US hospitals utilize a GPO, with hospitals purchasing nearly 73 percent of their supplies through them (Burns and Lee 2008; Schneller 2009). However, this reliance on GPOs is not universally applicable for all types of supplies. Hospitals reportedly purchase most of their commodity items and pharmaceutical supplies through them, but rely much less on them for physician-preferred items and medical equipment. The GPO market is highly concentrated, with more than 90 percent of all hospital-based GPO purchases being made through the top seven GPOs (Burns and Lee 2008).

The benefits of using a GPO arise from the premise that member hospitals, by pooling their purchases, should increase their bargaining power, enabling them to negotiate better rates and obtain quantity discounts. The realized savings can then be transferred back to the participating hospitals. GPO incentives may not always be aligned with the needs of their member hospitals, given that they only charge a fixed membership fee from hospitals, while making most of their revenues on sales commissions from suppliers. Studies have also documented mixed results on the benefits of GPOs in improving hospital procurement costs (Burns and Lee 2008; Hu et al. 2012; Scanlon 2002; Schneller 2009).

Care Coordination and Supply Chain Challenges

Since the start of the 2000s, a drive toward cost containment, coordination of care, and patient-centered care has encouraged hospitals to expand their

channels and levels of care delivery, which has compounded supply chain management challenges. Hospitals are now using different care delivery channels depending on patient convenience and needs. Channels gaining prominence include virtual care, home health, and even involvement of hospitals in population health. Chapter 15 discusses these trends in more detail. Hospitals are also increasing the range of services offered to patients and ensuring better coordination across different levels of care delivery (primary, inpatient, postdischarge, etc.). This broader range is being achieved through mergers and acquisitions, participation in care provider networks, and membership in accountable care organizations (ACOs). As an example, between 2007 and 2013, a staggering 607 hospitals have been involved in mergers and acquisitions transactions (Center for Health Economics and Policy, 2013), and the number of ACO contracts has risen from under 100 in 2011 to 1,477 in 2018.

Although these changes have improved patient visibility and added scale to healthcare organizations, they have also come with increased challenges of forecasting demand across multiple channels and levels, larger variety of SKUs for procurement, and the need to integrate technology and operations across healthcare providers.

Strategic View

Most important of all the discussion related to the supply chain, effective SCM requires a strategic systems analysis and design. This strategic view enables systems solutions rather than individual solutions—an important distinction, as best-practice solutions can be standardized across an entire organization rather than applied haphazardly or incorrectly. A strategic design enables system-level integration, allowing for improved decision making throughout the organization.

Successful SCM initiatives require the same elements as Six Sigma, Lean, and the Baldrige criteria:

- Top management support and collaboration, including time and money
- Employee buy-in, including clinician support and frontline empowerment
- Evaluation of the structure and staffing of the supply chain to ensure that it supports the desired improvements and that all relevant functions are represented in a meaningful way (cross-functional teams may be the best way to ensure this adherence)
- Process analysis and improvement, including a thorough and complete understanding of existing systems, processes, and protocols (through process mapping) and their improvement

- Collection and analysis of relevant, accurate data and metrics to determine areas of improvement, means of improvement, and whether improvement is achieved
- Evaluation of technology-enabled solutions in terms of both costs and benefits
- Training in the use of new technologies and techniques, which is essential for broad application and use in the organization
- Internal awareness programs to highlight the need for and benefits of strategic SCM
- Improved inventory management through enhanced understanding of the system-level consequences of unofficial inventory, JIT systems, and inventory tracking systems
- Enhancement of vendor partnerships through information sharing and the investigation and determination of mutually beneficial solutions
- Performance tracking of vendors to determine the best vendors to involve in the SCM process
- Periodic education and continuous support by the organization for a systemwide view of the supply chain
- Pursuit of continuous improvement of the system rather than of individual departments or organizations in that system

Conclusion

In the past, healthcare organizations did not focus on SCM issues; today, increasing cost pressures drive them to examine and optimize their supply chains. The ideas and tools presented in this chapter help the healthcare supply chain professional achieve improvements and thereby lower costs.

Discussion Questions

1. Why is SCM important to healthcare organizations?
2. List some inventory items found in your organization. Which of these might be classified as A, B, or C items? Why? How would you manage these items differently depending on their classification?
3. Think of an item for which your organization carries SS. Why is SS needed for this item? Can the amount of SS needed be reduced? How?
4. Describe the ERP system(s) found in your organization. How could it be improved?

Exercises

1. Using the materials available at the book's companion website, investigate and summarize commercially available software solutions for healthcare organizations. Using the forecasting template found on the companion website, forecast total US healthcare expenditures for 2017 with SMA, WMA, SES, trend-adjusted exponential smoothing, and linear trend models.
 - a. Which model do you believe offers the best forecast?
 - b. Do you see any problems with your model?
 - c. Repeat this exercise for hospital care, physician services, other professional services, dental services, home health care, and prescription drugs. According to your findings, do any one of these areas drive the increase in healthcare expense?
2. Using the Excel inventory template found on the companion website if you choose, and starting with an Excel spreadsheet including data for this problem, which also is available on the companion website, prepare the following exercise.

On the web at ache.org/books/OpsManagement4 

On the web at ache.org/books/OpsManagement4 

Hospital purchasing agent Abby Smith needs to order examination gloves. Currently, she orders 1,000 boxes of gloves whenever she thinks a need for the item exists. Abby has heard that a better way is available to do her job and wants to use EOQ to determine how much to order and when. She collects the following information.

Cost of gloves:	\$4.00/box
Carrying costs:	33%, or \$_____/box
Cost of ordering:	\$150/order
Lead time:	10 days
Annual demand:	10,000 boxes/year

- a. What quantity should Abby order? Prove that your order quantity is “better” than Abby’s by graphing ordering costs, holding costs, and total costs for 1,000, 1,500, and 2,000 boxes.
- b. How often should Abby place the order? Approximately how much time (in days) will elapse between orders?

- c. Assuming that Abby is not worried about SS, when should she place her order? Draw another graph to illustrate why she needs to place her order at that particular point.
- d. Abby is concerned that the reorder point she determined is wrong because demand for gloves varies. She gathers the following usage information:

Period (10 days each)	Demand
1	274
2	274
3	284
4	274
5	254
6	264
7	264
8	284
9	274
10	294
11	274
12	284
13	264
14	274
Average	274

- e. Abby decides she will be happy if the probability of a stockout is 5 percent. How much SS should Abby carry?
- f. If Abby were to set up a two-bin system for gloves, how many boxes of gloves would be in each bin?

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IMPROVING FINANCIAL PERFORMANCE WITH OPERATIONS MANAGEMENT

Operations Management in Action

To explore opportunities to improve productivity in healthcare, a team from Johns Hopkins University Hospital convened leaders from several technology and management consulting companies to discuss the use of systems engineering to reduce costs in their system. They felt that as care had become more complex, new equipment, capabilities, and requirements had simply been added without a system integration plan. They knew that other complex industries had succeeded in applying contemporary operations-improvement tools to decrease costs and improve performance. For example, the aviation industry had demonstrated that purposely designed and integrated systems could reduce materials and labor costs while increasing efficiency and safety.

As a result of their work in bringing best practices from other industries to hospital operations the Hopkins team identified five areas of opportunity for significant savings in labor force costs:

Manage the Last 10 Feet of the Supply Chain

Nurses spend approximately 7 percent of their time searching for supplies. The application of Lean principles such as 5S (see exhibit 10.4) and advanced supply-chain tools can minimize this waste.

OVERVIEW

Reducing Waste to Improve Financial Performance

Revenue and expense are the building blocks of financial performance. As reimbursement continues to shift to value purchasing and various forms of capitation, expenses become the most important source of improved financial performance. Identifying and eliminating non-value-added activities—waste—will be a clear strategic goal for high-performing organizations. As described in chapter 1, Shrank, Rogstad, and Parekh (2019) identified six categories of waste:

- Failure of care delivery
- Failure of care coordination
- Overtreatment or low-value care
- Pricing failure
- Fraud and abuse
- Administrative complexity

The major tools for cost reduction in the clinical areas of a healthcare organization are the use of evidence-based medicine (EBM) supported by electronic health records and advanced analytics. Poor care coordination resulting in rework (e.g., hospital readmissions) and the provision of low-value care historically have improved revenues under the traditional fee-for-service system. But as payment moves to value purchasing and capitation, the wide use of EBM and sophisticated care coordination will be critical.

(continued)

Convert Human Medication Double-Checking to Electronic

The double-checking of medication is an important safety system for the administration of high-risk medications. Johns Hopkins found this consumed as much as 22 percent of nurses' time. Using an Agency for Healthcare Research and Quality grant, they created an electronic system to automate dose calculations, which will significantly minimize the time spent on this task.

Eliminate False Alarms

On average, nurses answer false alarms every 45 seconds. All the devices creating alarms are independent and were not

designed to achieve a common purpose. A solution, modeled on other industries, will be to engage a system integrator to combine these technologies into a simple command center for nurses' use. New technologies such as advanced analytics and artificial intelligence (AI) will be key to progress in this area.

Minimize Human Documentation

Clinicians spend up to half of their time creating documentation for electronic health records (EHRs). The advent of a new profession—the scribe—shows how poor the human-machine interface is in these systems. However, new systems based on speech recognition and AI tools have the opportunity to minimize this unnecessary cost.

Eliminate Human Labor Costs for Submitting and Processing a Claim

Hospitals have multiple payers, each with a different process and claims-submission platform. Individual steps in the submission process, such as prior authorization, are often disconnected from the others (e.g., utilization management, payment integrity). As a result, providers often receive multiple requests for the same piece of data, and rework, repeated requests, and waste are the norm. Contemporary information technology systems using AI offer solutions to this long-standing dilemma in the American healthcare system.

Source: Pronovost, Sapirstein, and Ravitz (2019).

OVERVIEW (*continued*)

Competitive pricing is supported by the efficient delivery of care, but also can reflect lower costs if provider supply chains and inventory management systems are optimized—particularly in pharmaceutical purchasing.

Much of the fraud in the system, such as fake bills, is enabled by another area of waste—administrative complexity. The use of focused tools of process improvement (chapter 11) with advanced automation such as artificial intelligence can provide solutions that will minimize the costs of these types of waste and greatly improve the finances of a healthcare organization.

This chapter identifies approaches to achieve significant gains in financial performance in accord with the mandate to reduce waste in the system by using the improvement tools outlined in earlier chapters.

Environmental Pressures on Financial Performance

A number of forces have historically worked together to change revenue mix while increasing the total costs of care beyond inflation:

- The increasing incidence of chronic disease
- An aging population
- New diagnostic and treatment technologies
- A movement from inpatient hospital settings to outpatient and home
- The increasing complexity of billing and payment systems
- A provider payment system (fee-for-service) that today still encourages the use of healthcare services

Today's healthcare executive is therefore caught between two intense environmental pressures: the need to reduce costs in the face of continuing inflationary pressures and the expectation of little new revenue. This chapter provides a road map to stable or improved financial performance through the use of operations management tools presented in the preceding chapters of this book.

Specifically, this chapter

- defines improved financial performance,
- describes a systems view of reducing costs and increasing revenues that takes into consideration the new value purchasing methodologies used to pay for services,
- details how the operations tools described in this book can be used to optimize costs and revenue for each of these payment methodologies, and
- provides a case example of one hospital that has improved its operations enough to generate a positive margin on Medicare revenues.

Definition of Financial Improvement

Although this textbook is not primarily about financial management, a number of measures are generally accepted as indicators of the successful financial performance of a healthcare enterprise. (For a more comprehensive view, refer to Reiter and Song 2021.)

From a balance sheet perspective, three indicators are frequently used to assess an organization's performance:

1. Cash on hand
2. Percentage of debt financed
3. Age of plant

Three key indicators of financial health on the income statement are the following:

1. Revenue (growth or decline)
2. Margin, to maintain ongoing services and finance improvements
3. Costs (per unit of service), to service its customers as inexpensively as possible (Reiter and Song 2021)

Because revenue growth per service is likely to increase slowly (in Medicare's case, it may actually decline), healthcare executives must focus on collecting all available revenue while reducing costs. The approaches described in this chapter can achieve these goals. Furthermore, in addition to achieving these financial goals, the use of operations management tools almost always results in stable or improved clinical quality and patient satisfaction.

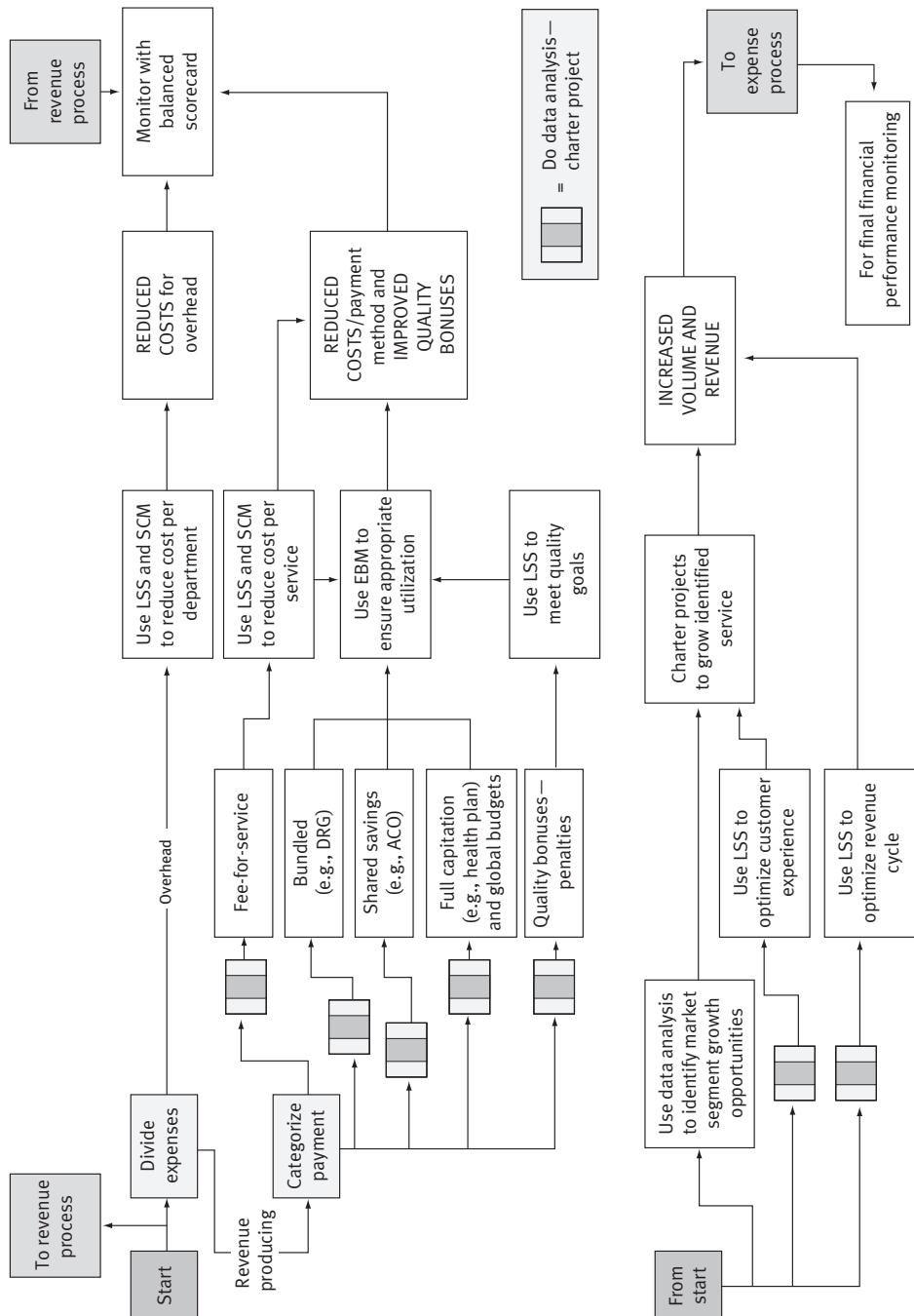
A Systems Approach to Financial Management

Meeting financial goals is part of most healthcare managers' job descriptions, yet many organizations lack a comprehensive approach to supporting the manager in achieving these goals. Without this type of framework, managers are often required to take measures that may provide immediate results but foster long-term problems. Some examples include

- adopting across-the-board expense reductions;
- eliminating overtime without changing any processes;
- using less expensive supplies without changes in the supply chain;
- tolerating queuing and long waits for service;
- outsourcing key activities without having quality monitoring systems in place; and
- implementing automation without a clear, positive financial impact.

A more effective and longer-lasting methodology than these measures is a systems approach to financial management (see exhibit 14.1). First, expenses are divided into those directly related to revenue generation and those considered overhead. Because multiple payment methodologies are in place today and for the foreseeable future, revenue is further divided into these various models. Each category can be addressed with the techniques described in this chapter.

Reduction in overhead expenses is more straightforward than in revenue-related expenses, and therefore more general techniques can be used. Revenue can be improved and optimized by growing service lines and optimizing the revenue cycle.

EXHIBIT 14.1**A Systems Approach to Financial Management**

Note: ACO = accountable care organization; DRG = diagnosis-related group; EBM = evidence-based medicine; LSS = Lean Six Sigma; SCM = supply chain management.

Expenses Directly Related to Revenue

All expenses directly related to revenue should be classified into six payment methodologies:

1. Fee-for-service
2. Bundled
3. Shared savings
4. Full capitation
5. Quality bonuses or penalties
6. Global payments

These payment areas are discussed in detail later in the section.

Next, projects are chartered with a focus on each specific payment methodology and operating unit(s). The first step in the project is to collect data on the current state of service delivery and determine where variance occurs in resources used and outcomes achieved. The tools of process improvement, supply chain management, and schedule optimization are then applied to reduce variance and improve outcomes. This approach reduces costs and, in many instances, increases throughput.

Fee-for-Service

The most atomic-level area of cost control is individual fee-for-service. Although the delivery of each service contains a variety of components (personnel, supplies, overhead), the “fee” is created to represent an identifiable service understandable by providers and payers. Examples include services such as an office visit and a laboratory test.

Activity-based costing (ABC) is a tool that can be used to deconstruct the billing service unit and identify opportunities for cost reductions. Reiter and Song (2021, chapter 7) provide a useful example of using ABC to analyze the clinic visit.

ABC follows five steps:

1. Identify the relevant activities.
2. Determine the total cost of each activity, including direct and indirect costs.
3. Determine the cost drivers for the activity.
4. Collect activity data for each service.
5. Calculate the total cost of the service by aggregating activity costs.

For example, assume that the total annual cost of patient check-in, consisting of clerical labor (direct costs) plus space and other overhead costs (indirect

activity-based costing (ABC)

A cost allocation model that assigns a cost to each activity in an organizational unit and then totals the cost for the unit on the basis of the actual consumption of each activity.

costs), is \$50,000 to support 10,000 visits per year. This calculation yields an allocation rate of \$5 per visit (Reiter and Song 2021). Similar calculations are made for each component of the office visit, and the allocation rate is then determined for each activity (exhibit 14.2). Once the allocation rates are determined, the total activity costs for each service can be calculated (exhibit 14.3).

Each cost element can be optimized with the tools described in this book. Exhibit 14.4 provides examples.

After each activity in a service is analyzed and improved, the total service cost can also be optimized by using Six Sigma and Lean techniques, as described in chapters 9 and 10, respectively. Chapter 11 outlines a number of specific techniques to optimize throughput in a clinic (hence reducing people cost per visit), and chapter 13 provides a number of supply chain management techniques to reduce supply costs. As costs are reduced at the fee-for-service level, costs at all other levels decrease as well.

Bundled Payments

Various fees are frequently bundled together and paid as one amount. The intent of bundling is to give the provider an incentive to minimize costs inside the bundle. Examples of bundled payments in hospitals include the following:

- *Per diem.* All payments for a day in a hospital are paid at one rate.
- *Medicare prospective payment.* All payments for a stay in the hospital are paid at one rate that is adjusted for the complexity of the admission by the diagnosis-related group (DRG) system.
- *Medicare bundled payment.* All payments for an episode of care are paid at one rate adjusted for complexity.

To optimize the cost structure of bundled payments, the underlying fee-for-service costs must be targeted and improved. Because hospitals have created and maintain thousands of individual fees in a document known as the chargemaster, an analysis project should be undertaken to identify which fees to target. Criteria for targeting may include the following:

- High volume
- High cost compared to benchmarks from other organizations
- High use in bundled payments where costs are highly variable

After reducing the costs for individual services, the tools of evidence-based medicine (EBM) can now be applied. They are particularly useful for optimizing costs in bundled payment models, as these protocols reflect the shared wisdom of many clinical studies on the most efficient and effective approach to a particular condition. Chapter 3 outlines contemporary approaches

EXHIBIT 14.2
ABC Illustration: Initial Data and Allocation Rate Calculation

Activity	Annual Costs	Cost Driver	Activity Data			Allocation Rate
			Service X	Service Y	Total	
Check-in	\$ 50,000	Visits	5,000	5,000	10,000	\$ 5.00
Assessment	75,000	Minutes per service	5	10	75,000	1.00
Diagnosis	250,000	Minutes per service	10	15	125,000	2.00
Treatment	450,000	Minutes per service	10	20	150,000	3.00
Prescription	2,500	Number of drugs	0.5	2	12,500	0.20
Check-out	50,000	Visits	5,000	5,000	10,000	5.00
Billing	150,000	Number of bills per visit	1	2	15,000	10.00
Total costs	<u>\$1,027,500</u>					

Source: Reprinted from Reiter and Song (2021), exhibit 7.4.

EXHIBIT 14.3
ABC Illustration: Final Aggregation of Activity Costs per Visit

Activity	Cost Driver	Rate	Service X		Service Y	
			Consumption	Cost	Consumption	Cost
Check-in	Visit	\$ 5.00	1	\$ 5.00	1	\$ 5.00
Assessment	Number of minutes	1.00	5	5.00	10	10.00
Diagnosis	Number of minutes	2.00	10	20.00	15	30.00
Treatment	Number of minutes	3.00	10	30.00	20	60.00
Prescription	Number of drugs	0.20	0.5	0.10	2	0.40
Check-out	Visits	5.00	1	5.00	1	5.00
Billing	Number of bills	10.00	1	10.00	2	20.00
Cost per service				<u>\$75.10</u>		<u>\$130.40</u>

Source: Reprinted from Reiter and Song (2021).

EXHIBIT 14.4
Use of
Operations
Improvement
Tools to Reduce
Costs

Activity	Improvement Tools	Opportunity
Check-in	Process improvement (Lean and Six Sigma, simulation, etc.) automation	Strong
Assessment	Process improvement	Low
Diagnosis	Evidence-based medicine	Medium
Treatment	Evidence-based medicine	Medium
Prescription	Supply chain management	Strong
Check-out	Process improvement, automation	Strong
Billing	Data mining and analysis, process improvement	Strong

to the use of EBM and the power of clinical decision support systems to support its implementation. Tracking physicians’ variance in their application of EBM provides another useful opportunity for cost reduction.

Shared Savings

shared savings model
A model of healthcare delivery that includes an organized system of delivery, accountability for the quality and costs of services, and a sharing of savings with the payer for these services.

The next higher level of payment is the **shared savings model**, which is most prominently featured in the Affordable Care Act (ACA) as the accountable care organization (ACO). In the initial shared savings model, reimbursement was still made via fee-for-service or bundled payments. However, patients were attributed to the ACO on the basis of their use of primary care providers (e.g., 50 percent of their primary care was provided by an ACO’s primary care team). Costs for all patients were then summed for a period, and if these total costs were less than a target set by the payer, the savings were shared with both providers and payer.

An advantage of the ACO model is that it permits a variety of providers to form new systems of care to deliver services to Medicare beneficiaries. The Centers for Medicare & Medicaid Services (CMS) continue to refine this model to increase provider participation and moderate healthcare costs for Medicare beneficiaries.

Success in the shared savings model requires sophisticated data systems to track patients from a longitudinal perspective beyond each episode of service to ensure that when higher-than-expected costs occur, case managers can intervene. The goal of management in this model is to stay within expected expenses per patient per month while achieving quality benchmarks. This type of challenge is well suited for tools of Six Sigma such as the following:

- Run and control charts
- Pareto diagrams

- Cause-and-effect diagrams
- Scatter plots
- Regression analysis
- Benchmarking

Six Sigma tools are detailed in depth in chapter 9. In addition, the full suite of analytical tools discussed in chapter 8 can be used for this task. The tools of EBM—including chronic disease management, the medical home, comparative effectiveness research, and EHRs with clinical decision support—are also important for implementing the shared savings model.

Full Capitation

The highest level of payment is **full capitation**. This type of arrangement with a payer should only be accepted if the organization has had experience and success with the shared savings model.

If an organization has successfully implemented an ACO-type organization and has a stable provider base and market, it may transition to being a fully state-certified health plan, or a partnership with an existing health plan, to receive full capitation. In this model, the savings or loss per member per month is fully borne by the provider organization.

The key to success in this model is to reduce the use of expensive resources, which can be achieved through disciplined attention to improving systems of care and using the tools contained in earlier chapters to make cost reductions.

full capitation

A methodology in which providers are paid a monthly fee for each patient who receives care in their system.

Quality Bonuses or Penalties

Chapter 3 reviews the use of EBM to define a number of current and anticipated value purchasing measures. The policy emphasis has shifted from paying for volume to paying for value. Because these payment systems are complex and frequently changing, establishing process improvement teams (chapter 6) and using balanced scorecard techniques (chapter 5) are important for healthcare leaders in monitoring results. These project teams can use all the tools of process improvement (Lean, Six Sigma, process simulation) to change procedures for improved results.

Monitoring the results of comparative effectiveness research is important to ensure that the provider is using the most current EBM. The Patient-Centered Outcomes Research Institute (www.pcori.org) is a useful guide for some of the newest discoveries.

Global Payments

The ACA contained a mandate for a demonstration to evaluate the use of global budgets for hospital payments. In this model, the hospital negotiates one annual

payment budget for its services and must keep its costs under this budget—regardless of patient volume or acuity. The global payment model is common in many countries other than the United States. The model has the advantage of predictability for both the payers and providers, and it substantially reduces overhead costs for billing systems. However, increases in patient demand or new technology cannot be easily or quickly accommodated, and in some cases a delay results in queuing for elective services such as hip replacement.

Maryland has created a regulatory system that emulates a global budgeting system and may be a model for the United States. The CMS Innovation Center provides this background:

The Maryland All-Payer Model, launched in 2014, established global budgets for certain Maryland hospitals to reduce Medicare hospital expenditures and improve quality of care for beneficiaries. Global budgets provide hospitals with a fixed amount of revenue for the upcoming year. A global budget encourages hospitals to eliminate unnecessary hospitalizations, among other benefits. Under the All-Payer Model, Maryland achieved significant savings for Medicare and improved quality. However, the Maryland All-Payer Model historically focused solely on the hospital setting, constraining the State's ability to sustain its rate of Medicare savings and quality improvements. The Maryland TCOC Model builds on the success of the Maryland All-Payer Model by creating greater incentives for health care providers to coordinate with each other and provide patient-centered care, and by committing the State to a sustainable growth rate in per capita total cost of care spending for Medicare beneficiaries (CMS 2021).

Maryland is in the process of expanding its models to all providers, and CMS estimates the Maryland system will save Medicare more than \$1 billion by the end of 2023 (CMS 2021).

All of the cost management tools contained in this book are useful to succeed in this environment. However, the following can carry the largest impact:

- Balanced scorecard strategy maps and reporting
- Analytics, benchmarking, and statistical tools to identify opportunities for cost reductions
- Process improvement with Lean and Six Sigma, with a special emphasis on services that develop queues
- Scheduling and capacity management
- Supply chain management

Overhead Expenses

All costs not directly related to revenue are overhead. Several general and specific tools can be used to reduce overhead expenses.

Process Improvement

All of the process improvement tools discussed in this book (chapters 9 through 11) can also be applied to administrative processes in overhead departments. Examples include hiring new employees, conducting marketing campaigns, and processing patient complaints.

Consolidated Activities

Many “miscellaneous” expenses are spread through all departments with no individual in charge of managing their costs. These items can include travel, consulting, and dues fees. By centralizing management costs, savings can be achieved through bidding and the selection of a prime vendor. The various tools of project management, including earned value analysis, can be useful in holding vendors accountable for results and costs—especially for consulting contracts.

Staffing Layers

As organizations grow, close attention should be paid to the layers of management. Symptoms of overlayering include many departmental assistant managers and a proliferation of administrative assistants. These layers can be avoided through the crisp use of strategy maps and scorecards, which are closely linked to the organization’s data warehouse.

Meetings, Reports, and Automation Tools

“Why do I need to go to these meetings? I have real work to do.” This is a familiar complaint from many healthcare workers—especially clinicians. Meetings should be minimized and the discipline of good meeting management maintained at all times (see chapter 5). One step in good meeting management is the evaluation of the meeting itself (usually at the end), and one question that should always be asked is, Do we need this meeting in the future?

Automation of many meeting tasks continues to improve as calendaring and virtual meeting tools grow increasingly sophisticated. However, care must be taken to plan a mix of in-person interactions with completely online activities to maintain cohesive teams.

Historically, many organizations have relied on paper reports that are sent to “management.” These reports should be either automated and emailed or moved to electronic scorecards. The five whys of Lean (see chapter 7) are useful in evaluating reports:

1. Why am I getting this report?
2. Why do you think I need these numbers?
3. Why can’t I use an exception report?

4. Why can't these exceptions be part of a scorecard with an andon indicator (red, yellow, blue)?
5. Why can't the scorecard include a follow-up task with assigned accountability?

Facility and Capital Costs

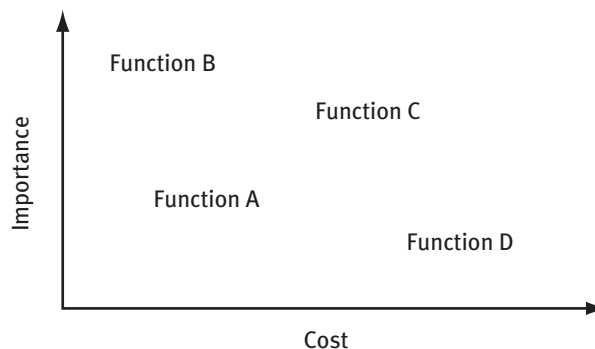
The acquisition and deployment of capital is beyond the scope of this textbook. However, evaluating the use of facilities can offer a significant opportunity for cost reduction. The increased use of digital health has decreased the need for hospital beds and new, expensive “bricks and mortar.” Optimizing use of the remaining clinical space is best exercised with the patient flow improvement tools in chapter 11. In addition, storage space can be minimized by the effective application of the Lean tool known as 5S (chapter 10).

Administrative space should be evaluated to discern whether employees need to be onsite. Many organizations have developed effective work-at-home policies for employees with high-speed internet access. A half-step toward completely working at home is *hoteling*. In this model, the employee works most of her time at home but comes to the office one or two days per week. When she is at the office, she is assigned a workspace in the same way hotel rooms are managed. Hoteling can save up to 80 percent of the space otherwise required for these employees.

Prioritized Departmental Activities

The most aggressive cost-reduction technique in a department is to eliminate an existing function. A useful approach is to create a cost/importance chart, as shown in exhibit 14.5. The location of each function dictates whether it may be eliminated. The vertical axis is the importance of a function to accomplishing a department's mission.

EXHIBIT 14.5
Cost/
Importance
Chart



The horizontal axis is the cost of the function. ABC is a useful costing method for these determinations, as most overhead budgets lump costs into basic expense types (e.g., personnel, supplies, services, miscellaneous). Once the chart is complete, managers may target high-cost, low-importance functions for reduction or elimination (function D in exhibit 14.5).

Revenue

The primary focus of this chapter is on cost reduction, but opportunities also exist for improving revenue through the use of operations management tools. Because of the complexity of the US healthcare reimbursement system, many of the analytical tools in this book can be applied to optimizing the cycle of billing and collection of charges. For example, Six Sigma in particular is a useful approach, as its goal is to reduce the variability of outcomes in processes. This method can be used to minimize the variance in the eventual payment amount and receipt time for the same service.

Linking All Cost and Revenue Models Together

Because many opportunities exist for financial improvement, prioritizing improvement efforts is useful. To assist in this task, build a financial model to understand the impact of various improvement projects. Exhibit 14.6 is a simplified financial model for a medium-sized hospital.

As discussed, the revenue is split into its components and associated costs determined on the basis of a ratio of costs to charges. The baseline improvement column in exhibit 14.6 shows possible percentage improvements in each segment. Cells D5 to D10 (highlighted) are the variables that affect the bottom line—cell 37 (highlighted at bottom of exhibit). The user can manually test different improvement strategies to assess their effect on the bottom line.

Solver is a powerful tool for determining the optimal mix of strategies. However, its parameters must be set to ensure its recommended improvement percentages are achievable.

Exhibit 14.7 shows the results of a Solver run with pure fee-for-service savings allowed up to 30 percent. The Solver results suggest that this 10 percent increase in improvement from baseline is more important than either the DRG or bundled savings. This outcome is logical because these payment bundles are built out of the fee-for-service costs.

Conclusion

We have placed this chapter near the end of this book, as we feel that cost containment is the predominant challenge for healthcare executives in the

EXHIBIT 14.6
Hospital
Financial Model

IMPROVEMENTS					
Baseline	Amount (\$)	Cost/charge	Solver	Baseline	Notes
<i>Revenue</i>					
Pure fee-for-service	50	0.4	20%	20%	Improvement reduces cost per service
DRG	100	0.8	10%	10%	Improvement reduces number of services
Bundled	10	0.9	5%	5%	Improvement reduces number of services
Shared savings	20	0.9	5%	5%	Improvement reduces number of services
Capitation	40	0.95	3%	3%	Improvement reduces number of services
Overhead	50		1%	1%	Improvement reduces direct costs
Model					
<i>Revenue</i>					
Pure fee-for-service	50.0	50.0			
DRG	100.0	90.0			
Bundled	10.0	9.5			
Shared savings	20.0	20.0			
Capitation	<u>40.0</u>	<u>40.0</u>			
Total	220.0	209.5	207.3		
<i>Costs</i>					
Pure fee-for-service	20.0	16.0			
DRG	80.0	57.6			
Bundled	9.0	6.8			
Shared savings	18.0	13.0			
Capitation	38.0	27.4			
Overhead	<u>50.0</u>	<u>49.5</u>			
Total	215.0	170.3	170.3		
Net	5.0	39.2	39.2		

Note: DRG = diagnosis-related group.

Get External Data Connections Sort & Filter Data Tools Outline Analysis															
M46 fx =D24.D35															
1	Hospital Financial model														
2															
3	Baseline	Amount \$	Cost/charge	Solver	Baseline	Notes									
4	Bundled					Improvement reduces cost per service									
5	Pure Fee for Service	50	0.4	30%	20%	Improvement reduces number of services									
6	DRG	100	0.8	0%	10%	Improvement reduces number of services									
7	Bundled	10	0.9	0%	5%	Improvement reduces number of services and includes reduced DRGs and improved cost/service									
8	Shared Savings	20	0.9	5%	5%	Improvement reduces number of services and includes reduced DRGs and improved cost/service									
9	Capitation	40	0.95	3%	3%										
10				0	0										
11	Overhead	50		2%	1%										
12															
13															
14															
15															
16															
17	Model														
18	Revenue														
19	Pure Fee for Service	50.0			50.0										
20	DRG	100.0			100.0										
21	Bundled	10.0			10.0										
22	Shared Savings	20.0			20.0										
23	Capitation	40.0			40.0										
24	Total	220.0			220.0	207.3									
25															
26	Costs														
27	Pure Fee for Service	20.0			14.0										
28	DRG	80.0			56.0										
29	Bundled	9.0			6.3										
30	Shared Savings	18.0			12.6										
31	Capitation	38.0			25.6										
32															
33	Overhead	50.0			49.0										
34															
35	Total	215.0			164.5	170.3									
36															
37	Net	5.0			55.8	39.2									
38															
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46															

EXHIBIT 14.7
Hospital
Financial Model
Using Solver
to Prioritize
Financial
Improvement
Projects

United States and throughout the world. As medical technology improves, cost pressures will only increase. And yet we know that the widespread use of the principles discussed in this chapter, supported by the application of the tools and techniques discussed throughout this book, can stabilize or reduce healthcare inflation. Furthermore, it can be done, as we have demonstrated throughout the book with our “Operations Management in Action” examples. Cost management with improved financial performance is an achievable goal for organizations willing to engage with discipline and energy.

Discussion Questions

1. Why do other payers use Medicare as the benchmark for payment? What are other options?
2. How important is it to involve physicians in financial improvement efforts? What is the best strategy for physician engagement?
3. Compare and contrast the following three organizational approaches to financial management using operations management tools:
 - a. A centralized department that has experts (Six Sigma black belts) on staff who charter and lead projects throughout an organization

- b. A centralized department that only conducts training in process improvement and maintains the project management office; all projects are led by line staff who have been trained in process improvement tools
- c. The use of consultants to lead process improvement projects

Exercises



On the web at
[ache.org/books/OpsManagement4](https://www.ache.org/books/OpsManagement4)

1. Use the financial model discussed in exhibit 14.6 (available on the book's companion website) to find alternative priorities for financial improvement.
2. Develop a project charter for a bundled payment financial improvement project (see chapter 5).

Note

1. This section is excerpted and adapted from Goodnow (2015). Used with permission.

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PUTTING IT ALL TOGETHER FOR OPERATIONAL EXCELLENCE

EMERGING TRENDS IN HEALTHCARE

Operations Management in Action

Healthcare delivery is set to undergo a transformation driven by technological innovation, which is also facilitating the emergence of new care delivery models. The use cases for these innovations are varied and pilots are already underway. A few examples include use of prescription chatbots using natural language processing (e.g., Woebot) to assist mental health patients; use of health mirrors to measure, track, and monitor patient vitals; robotic delivery of food and services to COVID-19 patients (e.g., BeamPro in Singapore) to prevent disease spread; Mayo Clinic's use of autonomously driven vehicles to deliver coronavirus nasal swab tests across their medical campus; and Zipline's initiative to use drones for COVID-19 vaccine delivery in the rural United States as well as in African countries such as Rwanda, Ghana, and Nigeria.

OVERVIEW

Advancements in technology and emergence of new care delivery models hold the potential to make substantial changes to healthcare delivery. In this chapter we discuss some of these emerging trends and their applications. The major topics covered in this chapter include the following:

- Patient-centered care
- Blockchain and decentralized applications in healthcare
- Virtual care
- Home health
- Care providers' involvement in population health
- Other advancements in healthcare, including artificial intelligence and machine learning, digital therapeutics, Internet of Medical Things, virtual and augmented reality, computer vision and image processing, facial recognition, medical chatbots, robotic process automation, cobots, 3D printing, autonomous vehicles, and drones

Introduction

Innovations in healthcare through alternative care delivery models and technological advancements are changing the care delivery landscape. These innovations hold the potential to advance care delivery through improved processes, enhanced productivity, cost efficiencies, and improved quality. We discuss some of the prominent emerging trends in this chapter.

Patient-Centered Care

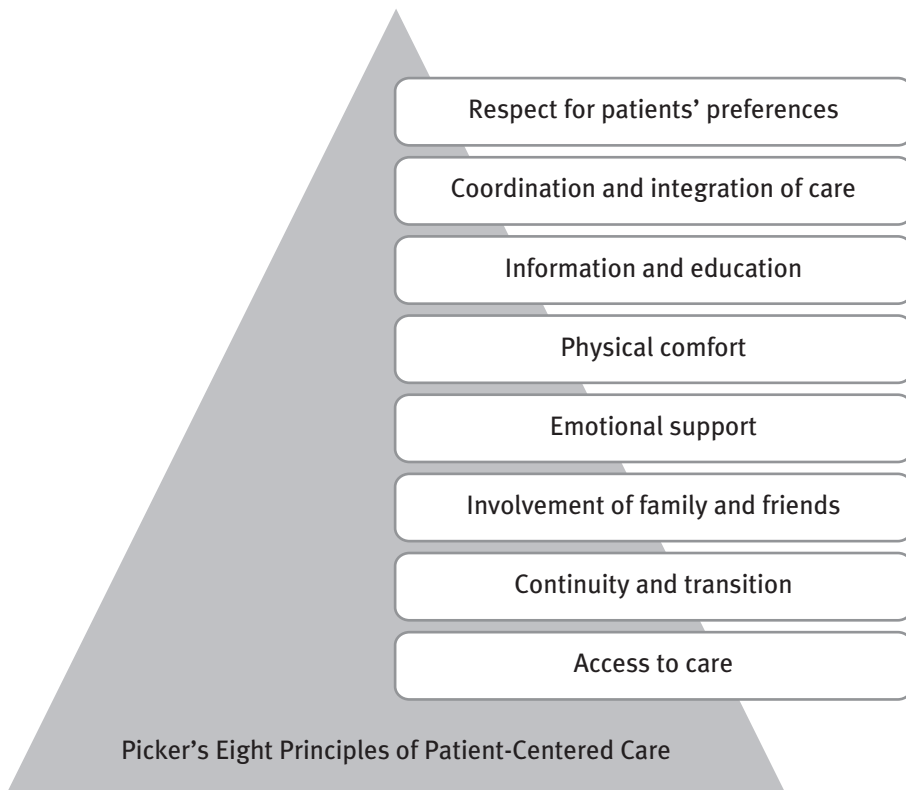
The Institute of Medicine defines patient-centered care as “providing care that is respectful of, and responsive to, individual patient preferences, needs and values, and ensuring that patient values guide all clinical decisions” (Wolfe 2001).

Supporting patient-centered care requires a different philosophy for care delivery and changes in multiple aspects of hospital operations. Exhibit 15.1 highlights key differences between traditional and patient-centered care delivery models. The greatest difference lies in the care delivery approach, which in the traditional model is based on episodes of care, but is more holistic and integrated in the patient-centered care delivery model.

The key dimensions of patient-centered care are captured in the framework proposed by Harvard Medical School, on behalf of the Picker Institute

EXHIBIT 15.1
Key Differences
Between the
Traditional
and Patient-
Centered Care
Delivery Models

	Traditional Care Delivery Model	Patient-Centered Care Delivery Model
Care delivery philosophy	Disease-centric approach where care delivery is focused on addressing individual episodes of care.	Holistic and integrated care delivery focused on improving the overall health, well-being, and quality of life of the patient.
Patient’s role	Patient plays a passive role, often following the treatment plan prepared by caregivers.	Patient plays an active role in their care, often a co-creator in the treatment plan.
Care provider’s role	Primary determinant of the treatment plan based on best generalized clinical guidelines available.	Collaborates with the patient to determine a customized treatment plan that accounts for the best available clinical guidelines and patient needs.
Healthcare organization’s role	Less need for coordination of care.	Higher need for coordination of care, necessitating integration and collaboration between different levels of care delivery.
Family participation	Family members play a passive role in patient’s care delivery.	Family participation in developing patient’s treatment plan and family caregiving is encouraged.
Outcomes	Potential lower adherence to treatment plan.	Patient has a better understanding and higher likelihood of adherence to their treatment plan, resulting in improved clinical outcomes and quality of life.

EXHIBIT 15.2
Dimensions
of Patient-
Centered Care

Source: Reprinted from Barrett et al. (2019).

and the Commonwealth Fund. This framework is demonstrated in exhibit 15.2, and the dimensions are discussed here:

1. *Respect for patient preferences:* This dimension encourages the involvement of patients in clinical decision making, a respect for their preferences, and customization of care given their unique situation and preferences.
2. *Coordination and integration of care:* This dimension encourages coordination of clinical care, transitions of care within and across care providers.
3. *Information and education:* This dimension encourages keeping patients abreast of their clinical progress, instructions on self- and postdischarge care for better quality of life.
4. *Patient comfort:* This dimension encourages ensuring physical comfort of patients during their hospital stay through pain management, assistance with daily activities, and a pleasant hospital environment.

5. *Emotional support*: This dimension encourages actions to support patients through the anxiety of treatment, post-treatment quality of life, and financial impact of treatment.
6. *Involvement of family and friends*: This dimension encourages involvement of family members in clinical decisions, accommodating them during hospital stays and involving them in postdischarge care education.
7. *Continuity and transition*: This dimension encourages providing patients with customized instructions on postdischarge care, coordination of care after discharge, and access to resources for questions about access to care, support groups, and resources for financial support.
8. *Access to care*: This dimension encourages providing clear instructions on the types of care delivery options available to patients, how to access them, and resources to guide them through the process of seeking care.

Establishing patient-centered care requires operational changes in key dimensions of care delivery: clinical care (i.e., the clinical dimension), interactions with patients (i.e., the interpersonal dimension), and hospital environment (i.e., the structural dimension). *Clinical care* focuses on areas like developing customized care, holistic care, coordination, and continuity of care. *Interactions with patients* concerns areas like effective and empathetic communication between caregivers and patients, as well as a need to understand the unique needs and constraints of the patient. Effective communication between caregivers and patients not only improves patient satisfaction but also has been associated with improved clinical outcomes, like reduced readmissions. Last, *hospital environment* addresses structural elements that influence a patient's experience: hospital room design, location of patient services, format of clinical information, appointment scheduling and waits, and ease and flexibility of payment options. Exhibit 15.3 shows a summary of key operational decisions.

Blockchain and Decentralized Applications in Healthcare

Blockchain is a decentralized distributed ledger: a data repository that is synchronized and stored in multiple separated geographical locations. Data can be added to and retrieved from a blockchain by authorized users with a cryptographic key. Decentralized applications (DApps) are software solutions that rely on blockchains for data storage and build programmatic logic to develop context-specific solutions. DApps have multiple unique characteristics that are beneficial in healthcare settings, including interoperability, data security,

EXHIBIT 15.3
Key Operational
Decisions
Impacting
Patient-
Centered Care

Interpersonal dimension (relationship)	Clinical dimension (provision of care)	Structural dimension (system features)
Communication Begins with listening Creates a fabric of trust Promotes clear, empathic communication, tailored to patients' needs and abilities Welcomes participation of family, friends, and caregivers	Clinical decision support Ensures shared decision making on the basis of best-available evidence coupled with patient preferences Supports self-management	Built environment Provides calm, welcoming space Accommodates patient, clinician and family needs Emphasizes easy "Way-finding" and navigation through the system
Knowing the patient Uses knowledge of patient as a whole and unique person for effective interactions Finds common ground on the basis of patient preferences Facilitates healing relationships	Coordination and continuity Manages care transitions and seamless flow of information—whether for a broken arm or life-altering illness Coordinates with community resources	Access to care Eases appointment-making process Minimizes clinic wait times Payment system accommodates patients' circumstances Coordinated, consistent, efficient
Importance of teams Ensures responsiveness by entire care team to patient and family needs Recognizes that actions of both clinicians and staff can influence perceptions of care	Type of encounters Accommodates virtual visits (Phone, email) as well as in-office visits Reimbursement structure supports range of encounters that meet patients' varied needs	Information technology Supports patient and clinician before, during, and after encounters Tracks patients' preferences, values, and needs dynamically Provides self-management tools and information

Source: Reprinted from Greene, Tuzzio, and Cherkin (2012).

cost-effective data access, patient data ownership, privacy, and smart contracts. These features have the promise to reduce cost and promote patient-centered care in healthcare settings. In what follows, we discuss some of the key features of DApps and their impact on healthcare operations. We conclude with examples of DApps for the healthcare sector.

As discussed, patient-centered care has a goal of providing individualized and holistic care to patients through coordination among care providers,

patients, and their families. DApps can promote patient-centered care while reducing costs of healthcare delivery—often considered competing objectives—through the unique characteristics of blockchain. For example, the decentralized nature of the blockchain ledger inherently promotes interoperability among participating organizations. This eliminates the need for interface design, often required for data exchange among the health information technology (HIT) systems of hospitals, thus reducing costs and improving the speed of access to patient data.

The distributed ledger and immutable nature of blockchain transactions improve data security. Once data are entered in a blockchain ledger, they cannot be altered or deleted, thus creating a permanent transaction history. This can potentially solve the challenges of creating a comprehensive patient history, which in the current US healthcare system is stored in HIT systems of different care providers. Lack of a universal medical ID often necessitates probabilistic matching of these disparate records on patient characteristics to create a comprehensive patient history. The distributed nature of the blockchain ledger also makes large-scale hacking and unauthorized modification of data practically impossible. Unlike with centralized databases, tampering with blockchain ledgers would require access to numerous users' private cryptographic keys and the simultaneous updating of all geographically dispersed copies of the ledger. Hence, the use of DApps can improve care delivery and reduce costs because they offer easier access to a comprehensive patient history and higher data security.

A blockchain ledger can potentially transfer the ownership of data to patients. A DApp can be designed where patients have ownership of their medical history and grant access to providers through shared keys to update their medical records after any event. Such ownership can result in a more empowered and engaged patient—both critical factors influencing patient-centered care.

Last, DApps have the capability to enforce customized micro-contracts between stakeholders in the care delivery process. Such so-called smart contracts are executable functions that are automatically triggered when certain conditions are met (Olsen and Tomlin 2020). An example would be customized payments to providers, which are automatically launched by the clinical outcomes of the care delivery episode. Thus, smart contracts can improve business process efficiency through faster transaction execution, reduced need for manual contract vetting, and individually customized outcomes. Combined, these benefits reduce costs and expand patient-centered care delivery.

Several DApps are under development, targeting different stakeholders involved in the care delivery process. For a detailed review of such DApps, see Sharma et al. (2021). Two examples related to electronic medical records and remote medicine follow.

Electronic Medical Records

Patients may receive care at different provider locations, which generally use different HITs for recordkeeping. These HITs are often not fully compatible, which makes interoperability a challenge, often requiring manual reconciliation and entry of patient information to create a complete medical history. Additionally, housing patient data in centralized databases with access to multiple individuals in the organization increases data privacy and security concerns.

A number of DApps attempt to address these challenges using different approaches. For example, MedRec, a project being jointly developed by MIT and the Beth Israel Medical Center, is developing a decentralized ledger for patient medical records where data integrity is validated at the point of entry and caregivers with authorized cryptographic keys can access medical records. Similarly, Google, in collaboration with the National Health Service, is developing a decentralized ledger to manage patient medical records, which can be shared across multiple hospitals.

Remote Medicine

A key challenge for hospitals is to extend care for chronic disease patients in remote settings. This type of care involves remote vital signs monitoring, consultations, postdischarge care, and ensuring adherence to postdischarge instructions. Among the DApps targeting this challenge is the Hippocrates DApp, which allows patients and providers to discuss dermatology-related conditions, with integrated payment services using their MEDX tokens (the platform currency for this DApp). Similarly, ScriptDrop is creating a DApp for tracking medication adherence. Data thus collected can be shared with providers in real time, allowing them to design appropriate interventions and customized care delivery plans.

Virtual Care

Access to healthcare is evaluated on five dimensions: affordability, availability, accessibility, accommodation, and acceptability (McLaughlin and Wyszewianski 2002), called the five As of access to care. According to a 2017 World Health Organization and World Bank report, about 50 percent of the world's population lacked access to essential healthcare services. Healthcare access is a major concern even in developed countries like the United States, where about 33 percent of adults go without recommended care over cost concerns. This number has increased following the COVID-19 pandemic, primarily driven by the reallocation of already constrained healthcare resources toward managing the outbreak. Virtual care has the promise to improve healthcare access, especially for rural and low-income communities, as well as high risk and older populations with reduced mobility.

Virtual care refers to a holistic and comprehensive system of technology-enabled care delivery, which removes constraints on the location and time of care. Virtual care relies on software solutions like chatbots, text-based messaging, sensors, the Internet of Medical Things (IoMT), telemedicine, and the like to provide a comprehensive set of care delivery services to patients, including virtual consultations, asynchronous visits, and remote monitoring and adherence tracking. The scientific evidence on the effectiveness of virtual care is evolving but largely positive. Compared to conventional care delivery settings, virtual care demonstrates improved clinical outcomes, reduced cost of care, and higher utilization of healthcare resources, as well as high levels of patient satisfaction. Virtual care also adds a level of convenience for patients, especially those living in rural areas who face acute provider shortages and must travel long distances to access care.

According to a report published by McKinsey & Company (Fowkes et al. 2020), there are multiple virtual care solutions that cater to different patient needs. As evident from exhibit 15.4, virtual care solutions cover a host of functions, including tracking patient adherence to medication, vital signs monitoring, day-to-day activity and lifestyle monitoring for chronic disease patients, location- and time-independent consultation, and capturing or transmitting data from patient lab tests or scans to a physician for an offline assessment.

Home Health

Although virtual care is technology-enabled care provided in a home setting, *home health* involves in-person interactions between the care providers and patients in their home setting. Home health constituted more than 40 percent of care delivered in the US in the 1930s, but declined dramatically to less than 1 percent in the 1980s. This decline was attributed to increased liability claims on providers, poor reimbursements for home visitations, and an increased reliance on evidence-based decision making, which necessitated the use of lab tests, X-rays, ultrasounds, and the like in primary care settings.

In the first decades of the 21st century, home health has seen a resurgence, with caregiver home visits in 2016 more than doubling compared to 1996 and expected to continue growing. One in five US individuals are estimated to be recipients of home health services by 2030 (Schuchman, Fain, and Cornwell 2018). Several factors have supported this resurgence, including an aging demographic, increasing prevalence of chronic diseases, improved reimbursement for home visits, and technological advancements that have miniaturized commonly used medical devices. We discuss these factors in detail next.

One key motivator driving growth in home health is a rapidly aging population. Currently Americans aged 85 years or older are the fastest-growing

EXHIBIT 15.4
 Virtual Care
 Solutions Based
 on Patient
 Needs

Category	Subcategory	Definition
Telehealth	Synchronous (telemedicine)	Live, two-way audiovisual interaction between patients and providers (e.g., video conference visits) Live, two-way interaction between providers and providers (e.g., video conference review of pharmacy prescriptions)
	Asynchronous (store and forward)	Provider-to-provider transmission of recorded health history (e.g., sending a lab test, X-ray, MRI, to a specialist to request a clinical opinion) Provider-to-patient transmission of patient information (e.g., a provider emailing/texting a patient to check on them in post-visit follow-up, a patient sharing photos of a skin rash for review and diagnosis)
	Remote patient monitoring	Collection of electronic personal health/medical data, which is transmitted for review by a remote provider
Digital therapeutics	Replacement therapies	Evidenced-based therapeutic interventions, which leverage software to prevent, manage, or treat a medical condition, in lieu of conventional treatments (e.g., pharmaceuticals)
	Treatment optimization	Optimizes medication, extending the value of pharmaceutical treatments (e.g., improving medication adherence, monitoring side effects of medication)
Care navigation	Patient self-directed care	Patients accessing their own information (e.g., website with secure, 24-hour access to personal health information)
	E-triage	Tools that provide support in searching for and scheduling appropriate care-based on symptoms/conditions as well as price quality of providers

Source: Exhibit from “Virtual Health: A Look at the Next Frontier of Care Delivery,” June 2020, McKinsey & Company, www.mckinsey.com. Copyright © 2021 McKinsey & Company. All rights reserved. Reprinted by permission.

age group in the United States, with about 50 percent projected to require assistance with at least one activity of daily living (ADL). In addition, chronic disease prevalence has increased manifold in the past century, with 60 percent of Americans living with a chronic disease as of 2020. Chronic disease management

may involve vital signs monitoring, medication and therapy reminders, and help with ADLs. Combined, aging and chronic disease drive rising demand for home health.

Legislative actions and changes in reimbursement policies have also supported a growth in home health. The shift toward value-based care and more patient-centric care delivery models have further increased its use. Offering home health to patients with limited mobility, for instance, is a more patient-centric approach. Additionally, offering home health during the postdischarge transition period has been shown to reduce hospital readmissions by up to 50 percent (Naylor et al. 1999), which carries monetary benefits for hospitals under the Hospital Readmissions Reduction Program. Additionally, reimbursements for home health have improved. For example, in 1996, home visits paid only \$3 more than office visits for Medicare-insured patients. Since then, home health charges have more than doubled, outpacing the charges for office visits and Medicare, and adding additional reimbursements for more complex care-delivery activities performed during home visits (Landers et al. 2005; Schuchman, Fain, and Cornwell 2018).

Home-based care of greater complexity has been enabled by technological advancements. For example, a patient's medical records can be accessed and updated securely using an electronic health records app on a caregiver's smartphone. Common lab and phlebotomy tests can be performed using use-and-throw kits or portable blood centrifuges. Portable X-ray and ultrasound services are also available from multiple medical device providers, and smartphones can now serve as an electrocardiogram machine or ultrasound console for quick diagnostics.

Home health programs differ significantly in terms of their intensity of interaction with patients and the longevity of the association. The following are some commonly used settings for home care:

- *Episodic care*: Designed to provide one-off, often noncritical episodes of care. A good example is Heal.com, which offers home visits by caregivers for a fixed, up-front payment.
- *Long-term assistance services*: Involves multiple home health visitations to care for patients with chronic diseases or limited mobility, or those requiring end-of-life care.
- *Rehabilitative services*: Also involves multiple visitations, but generally fewer than for long-term assistance. This service helps patients with recovery following an injury, illness, or surgery.
- *Transition care*: Designed for patients' transition to normal life postsurgery for a chronic condition (e.g., kidney transplant) and to reduce readmissions. This type of care is also for a shorter duration compared to long-term assistance services, but requires caregivers

who are knowledgeable about the patient's specific condition and postdischarge care. Services include assistance with medication adherence, postdischarge instructions adherence, and teaching.

- *Nonclinical care:* Focuses on personal care, companion care, and travel companion services for older individuals with limited mobility.

Care Providers' Involvement in Population Health

A growing body of literature has linked an individual's medical condition to nonmedical determinants such as social and behavioral factors. To improve population health and reduce their care burden, hospitals are increasing their community involvement to influence these determinants. Participation in population health enables hospitals not only to influence nonmedical determinants of health but also to provide preventive care to their target communities. Combined, these factors can reduce chronic disease rates in their communities.

A big motivation for hospital involvement in population health is an emphasis on value-based care. Under value-based care, hospital reimbursements are based on outcomes of care delivery, which encourages a holistic approach to improving patient health, rather than focusing on individual episodes of care.

Hospitals have taken different approaches to community involvement:

- *Coordination of care:* Improving population health involves educating people to receive the right care at the right time and place. This requires collaboration among care providers within and across hospital boundaries. Initiatives could include partnerships with insurance providers to encourage primary care; teamwork among in-hospital care providers to educate patients about nonmedical determinants of health and the importance of preventive care; and collaborations with clinics, urgent care centers, and other hospitals to ensure community access to the appropriate level of care. Benefits of patient education and a coordinated care approach include reduced emergency visits for noncritical conditions and fewer readmissions.
- *Collaboration with community employers:* Such collaboration could involve setting up onsite employee education events, preventive screenings, and health clinics.
- *Collaborations with community service organizations:* Entities like food banks, soup kitchens, schools, and churches are embedded in local communities and have a good understanding of their patrons' needs. Partnering with such organizations to educate the community on nonmedical determinants of health and conducting preventive screening events can help reach the most vulnerable populations.

- *Collaborations with government agencies:* Hospitals conducting community health assessments and working with government agencies to enact policies that target identified shortfalls can improve the effectiveness of legislative directives.

Other Advancements in Healthcare

Artificial Intelligence and Machine Learning

Machine learning enables systems to automatically upgrade their algorithms using artificial intelligence. The technology has multiple applications in health-care that can improve processes through automation, decision support, and reduced handoffs. On the clinical side, machine learning can provide better decision support by leveraging and learning from the volumes of patient data collected by hospitals, not only alleviating caregiver workload but also improving clinical care. For administrators, artificial intelligence can automate routine tasks like preauthorization of patients, appointment scheduling, and follow-ups on late payments. Such automation will not only lower costs and improve efficiency, but also reduce manual errors.

Digital Therapeutics

The Digital Therapeutics Alliance defines *digital therapeutics* as the delivery of “evidence-based therapeutic interventions to patients that are driven by high quality software programs to prevent, manage, or treat a medical disorder or disease” (Burrone, Graham, and Bevan 2020). A common example of digital therapeutics are mobile apps that connect with wearable devices to track patient health data and, after analyzing it, offer behavioral recommendations to promote healthier lifestyles. Digital therapeutics also is increasingly being used to manage psychiatric conditions, help overcome addictions, and provide support to patients undergoing treatment/postdischarge care. In addition to providing immediate and convenient support to patients (i.e., without the need to make a provider appointment) digital therapeutics also alleviate workload on an already stressed healthcare system.

Internet of Medical Things

The IoMT refers to a system of connected medical devices, sensors, and software applications capable of collecting, analyzing, and transmitting patient health data among themselves and to a care provider network. IoMT enables remote patient monitoring, reducing the need for routine medical visits while providing real-time data on patient vitals. An example of IoMT-enabled development is *smart pills*: pills containing microscopic sensors, activated once swallowed, that can transmit patient data to networked medical devices. These features

have the potential to reduce cost while improving patient care both in the hospital and at home.

Virtual and Augmented Reality

Whereas augmented reality (AR) enhances the existing environment of the individual engaging in the experience, virtual reality (VR) provides a completely immersive experience where the entire environment and all actions are generated within the VR headset. AR and VR are being used to educate patients and caregivers. A common application of VR is simulating a surgery environment for physician training. AR has been used to enhance surgical environments by displaying live patient-vitals data in the physician's field of vision. These technologies can lower training costs, reduce medical errors, and improve care delivery outcomes.

Computer Vision and Image Processing

Healthcare relies heavily on scans of organs for diagnosis, in which medical professionals review these images for patterns associated with a given medical condition. This is where computer vision is helpful, because it relies on artificial intelligence and machine learning to train computers in analyzing and identifying such patterns. Computer-vision-aided analysis of medical scans is both faster and aids earlier symptom detection. Hence, the use of computer vision can help reduce caregiver workload while improving diagnosis quality.

Facial Recognition

Facial recognition is an application of computer vision to identification of faces and expressions. This technology has been used in healthcare settings for activities like patient check-ins, disease diagnosis, and emotion tracking. Facial recognition can facilitate check-ins by matching a patient's face against the hospital database, which prevents impersonation, reduces staffing burden, and readies the patient's file for caregiver review. Facial recognition technology embedded in *health mirrors* uses light to measure an individual's vital signs like blood pressure, heart rate, and stress levels, thus facilitating early disease diagnosis. Additionally, facial recognition can be used to track emotions of patients with mental disorders, easing timely interventions.

Medical Chatbots

Medical chatbots are software programs that use machine learning and natural language processing to provide real-time assistance to patients. Three types of medical chatbots are commonly used, each with different levels of sophistication: information chatbots, which provide information via prerecorded responses; conversational chatbots, which offer more personalized responses to specific patient queries; and prescriptive chatbots, which provide solutions for specific

patient conditions. Medical chatbots provide a convenient way for patients to access relevant medical information, thereby avoiding office visits for minor medical conditions while reducing caregiver workload and cost.

Robotic Process Automation

Robotic process automation (RPA) is a software-enabled process that streamlines processes by automating task execution (e.g., moving files, filling out forms, sending notifications). A number of clinical and administrative workflows can be automated using RPA, saving time and money while improving process efficiency. For example, RPA can automatically integrate data on patient profiles and medical procedures to generate insurance claims for review and filing, thus streamlining claim processing.

Cobots

Although robots are used in heavy-duty production settings involving rapid movements and tasks in often isolated environments, cobots have slower movements and are designed to work directly with people. Cobots have multiple applications in healthcare, ranging from taking care of older patients and people with disabilities to rehabilitating patients and assisting caregivers with clinical care. For example, Alexandra Hospital in Singapore is using a cobot called BeamPro to deliver food and medicines to patients diagnosed with COVID-19. Similarly, the Patient@Home Project in Denmark uses cobots made by Universal Robots to rehabilitate patients with stroke-related injuries.

3D Printing

3D printing is a technology that enables printing of three-dimensional objects from commercially available printers. Such printers are increasingly being used in healthcare; applications include localized printing of medical equipment, bioprinting, and precision medicine. During the COVID-19 pandemic, when supply chain disruptions and increased demand resulted in shortfalls of personal protective equipment, 3D printers were used to produce scarce gear (e.g., face shields). Bioprinting involves 3D printing of soft biomaterials and has been used to create simple organs (e.g., bladders) for transplant purposes. Additionally, use of 3D printing in pharmacies can enable preparation of medicine personalized to patients' age, gender, weight, and other factors.

Autonomous Vehicles and Drones

These uncrewed transportation options can be used by healthcare organizations to move patients, medical supplies, and samples. They can improve healthcare access during times of crisis or for rural communities, older patients, and individuals without transportation. In addition to transporting patients,

autonomous vehicles can be designed to connect with patients' wearable devices, collecting data en route and feeding it to the hospital's cloud server using the IoMT—thus improving response times when patients arrive at the hospital. Drones can deliver medicines, transport blood samples, and even be equipped with medical devices like a defibrillator, which may prove helpful during an emergency response.

Conclusion

Technological advancements and recent legislative actions are changing health-care delivery and inspiring new business models. Although the use cases for these advancements are clear, they are still in their infancy. Hospital management should take steps to keep abreast of such advancements and be prepared to implement them when a suitable use case arises and business value is identified. It is safe to assume that healthcare delivery in the near future will be significantly different compared to its current state.

Discussion Questions

1. Have you witnessed any of the emerging trends and technologies discussed in this chapter at your organization? Discuss your experience.
2. Can you foresee any of the emerging technologies discussed in this chapter being applied to streamline processes at your workplace? Discuss the road map and challenges with such an implementation.

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HOLDING THE GAINS

A strategy for holding the gains must be developed at the beginning of any operations improvement effort. Human resources (HR) planning, managerial accounting, and control systems are the keys to maintaining the gains. Although this book is not focused primarily on HR or finance, these functions are essential to sustaining the improvements achieved. Staff from these support departments should be engaged at the beginning of operations improvement activities and invited to be part of project teams if possible.

Approaches to Holding Gains

In this section, we introduce the three approaches; later in the chapter, we discuss them in the context of a general algorithm for using operations management tools. More extensive information related to these functional areas can be found in *Human Resources in Healthcare: Managing for Success* (Sampson and Fried 2021) and *Healthcare Finance: An Introduction to Accounting and Financial Management* (Reiter and Song 2021).

Human Resources Planning

Many of the project management and process improvement tools described in this book can bring major change in the work lives of a healthcare organization's

OVERVIEW

This chapter concludes the book and integrates its concepts. The chapter includes

- three strategies to maintain the gains in operational improvement projects, both short term and in the future: human resources planning, managerial accounting, and control systems;
- an algorithm that assists practitioners in choosing and applying the tools, techniques, and methods described in this book;
- an examination of how Vincent Valley Hospital and Health System uses the tools for operational excellence; and
- a look at an optimized healthcare delivery system of the future.

The preceding chapters presented an integrated approach to achieving operational excellence. First, strategy execution and change management systems must be well developed. Next, the balanced scorecard and formal project management techniques are effective methods to employ in these key organizational challenges.

The third step is the application of quantitative tools to meet those challenges, such as state-of-the-art data collection and analytics tools, and problem-solving and decision-making techniques. Processes and scheduling systems can be improved with Six Sigma and Lean. Supply chain techniques help maximize value and minimize costs in operations.

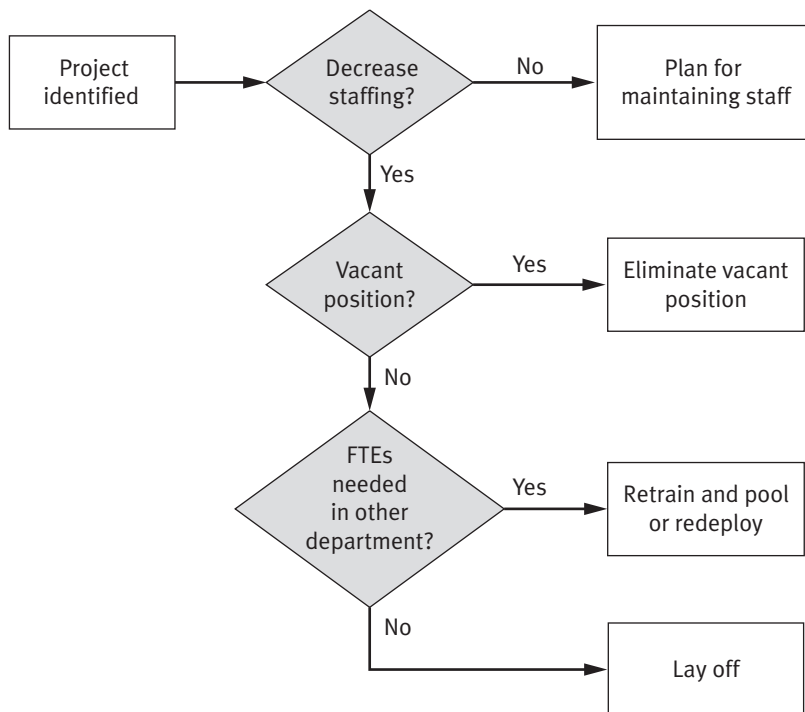
The final step in achieving healthcare operations excellence is to hold the gains. Staff and leadership energy is usually high when an initiative is introduced, at the start of a large project, or at the beginning of an effort to solve a problem. However, as time passes, new priorities emerge, team members change, and operations can drift back to unsatisfactory levels.

employees. Employees will use these tools in the process of their work, with the hope of making that work productive and fulfilling. Some of the more powerful tools, such as Lean and Six Sigma, can provide major productivity gains—in some cases, by 30 percent to 60 percent. A clinical process improvement project may significantly alter the tasks that fill an employee's workday. In this environment, a disciplined plan for employee redeployment or retraining is essential. Many healthcare organizations fail at this critical step, as they lack processes to capture and maintain gains in productivity and quality improvement. Although this connection may not be readily apparent, the presence of such a plan aids in an organization's ability to hold its improvement gains.

As part of the executive function of a healthcare organization, the HR department serves as a strategic partner in making effective and long-lasting change. During each annual planning cycle, strategic projects to further the goals of the organization are identified. Many of these initiatives become part of the balanced scorecard. At this point, the HR department should be included to undertake planning to place the right person in the right job at the right time. This process is shown in exhibit 16.1.

The HR staff need to estimate the impact of each project or initiative that will be undertaken during the year. If the project has a goal of providing more

EXHIBIT 16.1
Process for HR
Planning



Note: FTE = full-time equivalent.

service with the same number of staff members, HR's task will be to maintain this staffing level. Broader HR planning can now occur, such as tracking the availability of workers for these positions in external labor pools or identifying and training existing employees to fill these roles if turnover occurs.

If, on the other hand, the likely outcome of a project will be to reduce staff in a department, ensuring clarity about the next steps is important. If unfilled positions are no longer needed, the most prudent step is to eliminate them. However, if the position is currently filled, existing employees need to be transferred to different departments in need of full-time equivalents. If no openings exist in other departments, these employees may become part of a pool of employees used to fill temporary shortages inside the organization. Retraining for other open positions is also an option if the displaced employee has related skills. Because they have just participated in process improvement projects, these staff members may also receive additional training in process improvement tools and be assigned to other departments to aid in their projects.

If none of these options is feasible, the last action available to the manager is to lay off the employee. Executing projects that will clearly result in job loss is difficult—getting employees to redesign themselves out of a job is almost impossible. However, layoffs can generally be avoided in healthcare, as labor shortages are widespread. In addition, most projects identified should be of the first type, those that will increase throughput with existing staff, as these tend to be the most critical for improved patient access and increases in the quality of clinical care.

The HR planning function should be ongoing and comprehensive, and a well-communicated plan for employee reassignment and replacement should be in place. By identifying all potential projects during the annual planning cycle, the HR department can develop an organization-wide staffing plan. Without this critical function, many of the gains in operating improvements will be lost.

Managerial Accounting

The second key tool for holding the gains is the use of **managerial accounting** (Reiter and Song 2021). In contrast to financial accounting, which is used to prepare financial statements (the past), managerial accounting focuses on the future. Managerial accounting can be used to anticipate the profitability of a project intended to improve patient flow or model the revenue gains from a clinical pay-for-performance (P4P) contract. Even projects that appear to have no financial impact can benefit from managerial accounting. For example, a project to reduce hospital-acquired infections may not only provide improvements in the quality of care but also reduce the length of stay for a number of patients and therefore increase the hospital's profitability. Managerial accounting is a primary analytical tool to reduce costs and increase revenue, as discussed in chapter 14.

managerial accounting
The field of accounting that focuses primarily on subunit (i.e., departmental) data used internally for managerial decision making.

Having a member of the finance staff engaged with operations improvement efforts is useful. This team member should perform an initial analysis of the expected financial results for a project and monitor the financial model throughout the project. She should also ensure that the financial effects of an individual project flow through to the financial results for the entire organization. The use of predictive analytics and business modeling (chapter 8) can help in evaluating the risks and rewards associated with various projects or decisions.

The first step in managerial accounting is to understand an operating unit's revenue source and how it changes with a change in operations. For example, capitation revenue may flow to a primary care clinic; in this case, a reduction in the volume of services will result in a profitability gain. However, if the revenue source for the clinic is fee-for-service payments, the reduction in volume will result in a revenue loss. The transition from fee-for-service to value will continue; chapter 3 provides a road map for making this journey successfully.

Evaluating many revenue sources in healthcare can be complex. For example, understanding inpatient hospital reimbursement via diagnosis-related group can be difficult, as some diagnoses pay substantially more than others. In addition, many rules affect net reimbursement to the hospital, so a comprehensive analysis must be undertaken.

The trend toward consumer-directed healthcare and healthcare savings accounts means that the retail price of some services also affects net revenue. If a market-sensitive outpatient service is priced too high, net revenue may decline as consumer demand decreases.

Next, the costs for the operation must be identified and segmented into three categories: variable, fixed, and overhead. Variable costs are those that vary with the volume of the service; a good example is supplies used with a procedure. Fixed costs are those that do not vary with volume and include such items as space costs and equipment depreciation. Employee wages and benefits are usually designated as fixed costs, although they may be variable if the volume of services changes substantially and staffing levels are adjusted accordingly.

The final cost category is overhead, which is allocated to each department or unit in an organization that generates revenue. This allocation pays for costs of departments that do not generate revenue. Knowing which overhead formulas are used to allocate costs is critical to understanding the impact of operational changes. For example, an overhead rate based on a percentage of revenue has a substantially different effect than one based on the square footage a department occupies.

The next step in the managerial accounting process is to conduct a **cost-volume-profit (CVP) analysis**. Exhibit 16.2 illustrates a CVP analysis of two outpatient services at Vincent Valley Hospital and Health System (VVH).

cost-volume-profit (CVP) analysis

A managerial accounting method used to evaluate the impact of cost and volume on profit in an organizational unit.

EXHIBIT 16.2
 Managerial
 Accounting: CVP
 Analysis

	Backlogged		Financial Loss	
	Base	Process Improvement Project	Base	Process Improvement Project
Test volume	1,000	1,500	1,000	1,050
Revenue/test	\$150	\$150	\$150	\$150
Total revenue	\$150,000	\$225,000	\$150,000	\$157,500
Costs				
Variable cost/unit	\$38	\$38	\$38	\$38
Fixed costs	\$85,000	\$85,000	\$120,000	\$80,000
Overhead	\$20,000	\$20,000	\$20,000	\$20,000
Total cost	\$143,000	\$162,000	\$178,000	\$139,900
Profit	\$7,000	\$63,000	(\$28,000)	\$17,600

Note: CVP = cost-volume-profit.

In the first case, the service is backlogged and current profit (base case) is \$7,000 per year. However, if a process improvement project is undertaken, the volume can be increased from 1,000 to 1,500 tests per year. If staffing and other fixed costs remain constant, the net profit is increased to \$63,000 per year.

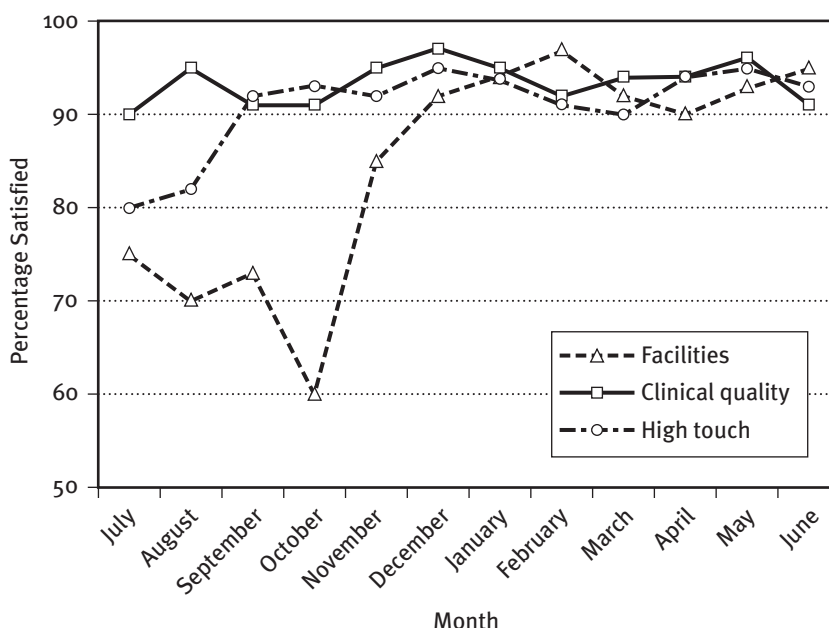
The second example shows a situation in which the service is operating at an annual loss of \$28,000. In this case, the process improvement goal is to reduce fixed costs (staffing) with a slight increase in volume. The result is a \$40,000 reduction in fixed cost, which yields a profit margin of \$17,600. HR planning is critical in a project such as this to ensure a comfortable transition for displaced employees.

Control System

The final key to holding the gains is a control system. Control systems have two major components: measurement/reporting and monitoring/response.

Chapter 7 discusses many tools for data capture and analysis with an objective of finding and fixing problems. Many of the same tools should be deployed for continuous reporting of the results of operations improvement projects. Data collection systems for monitoring outcomes should be built into any operations improvement project from the beginning.

Once data collection is under way, results should be displayed both numerically and graphically. The run chart (chapter 9) is still one of the most

EXHIBIT 16.3**Run Chart
for Birthing
Center Patient
Satisfaction**

effective tools for monitoring the performance of a process. Exhibit 16.3 illustrates a simple run chart for birthing center patient satisfaction, where a goal of greater than 90 percent satisfied patients has been set. This type of chart can show progress over time to ensure that the organization is moving toward its goals.

In addition to a robust data capture and reporting system, a plan for monitoring and response is critical. This plan should include identification of the individual or team responsible for the operation and a method for communicating the reports to them. In some cases, these operations improvement activities are of such strategic importance that they become part of a departmental or organization-wide balanced scorecard.

A response procedure or plan should be developed to address situations in which a process fails to perform as it should. Jidoka and andon systems (chapter 10) can help organizations discover and correct problems with system performance. Control charts (chapter 9) can be used to identify out-of-control situations. Once an out-of-control situation is identified, action should be taken to determine the special or assignable cause and eliminate it.

Which Tools to Use: A General Algorithm

This book presents an array of techniques, tools, and methods to achieve operational excellence. How does the practitioner choose from this broad array? As

in clinical care, a mix of art and science is involved in choosing the best approach.

A general algorithm for selecting tools is presented next, and the book's companion website contains an automated and more detailed version. The framework for this detailed path through the logic (exhibit 16.4) is represented by a series of steps.

On the web at
ache.org/books/OpsManagement4



Step A. Issue Formulation

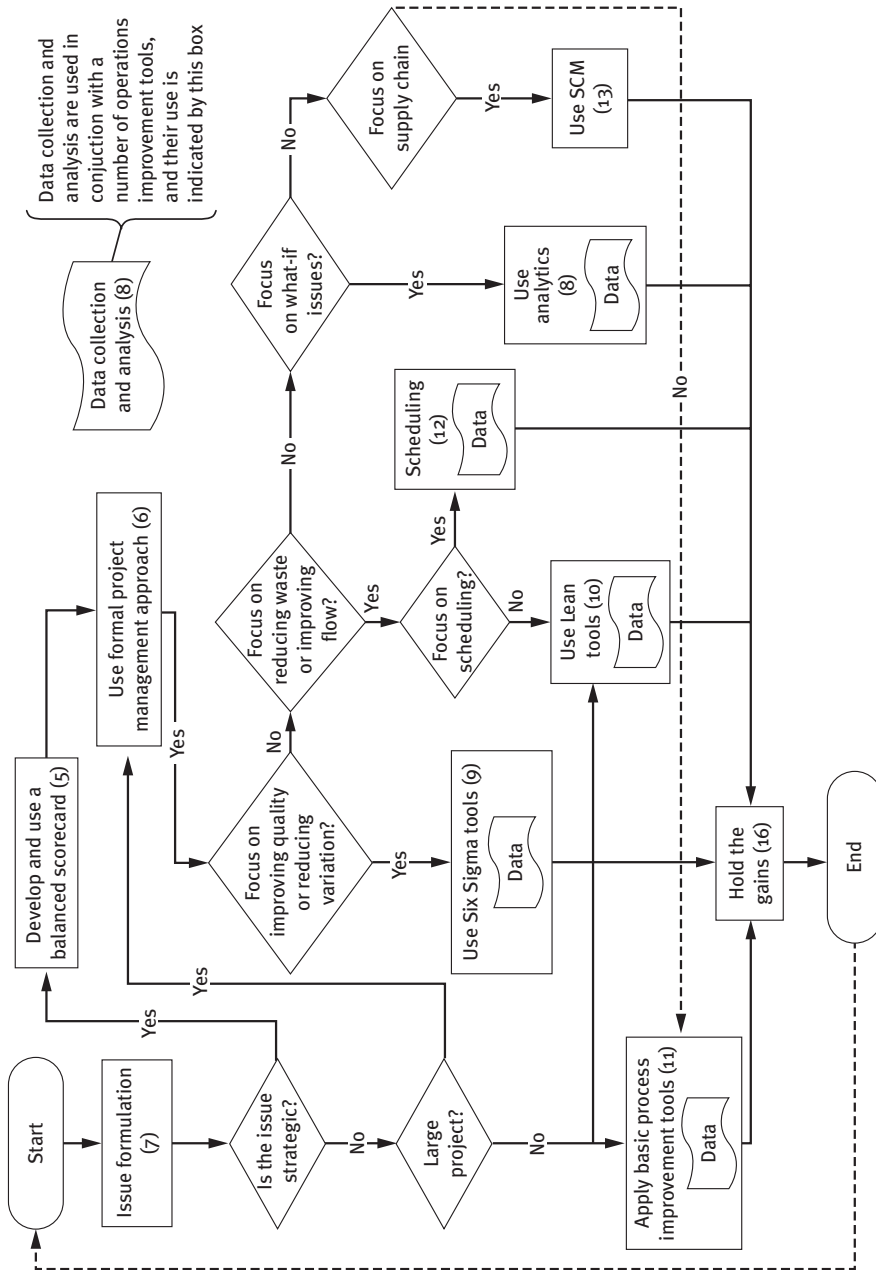
First, formulate the issue you wish to address. Determine the current state and a desired state (e.g., competitors have taken 5 percent of our market share in obstetrics, and we want to recapture the market; the pediatric clinic lost \$100,000 last year, and we want to break even next year; public rankings for our diabetes care place our clinic below the median, and we want to be in the top quartile). Framing the problem correctly is important to ensure that the outcome is the right solution to the right issue rather than the right answer to the wrong question; all relevant stakeholders should be consulted at this step.

A number of effective decision-making and problem-solving tools can be used to

- frame the question or problem,
- analyze the problem and various solutions to the problem, and
- implement those solutions.

The tools and techniques identified next provide a basis for tackling difficult, complicated problems.

- *The decision-making process*: a generic decision process used for any type of process improvement or problem solving (plan-do-check-act [PDCA], define-measure-analyze-improve-control [DMAIC], and project management all follow this same basic outline)
 - Framing: used to ensure that the correct problem or issue is being addressed
 - Gathering intelligence: finding and organizing the information needed to address the issue (data collection)
 - Coming to conclusions: determining the solution to the problem (data analysis)
 - Learning from feedback: ensuring that learning is not lost and that the solution actually works (holding the gains)
- *Mapping tools*
 - Mind mapping: used to help formulate and understand the problem or issue

EXHIBIT 16.4**Algorithm for Using the Tools, Techniques, and Methodologies in This Book**

Note: Chapter numbers are in parentheses. Model created in Microsoft Visio. SCM = supply chain management.

- Process mapping, activity mapping, and service blueprinting: used to “picture” the system and process steps
- *Root-cause analysis (RCA) tools*
- Five whys technique and fishbone diagrams: used to identify causes and root causes of problems to determine how to eliminate those problems
- Failure mode and effects analysis: a more detailed root cause–type analysis used to identify and plan for possible and actual failures

Step B. Strategic or Operational Issue

Next, decide whether the issue is strategic (e.g., major resources and high-level staff will be involved) or part of ongoing operations. If the issue is strategic, go to step C, balanced scorecard for strategic issues. If it is operational, go to step D, project management, or E, basic performance improvement tools, depending on the size and scope of possible solutions.

To effectively implement a major strategy, develop a balanced scorecard to link initiatives and measure progress.

Step C. Balanced Scorecard for Strategic Issues

To effectively implement a major strategy, develop a balanced scorecard to link initiatives and measure progress. Elements of the balanced scorecard include the following:

- *Strategy map*—used to link initiatives or projects to achieve the desired state
- *Four perspectives*—ensures that initiatives and projects span the four main perspectives of the balanced scorecard, including financial, customer/patient, operations, and employee learning and growth
- *Metrics*—used to measure progress through leading (predictive) and lagging (results) indicators

If the balanced scorecard contains a major initiative, go to step D; otherwise, go to step E.

Step D. Project Management

The formal project management methodology should be used for initiatives that typically last longer than six months and involve a project team. Project management includes the following tools:

- *Project charter*—a document that outlines stakeholders, the project sponsor, the project mission and scope, a change process, expected results, and estimated resources required

- *Work breakdown structure*—a list of tasks for accomplishing the project goals, with assigned responsibilities and estimated durations and costs
- *Schedule*—a progression of tasks in order of precedence and linked by relationship, and the identification of the critical path that determines the overall duration of the project
- *Change control*—a method by which to formally monitor progress and make changes during the execution of a project
- *Risk management*—the identification of project risks and plans to mitigate each risk

If the project is primarily concerned with improving quality or reducing variation, use the project management technique and tools described in step F, quality and Six Sigma. If the operating issue is large enough for project management and primarily concerned with eliminating waste or improving flow, go to step G, Lean. If the issue is related to evaluating and managing risk or analyzing and improving processes, go to step H, analytics. If the project is focused on supply chain issues, go to step I, supply chain management (SCM). If the project focus is not encompassed by Six Sigma, Lean, simulation, or SCM, return to step E and use the basic performance improvement tools in the larger project management system.

Step E. Basic Performance Improvement Tools

Basic performance improvement tools are used to improve and optimize a process. In addition to RCA, the following tools can be helpful in moving toward effective and efficient processes and systems.

- *Optimization using linear programming*—used to determine the optimal allocation of scarce resources.
- *Theory of constraints (TOC)*—five steps for identifying and managing constraints in the system:
 1. Identify the constraint (or bottleneck).
 2. Exploit the constraint by determining how to get the maximum performance out of the constraint without major system changes or capital improvements.
 3. Subordinate everything else to the constraint by synchronizing other nonbottleneck resources (or steps in the process) to match the output of the constraint.
 4. Elevate the constraint by taking some step (e.g., capital expenditure, staffing increase) to increase the capacity of the constraining resource until it is no longer the constraint and another activity becomes the new constraint.

5. Repeat the process for the new constraint.
- *Force field analysis*—used to identify and manage the forces working for and against change (applicable to any change initiative, including TOC, Six Sigma, and Lean).

If these tools provide an optimal solution, go to step J, holding the gains. Sometimes the operating issues are so large that they will benefit from the formal project management discipline. In this case, go to step D. If the project is relatively small and focused on eliminating waste, go to step G, where the kaizen event tool can be used to achieve quick improvements.

Step F. Quality and Six Sigma

The focus of quality initiatives and the Six Sigma methodology is on improving quality, eliminating errors, and reducing variation.

- *DMAIC*—the five-step process improvement or problem-solving technique used in Six Sigma:
 1. Define the problem or process (see step A, issue formulation).
 2. Measure the current state of the process (see the section titled Data and Analytics later in this chapter).
 3. Analyze the collected data to determine how to fix the problem or improve the process.
 4. Improve the process or solve the problem.
 5. Control to ensure that changes are embedded in the system (see step J).

Note that at any point in the process, looping back to a previous step may be necessary. Once the process is complete, start the loop again.

- *Seven basic quality tools*—in the DMAIC process, tools used to improve the process or solve the problem:
 1. Fishbone diagram, for analyzing and illustrating the root causes of an effect.
 2. Check sheet, a simple form used to collect data.
 3. Histogram, a graph used to show frequency distributions.
 4. Pareto chart, a sorted histogram.
 5. Flowchart, a process map.
 6. Scatter plot, a graphic technique to analyze the relationship between two variables.
 7. Run chart, a plot of a process characteristic in chronological sequence.

- *Statistical process control*—an ongoing measurement of process output characteristics for ensuring quality that enables the identification of a problem situation before an error occurs.
- *Process capability*—a measure of whether a process is capable of producing the desired output.
- *Benchmarking*—the determination of what is possible on the basis of what others are doing; used for comparison purposes and goal setting.
- *Quality function deployment*—used to match customer requirements (voice of the customer) with process capabilities, given that trade-offs must be made.
- *Poka-yoke*—mistake proofing.

Once these tools have produced satisfactory results, proceed to step J, holding the gains.

Step G. Lean

Lean initiatives are typically focused on eliminating waste and improving flow in the system or process.

- *Kaizen philosophy*—the five-step process improvement technique used in Lean:
 1. Specify value by identifying activities that provide value from the customer's perspective.
 2. Map and improve the value stream by determining the sequence of activities or the current state of the process and the desired future state, and eliminating non-value-added steps and other waste.
 3. Initiate flow, enabling the process to proceed as smoothly and quickly as possible.
 4. Pull to enable the customer to trigger movement of products or services toward them.
 5. Build perfection by repeating the cycle to ensure a focus on continuous improvement.
- *Value stream mapping*—used to define the process and determine where waste is occurring.
- *Takt time*—a measure of time needed for the process on the basis of customer demand.
- *Throughput time*—a measure of the actual time needed in the process.
- *Five Ss*—a technique to organize the workplace.
- *Spaghetti diagram*—a mapping technique to show the movement of customers (patients), workers, equipment, and so on.

- *Kaizen blitz or event*—used to improve the process quickly, when project management is not needed.
- *Standardized work*—written documentation of the precise way in which every step in a process should be performed; a way to ensure that activities are completed the same way every time in an efficient manner.
- *Jidoka and andon*—techniques or tools used to ensure that “things are done right the first time” to catch and correct errors.
- *Kanban*—a scheduling tool used to pull rather than push work.
- *Single-minute exchange of die*—a technique to increase the speed of changeover.
- *Heijunka*—leveling production (or workload) so that the system or process can flow without interruption.

Once these tools have produced satisfactory results, proceed to step J.

Step H. Analytics

Big data and advanced analytics can be used to evaluate what-if situations. Usually, these data tools are less expensive or speedier than the cost or time needed to change the real system and evaluate the effects of those changes.

The *analytics process approach* consists of the following steps:

1. Develop an understanding of the data by using descriptive tools such as dashboards, key performance indicators, and scorecards. Use advanced software to perform data visualization.
2. Develop predictive models using statistical modeling and alternative data models.
3. Develop business solutions using prescriptive or analytical models. Use software tools to choose the best solution.

Once these tools have produced satisfactory results, proceed to step J.

Step I. Supply Chain Management

SCM focuses on all of the processes involved in moving supplies and equipment from the manufacturer to their use in patient care areas. SCM is the management of all activities and processes related to both upstream vendors and downstream customers in the value chain. Effective and efficient management of the supply chain requires an understanding of all of the following:

- Tools for tracking and managing inventory
- Forecasting
- Inventory models
- Inventory systems

- Procurement and vendor relationship management
- Strategic SCM

Once these tools have produced satisfactory results, proceed to step J.

Step J. Holding the Gains

On successful completion of operational improvements, the three tools introduced at the beginning of this chapter can be used to ensure that the changes endure:

- *HR planning*—a disciplined approach to using employees in new ways after an improvement project is completed
- *Managerial accounting*—a study of the expected financial consequences and gains after an operations improvement project has been implemented
- *Control system*—a set of tools to monitor the performance of a new process and methods to take corrective action if desired results are not achieved

Data and Analytics

All of the aforementioned tools, techniques, and methodologies require data and data analysis. Tools and techniques associated with data collection and analysis include the following:

- *Data collection techniques*—used to ensure that valid data are collected for further analysis
- *Graphic display of data*—used to “see” the data
- *Mathematical descriptions of data*—used to compare sets of data and for simulation
- *Regression analyses*—used to investigate and define relationships among variables
- *Forecasting*—used to predict future values of random variables

Operational Excellence

Many leading hospitals, medical groups, and health plans are using the tools and techniques contained in this book. However, these tools have not seen widespread use in healthcare, nor have they been as comprehensively applied as in other sectors of the economy. We have developed a scale for the application

of these tools to gauge progress toward comprehensive operational excellence in healthcare.

Level 1

No organized operations monitoring or improvement efforts are present at level 1. Quality efforts are aimed at compliance and the submission of data to regulating agencies.

Level 2

At level 2, the organization has begun to use operations data for decision making. Pockets of process improvement activity occur where process mapping and PDCA or rapid prototyping are adopted. Evidence-based medicine (EBM) guidelines are used in some clinical activities.

Level 3

Senior management has identified operations improvement efforts as a priority in level 3. The organization conducts operations improvement experiments, uses a disciplined project management methodology, and maintains a comprehensive balanced scorecard. Some P4P bonuses are received from payers, and the organization obtains above-average scores on publicly reported quality measures.

Level 4

A level 4 organization engages in multiple process improvement efforts using a combination of project management, analytics, quality tools, and Lean. It has trained a significant number of employees in the advanced use of these tools, and these individuals lead process improvement projects. EBM guidelines are comprehensively used, and all value purchasing bonuses are achieved.

Level 5

Operational excellence is the primary strategic objective of an organization at level 5. The executive leadership team has embraced operational excellence as a key component of the organization's strategic plan and demonstrates knowledge in all of its tools. Operations improvement efforts are under way in all departments, led by departmental staff who have been trained in advanced tools. Modern digital tools and automation are used extensively. The organization uses real-time simulation to control patient flow and operations. New EBM guidelines and best practices for administrative operations are developed and published by this organization, which scores in the top 5 percent of any national ranking on quality and operational excellence.

A few leading organizations currently are at level 4, but most reside between levels 2 and 3. Our friends at VVH are at the top of level 3 and moving toward level 4.

Vincent Valley Hospital and Health System Strives for Operational Excellence

As presented in chapter 3, VVH leadership believes it has a number of opportunities to succeed with the Hospital Value-Based Purchasing program and has added the program as an initiative to its corporate balanced scorecard, as follows: “Conduct projects to optimize Medicare value-based purchasing to generate at least a 2 percent increase in inpatient revenue.”

VVH has reorganized its structure to combine a number of operations and quality activities into a new organization-wide department known as operations management and quality.

One team is being created to target the following specific measures for improvement:

- Pneumonia patients assessed for and given a pneumococcal vaccination
- Pneumonia patients whose initial emergency department blood culture was performed prior to the administration of the first hospital dose of antibiotics
- Pneumonia patients given smoking cessation advice and counseling
- Pneumonia patients given initial antibiotic(s) within six hours after arrival
- Pneumonia patients given the most appropriate initial antibiotic(s)
- Pneumonia patients assessed for and given an influenza vaccination

The first step in the project is to identify this team and develop a project charter and schedule (chapter 6). Both the HR and finance departments are to be included in the project team to model financial consequences (new revenues, possible new costs, capital requirements) and the potential effect on staffing levels.

The project team begins by collecting data on current performance and summarizing them using visual and mathematical techniques to determine where performance does not meet goals (chapters 7 and 8). A process map is constructed and analyzed to determine where processes may be improved to achieve the desired results. Various Six Sigma tools (fishbone diagrams, check sheets, Pareto diagrams, scatter plots) are employed to further analyze and improve the process (chapter 9).

The clinicians on the project team perform a careful analysis to determine which areas of the treatment of patients at risk of pneumonia can be standardized and which need customization. The standard modules are then examined for effectiveness and efficiency using value stream mapping (chapter 10).

Changes are identified, many of them requiring either a staffing adjustment or a change in VVH’s electronic health record. Because many options

are available and the team is uncertain which will achieve the desired results, a decision tree (chapter 7) is constructed to identify the optimal process improvements. Finally, once the project team begins to implement these process improvements, the results are monitored with control charts (chapter 9).

The Healthcare Organization of the Future

A future healthcare organization operating at level 5 is illustrated in exhibit 16.5. This care delivery system will use many of the tools and techniques contained in this text. A demand prediction model will generate predictions of demand for inpatient, ambulatory, home, and telehealth services. Because much of the care delivered in these sites will be through the use of EBM guidelines (chapter 3) that have optimized processes (chapters 7 to 10), the resource requirements can be predicted as well; these predictions will drive staff scheduling and supply chain systems.

A key component of this future system is a real-time operations monitoring and control system. This system uses simulation and modeling techniques to monitor, control, and optimize patient flow and diagnostic and treatment resources. Macro-level control systems such as the balanced scorecard (chapter 5) ensure that this system meets the organization's strategic objectives. The result will be a finely tuned healthcare delivery system providing high-quality clinical care in the most efficient manner possible.

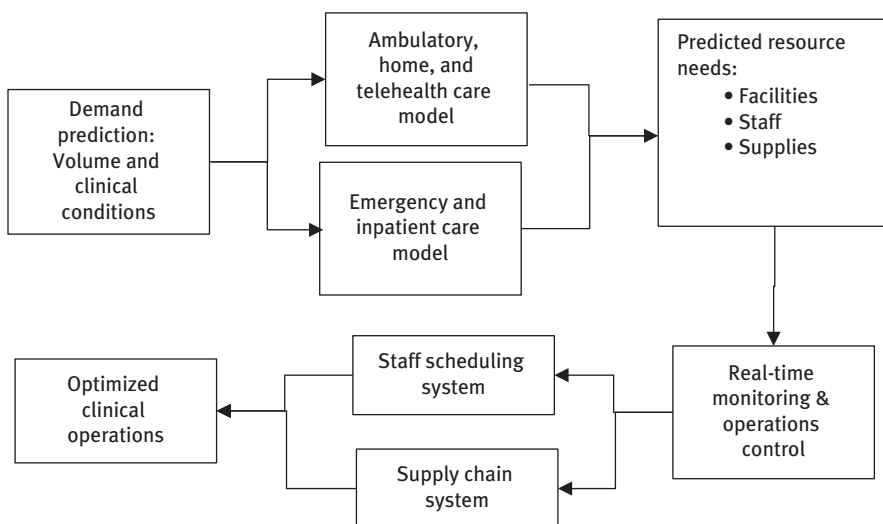


EXHIBIT 16.5
An Optimized
Healthcare
Delivery System
of the Future

Conclusion

We hope that this text is helpful to you and your organization on your journey toward level 5 operational excellence. We are interested in your progress whether you are a new member of the health administration team, a seasoned department head, or a physician leader—please use the email addresses provided on the companion website to inform us of your successes, and let us know what we could do to make this a better text.

Because many of the tools discussed in this text are evolving, we will continuously update the companion website with revisions and additions; check it frequently. We, too, are striving to reach level 5.



On the web at
ache.org/books/OpsManagement4

Discussion Questions

1. Identify methods to reduce employees' resistance to change during an operations improvement project.
2. What should be the key financial performance indicator used to analyze performance changes for hospitals? Clinics? Health plans? Public health agencies?
3. Describe tools (other than control charts) that can be used to ensure that processes achieve their desired results.
4. Describe the tools, methods, and techniques in this book that would be used to address the following operating issues:
 - a. A hospital laboratory department provides results that are late and frequently erroneous.
 - b. A clinic's web-based patient information system is not being used by the expected number of patients.
 - c. An ambulatory clinic is financially challenged but has a low staffing ratio compared to that of similar clinics.

Case Study

VVH has a serious problem: A major strategic objective of the health system is to grow its ambulatory care network, but the organization faces a number of challenges in doing so. Although a new billing system was installed and various reimbursement maximization strategies were executed, total costs in the system exceed revenue, even as the clinic staff feel busy and backlog appointments have increased in number. Analysis of clinic data indicates a growing number of patients are canceling appointments or are no-shows.

In addition, a new group of multispecialty and primary care physicians has been created from the merger of three separate groups; this clinic is aggressively competing with VVH for privately insured patients. The new large clinic is making same-day clinic appointments available and heavily advertising them.

The board of VVH has asked the CEO to develop a plan to address this growing concern. The CEO begins by forming a small strategy team to lead improvement efforts; its first step is to assign the chief operating officer, chief financial officer, and medical director to direct the planning and finance staff on the improvement team.

VVH ultimately decides that it needs to increase the number of patients seen by clinicians and begins to implement advanced-access scheduling in its clinics. Because VVH believes in knowledge-based management and the sharing of improved methods of delivering health services, the organization has made its data and information available on the book's companion website. VVH has invited students and practitioners to help the organization improve this system.

On the web at  ache.org/books/OpsManagement4

Case Study Questions

1. Frame the original issue for VVH. Mind maps and RCA may be useful here.
2. How would you address the no-show and cancelation issues?
3. Develop a project charter for one project associated with VVH's problems.
4. Develop a balanced scorecard for VVH's clinics.
5. If VVH were to focus on increasing throughput in the system, how would you go about doing so? Be specific.

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GLOSSARY

activity-based costing (ABC). A cost allocation model that assigns a cost to each activity in an organizational unit and then totals the cost for the unit on the basis of the actual consumption of each activity.

advanced-access scheduling. A method of scheduling outpatient appointments that provides open time slots every day for seeing patients on the same day they request an appointment. Also known as *open-access scheduling*.

Agency for Healthcare Research and Quality (AHRQ). A federal agency that is part of the Department of Health and Human Services. It provides leadership and funding to identify and communicate the most effective methods to deliver high-quality healthcare in the United States.

andon. A visual or audible signaling device used to indicate a problem in the process, typically used in conjunction with jidoka.

balanced scorecard. A system of strategy links and reporting mechanisms that supports effective strategy execution.

business intelligence. The process of converting raw data through a variety of methods into information that can assist with decision making.

capacity utilization. The percentage of time that a resource (worker, equipment, space, etc.) or process is actually busy producing or transforming output.

care path. A sequence of best practices for healthcare staff to follow for a diagnosis or procedure, designed to minimize waste and maximize quality of care.

consumer-directed healthcare. Healthcare systems in which the consumer (patient) is well informed about healthcare prices and quality and makes personal buying decisions on the basis of this information. Health savings accounts are frequently included as a key component of such systems.

continuous quality improvement (CQI). A comprehensive quality improvement and management system with three key components: planning, control, and improvement.

control limits. Common variation limits that are ± 3 standard deviations from the mean.

cost of quality. The costs associated with producing poor-quality goods and services, including tangible costs, such as scrap and rejects, and intangible costs, such as lost customer goodwill.

cost-volume-profit (CVP) analysis. A managerial accounting method used to evaluate the impact of cost and volume on profit in an organizational unit.

critical path method (CPM). The critical path is the longest course through a graph of linked tasks in a project. The critical path method is used to reduce the total time of a project by decreasing the duration of tasks on the critical path.

cross-functional process map. A map that follows the flow of a process through the various departments of the organization using dashed lines to show the work being completed by a particular department or individual in the process. Also called *swim lane process map*.

cycle time. The time required to accomplish a task in a system.

decision analysis. A structured process for examining and evaluating decisions.

decision tree. A graphical representation of the order of future and current events for how decisions are made.

economic order quantity (EOQ). An inventory model that indicates an optimal purchase quantity that will minimize total annual inventory costs.

enterprise resources planning (ERP). Global information systems that help individuals and groups manage the entire organization, including accounting, operations, and human resources.

evidence-based medicine (EBM). The conscientious and judicious use of the best current evidence in making decisions about the care of individual patients.

failure mode and effects analysis (FMEA). A technique developed by the US military to identify the ways in which a process (or piece of equipment) might fail and to determine how best to mitigate those risks.

fishbone diagram. A graphical technique used to display the relationship between the potential causes of a problem and the effect created by the problem. Sometimes called *Ishikawa diagram*.

five whys technique. A technique that uses a series of logical questions to find the root cause of a problem.

force field analysis. A graphical technique that demonstrates all the forces for and against making a key change.

full capitation. A methodology in which providers are paid a monthly fee for each patient who receives care in their system.

Gantt chart. A scheduling tool that lists project tasks, with bars indicating start and end dates for each task.

health savings account (HSA). A personal monetary account that can only be used for healthcare expenses. The funds are not taxed, and the balance can be rolled over from year to year. HSAs are normally used with high-deductible health insurance plans.

heijunka. The process of eliminating variations in volume and variety of production to reduce waste.

histogram. A graph summarizing discrete or continuous data. Histograms visually display how much variation exists in the data.

ISO 9000. A series of process standards developed by the International Organization for Standardization to give organizations guidelines for developing and maintaining effective quality systems.

jidoka. The ability to prevent defects by stopping a process when an error occurs.

just-in-time (JIT). An inventory management system designed to improve efficiency and reduce waste. Part of Lean manufacturing.

kaizen. Continuous improvement based on the beliefs that everything can be improved and that incremental changes result in an enhanced system.

kaizen event. A focused, short-term project aimed at improving a particular process.

kanban. A visual signal that triggers the movement of inventory or product in a system.

knowledge hierarchy. The foundation of knowledge-based management, composed of five categories of learning: data, information, knowledge, understanding, and wisdom.

lagging indicator. A performance measurement that assesses the outcome of existing actions.

leading indicator. A performance measurement that predicts the future and is specific to an initiative or organizational strategy. Also called *performance driver*.

linear programming. A mathematical technique used to find the optimal solution to a linear problem given a set of constrained resources.

Little's law. The relationship between the arrival rate to a system, the time an item (e.g., a patient) spends in the system, and the number of items in a system.

Malcolm Baldrige National Quality Award. An annual award established by the US Congress in 1987 to recognize organizations in the United States for their achievements in quality.

managerial accounting. The field of accounting that focuses primarily on subunit (i.e., departmental) data used internally for managerial decision making.

material requirements planning (MRP). A computer system designed to manage the purchase and control of dependent-demand items.

mind mapping. A nonlinear technique used to develop thoughts and ideas by placing pictures or phrases on a map to show logical connections.

mitigation plan. A set of tasks intended to reduce or eliminate the effect of risk in a project.

network diagram. A scheduling tool that connects tasks in order of precedence.

Pareto diagram. A rank-ordered frequency chart that indicates the number of times a particular item occurs in a situation.

Pareto principle. Developed by Italian economist Vilfredo Pareto in 1906 on the basis of his observation that 80 percent of the wealth in Italy was owned by 20 percent of the population.

patient care microsystem. The level of healthcare delivery that includes providers, technology, and treatment processes.

plan-do-check-act (PDCA). A core process improvement tool with four elements: Plan a change to a process, enact the change, check to make sure it is working as expected, and act to make sure the change is sustainable. PDCA functions as a continuous cycle and, as such, is sometimes referred to as the *Deming wheel*.

poka-yoke. A mechanism that prevents mistakes or makes them immediately obvious to prevent adverse outcomes.

prevention quality indicator (PQI). A set of measures that can be used with hospital discharge data to identify patients whose hospitalizations or complications might have been avoided with the use of evidence-based ambulatory care.

process capability. A measure of how well a process can produce output that meets desired standards or specifications.

process map. A graphic depiction of a process showing the sequence of events, including tasks, decisions, and other activities from inputs to outputs. A process map is a type of flowchart.

program evaluation and review technique (PERT). A graphic technique to link and analyze all tasks within a project; the resulting graph helps optimize the project's schedule.

public reporting. A statement of healthcare quality made by hospitals, long-term care facilities, and clinics. May also include patient satisfaction and provider charges.

quality function deployment (QFD). A technique that translates customer requirements to specific product or process requirements.

queue discipline. In queuing theory, the method by which customers are selected from the queue to be served.

queuing theory. The mathematical study of wait lines.

range (r) chart. Measures process performance of sample ranges for continuous data.

RASIC. A chart delineating all project team members' roles for each task in a project. The acronym comes from the members' roles: responsible, approval, support, informed, consult.

risk adjustment. Raising or lowering fees paid to providers on the basis of factors that may increase medical costs, such as age, sex, or illness.

risk management. Within a project, the identification of possible events that, if realized, will affect the execution of the project and a plan to mitigate these events.

rolled throughput yield (RTY). The probability that a unit (of product or service) will pass through all process steps free of defects.

root-cause analysis (RCA). A generic term describing structured, step-by-step techniques for problem solving.

rough-cut capacity planning. The process of converting the overall production plan into capacity needs for key resources.

scatter plot. A graph displaying two variables that indicates whether they are related, how strongly they are related, and the direction of the relationship.

scientific management. A disciplined approach to studying a system or process and then using data to optimize it to achieve improved efficiency and effectiveness.

sequencing rules. Heuristic rules that indicate the order in which jobs are processed from a queue. Also known as queuing priority.

service blueprinting. A style of process mapping that separates actions into onstage (visible to the customer) and backstage (not visible to the customer) activities.

service level. The probability of having an item on hand when needed.

shared savings model. A model of healthcare delivery that includes an organized system of delivery, accountability for the quality and costs of services, and a sharing of savings with the payer for these services.

single exponential smoothing (SES). A simple forecasting model that smooths data in a time series to predict the future.

spaghetti diagram. A visual representation of the movement or travel of materials, employees, or customers.

stakeholder. Anyone who has a vested interest in the outcome of a project, including (but not limited to) employees, customers, users, partner organizations, project sponsors, and the project manager.

standardized work. Documentation of the precise way in which every step in a process should be completed.

statement of work (SOW). A detailed set of tasks, expected outcomes, dates, and costs of a project undertaken by an external contractor.

statistical process control (SPC). A scientific approach to controlling the performance of a process by measuring the process outputs and then using statistical tools to determine whether this process is meeting expected performance.

strategy map. A set of initiatives that are graphically linked by if-then statements to describe an organization's strategy.

supply chain management. The management of all supplier, vendor, and distribution activities related to the production of value to end consumers.

systems thinking. A view of reality that emphasizes the relationships and interactions of each part of the system to all of the other parts.

takt time. The speed at which customers must be served to satisfy demand for the service.

theory of constraints (TOC). The idea that every organization and process is subject to at least one constraint that limits its movement toward or achievement of its goal.

throughput time. The time required for an item to complete the entire process, including waiting time and transport time.

total quality management (TQM). A management philosophy or program aimed at ensuring quality—defined as customer satisfaction—by focusing on it throughout the organization and for each product or service life cycle.

Toyota Production System (TPS). A quality improvement system developed by Toyota Motor Corporation for its automobile manufacturing lines. TPS has broad applicability beyond auto manufacturing and is now commonly known as Lean manufacturing.

trend-adjusted exponential smoothing. An extension of a single exponential smoothing model that accounts for a trend when smoothing the data.

value proposition. A marketing term summarizing the relative cost, features, and quality of a service or good.

value purchasing. A system using payment as a means to reward providers who publicly report results and achieve high levels of clinical care. Also known as value-based purchasing.

value stream map. An overview of how a system transforms supplies into finished goods for the customer.

work breakdown structure (WBS). A list of the tasks that need to be accomplished, their relationship to each other, and the resources required for a project to meet its goals.

X-bar chart. Measures process performance of sample means for continuous data.

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