California HealthCare Foundation

Operations Improvement Methods: Choosing a Path for Hospitals and Clinics

Prepared for

California HealthCare Foundation

by

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March 2010

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About the Foundation

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I. Summary

Today's health care providers face many challenges. As they strive to provide quality care, they also must maintain patient satisfaction, control costs, and maximize productivity throughout the organization. This paper describes operations improvement methods used by hospitals and clinics and compares these methods to help identify which are most useful in improving staffing, patient flow, and utilization of resources.

Three approaches—Lean, Six Sigma, and management engineering—have improved efficiency in many organizations outside of health care. These and other approaches have been successfully used in health care to improve processes, set standards, eliminate bottlenecks, and define quality goals.

Toyota developed the Lean method to create a culture focused on efficiency that could compete in a post-war market. Central to Lean is identifying and eliminating "waste" or work that is not valuable to the customer (or patient). The Lean method addresses the need for a smooth flow of work to reduce delays; it relies on the organization's front-line staff, such as nurses and doctors, to identify and make improvements. This emphasis on eliminating waste and improving flow has helped many hospitals and clinics successfully provide quality care and control costs.

Six Sigma was initially developed for manufacturing efficiency improvement, and it focuses on reducing variability. Variability puts quality at risk and decreases efficiency. By reducing variability, an organization can continuously improve and measure results. Six Sigma shares some tools with the Lean approach but places more emphasis on analysis, statistics, and verification. It uses trained and certified leaders who can identify and implement change.

The professional discipline of industrial engineering offers a range of design and modeling tools that have been used for many years in diverse industries. Industrial engineers, called management engineers (MEs) in the health care industry, use mathematical models and computer simulations to determine the optimum design of patient flow, queuing models to study waiting problems, and allocation models to manage staffing and supplies. MEs also measure staff productivity and reengineer work processes based on time standards to determine the best way work should be done. MEs can develop incentive systems and reports to track performance. Management engineering is a broader approach than Lean or Six Sigma, but all three methods give the health care provider a greater understanding of how work is done and how it can be improved.

In addition to Lean, Six Sigma, and management engineering, other approaches have proven effective in improving operations at health care organizations by providing targets and structure. These include:

- **Baldrige Award.** An annual award from the United States government recognizing outstanding performance. Health care organizations have used Baldrige criteria to organize changes and to provide a target that is beneficial even if the award is not won.

- **Balanced Scorecard.** A method that creates an overall organizational strategy using a broad set of measurements and responsibilities. It assures that the necessary targets are aligned with long-term interests and that responsibilities are clearly established from the start. The smaller-scale operational activities of an organization are aligned with larger-scale objectives, vision, and strategy.

- **ISO 9000.** International sets of publications and standards that specify good practices and provide goals for improvement.

Other well-known improvement approaches include *PDSA* (Plan-Do-Study-Act), which uses a cycle of four steps to continually improve a process; *TQM* (Total Quality Management), focusing on quality improvement by the entire organization; and *CQI* (Continuous Quality Improvement), which uses measurements of quality to drive organizational, behavioral, and attitudinal changes through a continuous cycle of improvement. While they are sometimes used independently, such concepts can be viewed as part of Lean, Six Sigma, and management engineering. Thus, they are not further discussed individually.

This paper describes the history, approach, and applications of each method and analyzes the pros and cons of each method to help organizations determine the best fit for their particular needs. Resources for further information and a list of key terms are provided in the appendix.

II. Usefulness of These Methods

Historically, health care work practices focused on patient care but not necessarily efficient delivery. Patient waiting times, staff scheduling, space allocation, and inventory were secondary considerations. However, with today's health organizations serving more patients, providing more services, and addressing more quality issues, organizations need to consider ways to increase efficiency and reduce costs. Better models make it possible to revise operations to improve efficiency while serving clinical requirements. They offer ways to streamline work and patient flow, reduce waste, improve staffing efficiency, improve patient-staff communications, and define clinical requirements for continuous quality care. They can be applied to all health care organizations — from hospitals and clinics to nonprofit or for-profit organizations, either privately or publically owned. The methods described in this paper have been used by many health care organizations to improve their operations.

The methods described in this paper were initially developed to improve efficiency in manufacturing and engineering. However, in recent years, as health care organizations have adopted these methods, they have seen significant improvements, notably:

- An 80 percent waste reduction (elimination of unnecessary work);[1]
- 50 percent increase in daily outpatient visit capacity;[2]
- 25 percent reduction in turnover time (between surgeries, inpatients and office visits);
- 50 percent or more reduction in materials inventory;[3]
- 60 percent reduction in patient waiting time;[4] and
- A 40 percent reduction in required floor space.[5]

When starting operations improvement, the goals should not be small. Some experts place a target of closing half of the gap between the current performance level and the potential maximum performance. If operating room turnover is ideally 30 minutes and the current room turnover time is 50 minutes, there is a gap of 20 minutes. Therefore, the minimum target goal should be to reduce that 20-minute gap by 10 minutes to achieve a turnover rate of 40 minutes. Of course, completely closing the gap to achieve a turnover time of 30 minutes is best.

Investing in operations improvement projects must result in a reasonable financial return on investment that can be measured with "hard" savings when the project is completed. For example, an operations improvement project costing $20,000 that promptly eliminated a staff position with an annual salary of $35,000 is obviously worthwhile and very good financially.[6] Other benefits — for example, the quality of care or patient satisfaction improvement — are difficult to quantify in dollar amounts. However, if operations improvement projects are focused on cost reductions or revenue enhancement, the success is more easily measured against the costs of the project itself.

III. Lean (or Toyota Management System)

Approach

The Lean, or Lean-Thinking, method provides a range of techniques to create a more efficient workplace. The intent is to create smooth patient and work flows and eliminate waste in time, effort, or resources to provide services patients find valuable. In addition, this method aims to continuously improve operational processes to achieve quality services and to promote a productive culture throughout the organization. Lean helps providers work toward a state of continuous improvement, whereby the product flows "at the pull of the customer in pursuit of perfection."[7] Thus, the desires of the patient drive the response of the health care provider.

The Lean method is particularly effective when an organization lacks standardization and waste is commonplace. Lean can be applied to a wide range of areas including financial processes, physical work areas, and patient flow.

"Lean improves health care delivery by applying the Japanese concept of Kaizen" (quick iterative experiments in change) combined with the Toyota Production System ideas that "change and create" new work practices. These methods allow health care providers to improve care processes, eliminate waste, reduce ambiguity in work assignments, and solve problems.

A successful Lean project requires the team working on change to question all process steps. However, the team must be unhindered by organizational constraints. When applying Lean, the organization must focus on the needs of the customer (patient) and redesign practices without limitations from the organization's structure. To achieve success, all staff and management must be prepared to throw out old practices and initiate new ones.

Background and History

The Lean approach was developed by Toyota during the 1950s to make the company's automobiles more competitive internationally. After World War II, Toyota had fewer resources than their larger auto competitors so they had to maximize the use of their resources. Initially, the "Toyota Way" was adopted by manufacturing organizations in order to become more competitive.[8] Eventually, service organizations began to adopt the approach as well. Some health care providers use the Toyota Management System or Toyota Production System label to define these methods, while others call it the Lean or Lean-Thinking approach, but all of these terms refer to the same concept.[9] Seattle Children's Hospital, St. Joseph Health System, and Denver Health are among the many examples of hospitals using the Lean methodology.

The term "lean" was coined in the 1980s by James Womack, Ph.D., of MIT, to describe the methods employed at Toyota.[10] However, Toyota's Lean method was based on the ideas of W. E. Deming and others who used existing quality methods and methods from industrial engineering.[11]

Techniques Employed

Originating in Japan, Lean uses Japanese terms that express specific improvement concepts: *Gemba* refers to "visible" problems that can be identified by observing; *Muda* refers to waste or un-useful work; *Kaizen* means making changes; and *Poke-Yoke* refers to a design that prevents work from being done incorrectly. Each term expresses a distinct element of improvement. Using these terms with their Japanese meanings helps teams understand Lean's unique approach. It lets everyone know this is a truly a new initiative which has been employed in other successful organizations. These improvement concepts are applicable to health care since work problems in organizations are often visible, waste frequently occurs, and work processes can be changed while still meeting clinical requirements.

Practitioners of Lean view it as a distinct philosophy that strives to achieve a Zen-like attitude to improving work. Lean tools used by health care providers include the following:

- **Create continuous flow.** This is the concept that patients or materials are moved directly from one step to the next. All inventories between processes should be reduced to zero. For example, patient waiting time can be considered as "inventory." Patients should go directly from registration to examination with no wait time.

- **Jidoka.** Taiichi Ohno, one of the founders of Lean, considered Jidoka one of the most important parts of the Toyota Production System. Jidoka's concept is that anyone involved in the production of work can stop the production line if the quality does not meet the standards set. Jidoka allows a nurse or technician to stop a procedure if she feels the process is not correct, and she can do this without fear of reprimand. It could also be an automatic device that stops work if the quantity or quality is wrong.

- **Eliminate Muda.** Waste refers to work or time that does not have value to the customer (the patient). If a patient is not willing to pay for a service, then this service should be considered waste. Lean defines seven types of waste (see Table 1).

Table 1. Lean's Seven Types of Waste

	EXAMPLES
Overproduction	• Extra copies of forms • Repeating a procedure when not required or sooner than is necessary
Waiting	• Patients waiting for discharge • Equipment not fully used
Excess inventory	• Lab samples batched for analysis • Doing things before they are needed
Unnecessary transport	• Excessive e-mail copies • Excessive travel of specimens for lab
Unnecessary movement	• Tasks and equipment are not adjacently places for optimum workflow • Walking about by staff not minimized
Defects	• Procedure errors • Redraws
Over- or incorrect processing	• Excessive bed moves • Euplicate questions to patients

Waste can be identified by observation during a walkthrough of an area, called a "waste walk." The intent is to eliminate all waste. In health care, some apparent waste is unavoidable, so-called "necessary waste," resulting from regulatory requirements. The challenge, however, is to reduce waste without harm to the patient.

- **Create pull.** Processes should "pull" work from the prior step rather than wait to have work "pushed" to it. This creates an efficient flow without delays or unnecessary inventories between processes. For example, cases are pulled by the operating room (OR) from pre-op rather than waiting for pre-op to push patients to the OR. This "pull" reduces the waste of waiting by both the OR and pre-op.

- **Use a Kanban.** Kanban is the Japanese term for a "signal" (this can be a piece of paper or flag) that indicates when something must be done. For example, these signals are used to indicate that an inventory item should be replenished, a product should be processed, or a patient should be moved forward. A card placed at the foot of a patient's bed can signal that he is ready for a procedure. A card placed under a certain number of inventory items can be used to indicate that supplies must be restocked. The Kanban concept has been used for many years in manufacturing and has been effectively used in health care.

- **Use Takt time.** Takt time defines the pace or rhythm necessary for smooth and efficient work flow. It is calculated as the time required to complete a task divided by the quantity required for the task. When work is assigned based on Takt time, patients and staff experience fewer delays. For example, the time required to do a group of repeated tasks, such as in a pharmacy, should be organized to match the arrival rate of the work.
- **Develop a value stream map (VSM).** A VSM is a diagram that identifies the flow of work and highlights non-value-added time and other waste. It includes more elements than a basic process map. The VSM can illustrate patient flow in general or for a particular patient request. The map is based on actual observation. It can help identify opportunities for standardization leading to reductions in material use and reduced process time for patients and staff.
- **Use 5-S.** The 5-S concept is based on the idea that a well-organized workplace will be efficient. The 5-S refers to sort, set in order, shine, standardize and sustain. "Set in order" may refer to how supplies should be arranged, such as for surgery, in the order needed. "Shine" can create visibility, such as a warning light lit when a room is ready or a patient is waiting.

Table 2. Lean's 5-S Concept

	DESCRIPTION	EXAMPLES
Shine	Area cleaned as work is done	• Put away equipment and papers after use. • Fix or replace equipment.
Straighten	Everything in its place, always	• Mark a place for items so it is apparent when they are missing.
Sort	Unneeded supplies removed	• Discard forms if not used. • Keep only equipment that is required.
Standardize	Identification consistently applied	• Develop and follow guidelines and checklists.
Sustain	Continually improve and maintain changes	• Don't postpone change. • Expect consistency.

Lean addresses quality as well as efficient flow. Flow is to be continuous, without waste or delays. Ideally, a patient does not wait from one procedure to the next. Quality is created during processes (identifying defects while carrying out tasks) rather than finding defects after the fact. With Lean, inspectors become unnecessary since defects become obvious as work is performed, particularly when inventories that hide delays are eliminated.

Hospitals that fully adopt Lean have created a culture promoting a better way of thinking about how work is accomplished. Organizational boundaries become less important and improving work processes becomes commonplace. To make this cultural change, the workforce must be trained and must adjust to Lean thinking. Such transformation often is part of an organization's operations improvement effort. The transformation can result from Kaizen (change) events such as accessing how patients are discharged from a hospital or redesigning the outpatient process.

Typical Lean Project

Lean defines seven types of waste, and Lean training helps people identify waste, even in their personal lives (waste at home in the closet or refrigerator). After Lean training, a trained team of observers goes on a "waste walk" of an area such as the emergency department. During the waste walk, they might identify an excess of inventory or an unorganized work environment, both of which wastes people's time. The example below shows how Lean was applied in an emergency department to improve form processing.

The Lean team during the waste walk noticed that paper forms were stored in bulk and without apparent organization. The team decided that a neater storage cabinet was needed, with shelves identified and redundant and unused forms eliminated. This change represents the "shine" idea in which these changes saved space and reduced errors. The labor of ordering, storing, and retrieving the forms was not value-added time (waste). Next the team determined that all forms could be printed when needed. This change represents continuous improvement in which one change leads to another. After securing approval from clinical emergency department managers, the team eliminated all paper forms and the need for storage space. Forms are now printed only when needed. This saves paper and labor and ensures that only the latest version of a form is used. The hospital estimated that eliminating printed ED forms saved $122,000 per year. By training and motivating staff to eliminate waste, the organization gained substantial savings and improved quality.

IV. Six Sigma

Approach

The Six Sigma method strives to ensure continuous improvement by reducing unwanted variability and meeting customer needs exactly every time. The effort in the organization is led by an expert or "black belt" who is trained and certified in Six Sigma's operational excellence ideas. The black belt, who can be an external consultant or an internal staff member, works with the health care provider's current staff to make improvements in work processes and to move the organization forward.

Six Sigma focuses on identifying and reducing defects. Defects are defined as anything that leads to customer dissatisfaction. To eliminate defects, staff follows a particular sequence of steps to achieve and measure the desired results.

Six Sigma builds on the ideas of Total Quality Management (TQM), which emphasizes an organization-wide focus on quality. According to the TQM philosophy, all work must be done correctly the first time, workers are responsible for quality, and processes must be visible, repeatable, and measurable.

Background and History

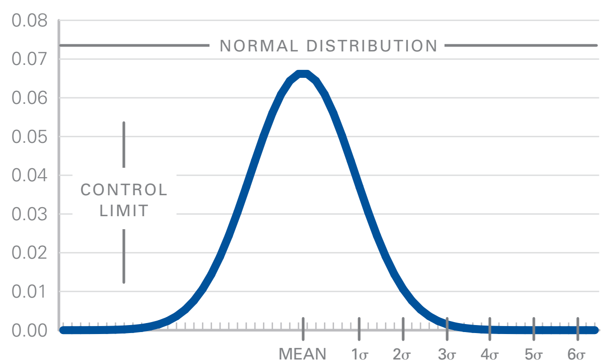
Six Sigma was first formalized as a set of practices at Motorola in the 1980s. Building on prior work in statistics and quality control, the method evolved into a set of quality improvement concepts with a formalized training program and a philosophy based on continuous measurable improvement to achieve optimum productivity. Six Sigma emphasizes making decisions based on verifiable data; the assumption is that processes can be measured, analyzed, and controlled. Six Sigma's popularity grew when General Electric (GE) became an early large-scale adopter of Six Sigma and publicized their success in using it.

Six Sigma initially was used in the manufacturing sector, but it is now widely used in the service sector. It, like other methods, has evolved over time. Government agencies and the military employ the method, as do service providers such as hotels and hospitals. Providence Health Care and the U.S. Department of Veterans Affairs hospitals are among the many examples of organizations using Six Sigma methodology.

The term "Six Sigma" comes from the statistical description of variability. All processes and products have variability: variability exists in the amount of time it takes to perform an examination, the time to register a patient, or the quantity of supplies used. The challenge is to reduce that variability while achieving the desired outcome. Variability should be controlled and reduced so that specifications are nearly always satisfactorily met.

The Greek letter *sigma* represents the statistical measure known as the standard deviation. Standard deviation is the extent of variability of a measurement. In health care operations, many different measurements are taken: measurements can be time, quantity, number of errors, revenue, etc. For example, measurements can be the time it takes to get a room ready for a new patient or the quantity of supplies needed for an outpatient visit. An objective might be to target consistent room cleaning time and identify how to make the time vary as little as possible. Good control would be indicated by good performance within a desired range, such as room cleaning within plus or minus two minutes of a time considered to be good performance. Six Sigma refers to six standard deviations from the mean, and therefore exceeding it is extremely rare (see Figure 1). If satisfactory process performance means operation within the six standard deviation range for the normal probability distribution, then only 3.4 defects per million will occur. In other words, the function will perform correctly 99.9997 percent of the time. The intent is to achieve near-perfect results nearly always.

Figure 1. Six Sigma Ranges



Note: Sigma, the Greek letter σ, is a statistical measure of variability.

Techniques Employed

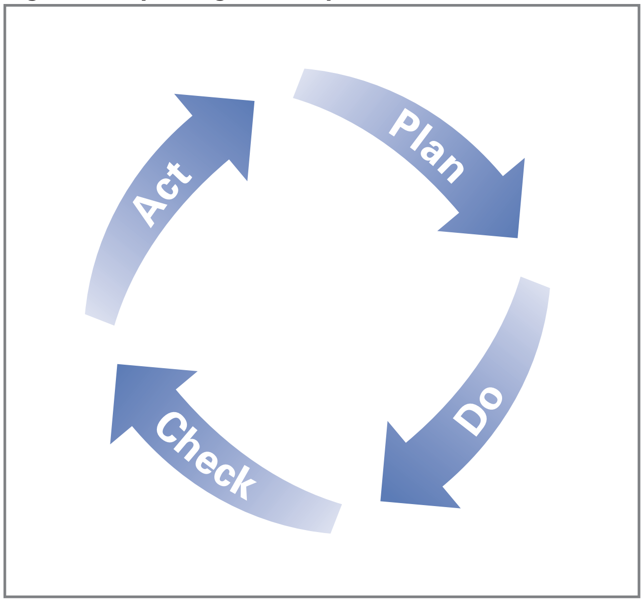
Six Sigma training and certification are available from a number of private organizations, associations, and colleges; there is no single provider of Six Sigma certification. Health care organizations committed to Six Sigma may have certified staff at various levels:

- **Master black belt** has an expert understanding of all aspects of the methodology. Master black belts can identify suitable projects and supervise multiple projects.
- **Black belt** is fully trained and experienced in Six Sigma and able to lead a project. Some health care providers have found this level of expertise so effective in promoting change they can justify the cost of a full-time black belt for every 50 to 100 hospital beds.
- **Green belt** is able to support a project and can identify where Six Sigma tools should be applied. Green belts work on specific projects during the improvement phase and then return to regular duties when a project is complete. In GE's implementation of Six Sigma, green belt training was required of all management. Some hospitals have found it useful to train many of its staff at the green belt level, particularly nursing and technical staff.
- **Yellow belt** has received basic training in the method and understands Six Sigma capabilities. Yellow belts are especially important in identifying opportunities for new projects and working on these projects in their own work areas.
- **"Champions"** are management or process owners who have received training and provide support, such as a senior executive who can express support from the leadership.

According to the Six Sigma method, a process can be controlled through a specific cycle of steps: Plan, Do, Check, Act (PDCA, see Figure 2), which is repeatable. The PDCA was made popular in the 1950s by Edward Deming as part of the quality improvement efforts in Japanese manufacturing. PDCA and variations of PDCA are utilized by Lean, Six Sigma, and other operations improvement methods.

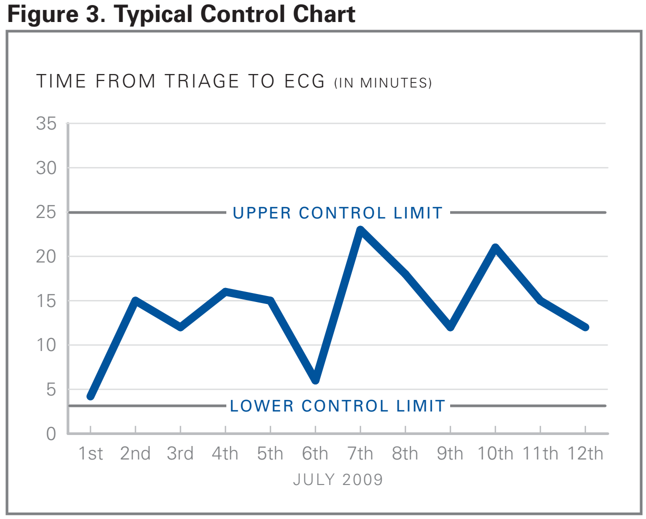
The Six Sigma method is a cycle of steps that helps adopters define, analyze, and measure an effort from various perspectives:

Figure 2. Repeating PDCA Cycle.



- **Define, measure, analyze, improve, and control (DMAIC).** Used to improve work processes and reduce defects:
  - **Define.** Determine the objective of the improvement, such as patient throughput or a better than average result on a clinical outcome;
  - **Measure.** A specific quantity must be identified in order to know if the objective is being met, such as exams per room per day or labor hours per surgery;
  - **Analyze.** Determine the relationships between the objective and the factors that impact the results, such as standard procedures, patient appointment schedules, equipment, etc.;
  - **Improve.** Determine the new standard procedures and an action plan to implement change; and
  - **Control.** An ongoing step that requires monitoring the change and sustaining it. Regular reports and assigning responsibilities are often involved. It may be necessary to repeat these five steps in order to achieve further improvements.
- **Define, measure, analyze, design, and verify (DMADV).** Used to create a new process or product or improve an existing one. It differs from DMAIC in the last two steps. DMADV can be used when there is no existing process or when DMAIC has not produced sufficient results.
- **Design of experiments (DOE).** Used in the "analyze" phase to efficiently test and understand the relationships between inputs and results. Because processes are the result of many factors, the possible combinations that can be tested are very large, so it is necessary to minimize the number of experiments or changes to determine the best design. In some cases a DOE is a project itself.
- **Control chart.** Tracks resulting performance and identifies when a process is out of control and requires correcting. The control chart displays a measurement over time and shows if the values are within a range of acceptable variability. If the measurement is outside the control limits or appears to be headed toward a limit, then an action is necessary. (See Figure 3.)

Figure 3. Typical Control Chart



- **Lean tools.** Many of the tools used by Lean, such as the value stream map or the cause-and-effect diagram, are also used by Six Sigma.

Typical Six Sigma Project

A hospital wanted to reduce emergency department (ED) patient wait time following the DMAIC sequence.[12] Led by a black belt employed by the hospital, the ED staff recorded wait times and other descriptive data about each patient visit. Factors that were statistically correlated to variability in wait time were then determined. Specific changes were identified and tested on a pilot basis, such as in order entry, registration, and nursing team communications. The final analysis showing the impact of the changes led to new guidelines; these guidelines reduced wait time from 62 minutes to 15 minutes and increased patient satisfaction scores. The new guidelines were then used to assign responsibilities, train staff, and monitor results.

V. Management Engineering

Approach

Engineers of all types are trained to use science and math to design things, including the design of better processes. Thus, management engineers (MEs) bring a broad range of tools to design, measure, test, analyze, provide feedback, and control operations to the design of improved performance and achieve system goals. The management engineer generally is not part of the clinical staff but is available to take on individual improvement projects or to help organize a broad improvement effort involving all types of staff. The ME can train others in operations improvement and can provide knowledge about improvement methods used by other health care and non-health care organizations.

Background and History

Industrial engineering, commonly called management engineering in the health care industry, began in the late 1800s. Fredrick Taylor is generally considered the father of industrial engineering, although many of his ideas came from others who wrote about the Industrial Revolution in the 1800s.[13] Taylor's ideas of "the one best way" were further popularized and revised by Frank and Lillian Gilbreth, who developed time-and-motion studies.[14] The couple studied surgery efficiency in the 1910s. Based on these time-and-motion studies, efficiency experts throughout the 20th century used stop watches to time tasks. These techniques were employed in manufacturing and construction work to improve efficiency. During and after World War II, engineers increasingly applied mathematics (operations research), computer modeling, and broader concepts such as ergonomics, psychology of employees, and logistics. Scheduling of nurses during a 24-hour day was among the early uses of operations research.

The application of industrial engineering to health care has a long history. Henry Ford wrote about efficiency in nursing in 1919.[15] In the 1970s and 1980s, industrial engineering became a popular method for assessing health care efficiency as a result of government-initiated cost containment efforts. However, as provider budgets became overburdened, many nonprofit and safety net providers dropped internal management engineering staff and increasingly relied on consultants. Now, with a national interest in health care reform and the high cost of U.S. health care, health care providers have a renewed interest in management engineering. Many university industrial engineering departments now offer classes and degrees in health care management and management engineers have created several professional societies.[16] Many hospitals and hospital systems employ management engineers. A 2007 survey by the Society for Health Systems found that 139 hospitals or hospital systems had a department identified as Management Engineering (although departmental titles vary from Performance Improvement and Operations Excellence to Management Engineering and Industrial Engineering).

Techniques Employed

The industrial engineer (IE) receives training in a range of techniques from various disciplines including social science, physics, and mathematics. These engineers must have a unique mix of skills; they must be good communicators, work with diverse staff, and have expertise in a variety of engineering practices. IE tools used in health care improvement include:

- **Simulation.** Computer models can replicate almost any type of system, from radiology to a pharmacy. These models are used to test changes without disrupting the real system. Simulation models are a helpful starting point to understand the dynamics of such things as patient waiting, staff scheduling, emergency room flow, or anticipated patient flow in a new facility.

- **Reengineering and time study.** Studies that investigate how work is done, measure the time for repeated tasks (such as filling a prescription or conducting a diagnostic imaging test), and use the results to improve productivity. Engineers have a long history of measuring work and developing standard times for tasks. These times can be used to determine staffing needs or design best practices.

- **Human factors and safety.** The study of working methods or how people perform work. These studies are useful for redesigning a workstation or designing the layout of the controls of equipment. MEs also work in organizational change and job design. For example, they may design a task checklist that involves identifying ways to reduce the time and improve accuracy for each task.

- **Facility layout and site selection.** Developing the best arrangement of new or existing workspace as well as the location of the site, such as for a clinic or a hospital. Utilizes economic and logistics data to minimize costs.

- **Inventory and supply chain management.** The design of methods to minimize inventory levels, minimize shortages, and control supplies, including the systems used to order, move, and store materials.

- **Statistics and quality control.** Mathematical and graphical methods that quantify performance and use statistical models to identify problems and control variability.

- **Data manipulation.** Analyzing, manipulating, and summarizing an organization's data from sources such as the electronic medical record and nursing notes. These data can be summarized and analyzed for a report card or dashboard to inform staff of improved performance or operational changes. This feedback is basic to help engineers determine solutions and their sustainability.

- **Queuing models.** A mathematical model used to study waiting lines for patients, staff, samples, records, or supplies. The expected wait times, the variability of wait times, and length of queues can be calculated based on descriptive equations and data about arrival patterns.

- **Operations research and resource allocation.** Uses applied mathematics to describe a system and identify optimal solutions that help decisionmakers determine nurse staffing and patient scheduling, for example, or to quantify and solve complex choices involving risk and uncertainty.

- **Engineering economics.** Evaluates decisions and projects in terms of costs and the time value of money and finance. Applicable to decisions such as the replacement and leasing of equipment.

- **Lean and Six Sigma.** Although not always part of an academic program in industrial engineering, these methods are often part of the ME's capabilities. The ME is capable of using the tools the other two methods provide.

These engineering tools represent a considerable body of knowledge; each tool addresses a range of problems. The ME can measure where an organization "is" versus where it "wants to be." The ME can help organizations determine the costs involved in quality and performance that support the business case for operations improvements. The ME can often identify hidden costs that traditional finance and health care organizations have trouble identifying.

Today's health care system is complex, and advocates of change believe that focusing on efficiency, quality, information systems, access to care, and delivery of care can result in broad system transformation. Systems redesign utilizes management engineering, takes a broad design view, and is supported by government agencies such as AHRQ and the Veterans Administration.[17,18]

Typical Management Engineering Project

To determine what causes prolonged patient wait times and what changes can reduce the time, an ME created a computer simulation of a radiology waiting room. The computer simulation replicated the arrival patterns of patients and the typical service times of registration and exams, and then computed the distribution of wait times. To create the simulation, the ME first gathered data about the patient flows and then created a model using computer simulation software. When the program was run, it simulated the events of a typical day and generated statistics on what was likely to occur as well as an animated video of patient movement throughout the day. The simulation made it possible to test changes to the radiology department process—such as adding a receptionist or revising the exam schedules—to learn what might occur during visits and what patients might experience. Based on the simulation study, the radiology department was able to reduce the average wait time by 30 percent by relocating certain work spaces, which provided more time to register patients, and by revising the appointment schedules to better accommodate peaks in demand. The simulation helped determine where changes would have the greatest effect.

Simulations make it possible to study and test changes without disturbing the department's current work practices. By experimenting with a model, MEs can identify what activities in the department contribute to a slow queue. The simulation also can create an on-screen animation showing the movement of patients and staff; this interactive view of daily operations helps providers better understand the complexity of their systems.

Simulations are also cost effective; typical costs include purchases of software and the MEs time to gather data and program the model. To model a typical hospital-based radiology department may take a few days of programming and time required to gather and input data. The cost, however, may be small compared to the impact of long patient wait time and throughput.

VI. Other Methods

In addition to the three methods already discussed, there are other operations improvement approaches that health care organizations can use to either augment or serve as an alternative to these three methods. The following approaches are often first initiated by top-level managers and broadly defined. They may be implemented with broad-based teams assisted by improvement advisors who help identify, plan, and execute improvement projects throughout the organization, deliver successful results, and promote changes throughout the entire system.[19]

Baldrige Award

In 1988, Motorola won the first Malcolm Baldrige National Quality Award, given by the U.S. Congress to recognize and inspire the pursuit of quality in American business. The award is named for Malcolm Baldrige, who served as secretary of commerce from 1981 until his accidental death in 1987. The award encourages improvement and provides a framework for organizations trying to improve work processes. Managed by the National Institute of Standards and Technology (NIST) of the U.S. Department of Commerce, the award initially began as a competition among companies applying the Baldrige principles. Today, the Baldrige method is used by many organizations, including hospitals and clinics, to improve operations.

Health care-specific guidelines are published by NIST.[20] Past health care Baldrige recipients include Sharp Health Care in San Diego, Sister St. Mary's Hospital in St. Louis, Mercy Health System in Wisconsin, and Robert Wood Johnson University Hospital in New Jersey. The VA issues a Robert W. Carey Award to outstanding facilities on a similar basis.

Baldrige's criteria define planning and tracking improvement efforts and the written procedures to conduct self-assessments. These criteria are used to judge award applicants; the criteria are also used by the organization to evaluate its own efforts. Organizations are given a numeric score based on the following criteria:

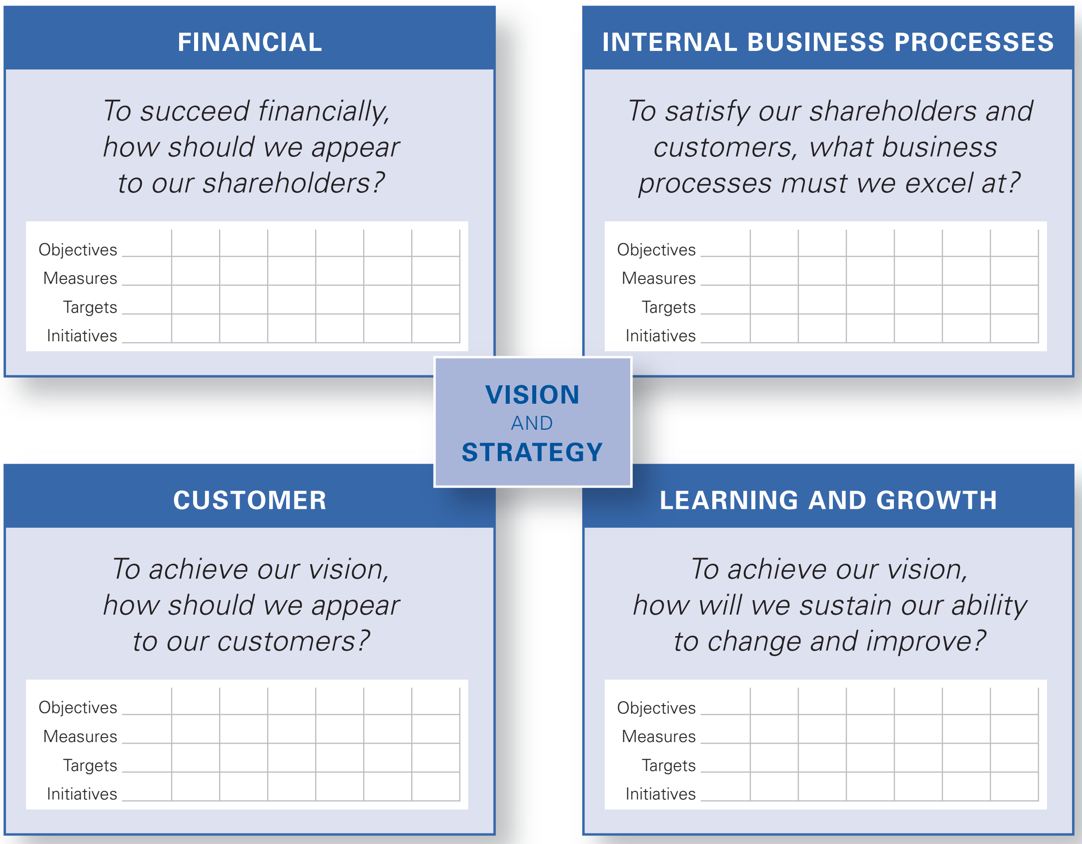
1. Leadership;
2. Strategic focus and planning;
3. Patient/customer and market focus;
4. Measurement, analysis, and knowledge management;
5. Staff focus, learning work systems and motivation;
6. Process management, patient care and support; and
7. Results: clinical, operational, financial, patient satisfaction.

Organizations can use the Baldrige criteria as a tool for ongoing assessment and continuous improvement.

Balanced Scorecard

The Balanced Scorecard is based on the idea that measuring improvement must be multi-dimensional and focused on four dimensions: (1) finances, (2) customers, (3) internal processes, and (4) innovation and learning.[21] (See Figure 4.) The process involves first defining an improvement strategy and objectives, and then setting measurements for the objectives.

Figure 4. The Balanced Scorecard



Source: Arveson, Paul, "What is the Balanced Scorecard?" The Balanced Scorecard Institute, 1998, www.balancedscorecard.org/basics/bsc1.html.

Once these are set, specific targets are identified, and the expected achievements and responsibilities are defined. Where gaps exist between current values and targets, a process improvement program is initiated, focusing on these gaps. People assigned to improvement efforts are held responsible for the results and then results are measured.

Adopters of the Balanced Scorecard include Los Angeles County General Hospital, Duke University Hospital, and the Montefiore Medical Center in New York.

ISO 9000

The International Organization for Standardization (ISO) is a worldwide federation of organizations that publishes a family of standards initially developed for engineering and manufacturing but also applicable to health care organizations. ISO was first established to define engineering and manufacturing standards that would be universally accepted and followed in all countries (especially the European Union). ISO's emphasis on standardization can be challenging in the case of health care.[22]

The standards address quality and performance improvement. By working to meet these standards, the provider has a ready-made set of guidelines. ISO technical committees publish standards for areas such as medical records, quality management, and process improvement.[23]

ISO emphasizes documenting processes (how work is performed) to ensure accuracy, repeatability, and compliance. ISO organizations document what processes are actually used — not the "ideal" process — and update as the tasks or processes change or are updated.

The ISO standards do not substitute for accreditation standards (such as from the Joint Commission [formerly JACHO] and others), but they do make preparing for compliance easier.

There are other sets of standards that promote improvement operations. The Magnet Recognition Program© from the American Nursing Credentialing Center (ANCC), for example, encourages high levels of performance.

VII. Comparison of Methods: Pros and Cons

These methods all have the same purpose—to improve operations efficiency. Although they vary in focus, they share certain tools (i.e., techniques and concepts) that are complementary, allowing an organization to implement a combination of methods.[24] Table 3 provides an overview each method.

Training and Certification

- Six Sigma offers training and certification in its tools. An organization can choose to train some or all staff levels, depending on the organization's goals.
- Lean requires an organization-wide commitment to change; therefore, the organization must be committed to training many of its staff in this method.
- ME requires having specialists in system redesign, so the costs of training current staff are minimal compared to Lean and Six Sigma.

Lean and Six Sigma offer training and certification to ensure that people using these methods understand what the methods are and how to apply them. However, no single company or organization is considered the one established

Table 3. Comparison of Lean, Six Sigma, and ME Methods

	LEAN (TOYOTA MANAGEMENT SYSTEM)	SIX SIGMA	MANAGEMENT ENGINEERING
Theory	• Remove waste • Maximize customer value	• Reduce variation • Identify and remove causes of variability	• Design system • Identify problems Implement solutions
Application sequence	• Define value • Identify value stream • Create flow and pull • Minimize waste • Perfection	• Define • Measure • Analyze • Improve • Control	• Identify problem • Model • Optimize • Design solution • Implement
Focus	• Flow, quality, and culture	• Problems and defects	• Efficiency and optimization
Example problems method can address	• Reduce supply costs • Address cross functional issues • Revise patient visits to be more customer focused	• Identify causes of patient dissatisfaction • Improve consistency of patient experience	• Design a more efficient workplace • Determine optimum inventory levels • Design scheduling system
Cost	• Staff and management time	• Hiring or training leaders • Gathering necessary operational data	• Hiring educated staff with a focus on improvement
Benefits	• Culture committed to meeting customer needs	• Focus on quality and improvement leadership	• Expertise in effective measurement, analysis, and design tools

authority or certifying body. Industrial engineering requires licenses in some states; schools of industrial engineering are accredited by ABET.[25] Management engineers provide a wide variety of skills and experience and are often knowledgeable in Lean and Six Sigma.

Data Gathering

All three methods require data (patient movement, supply activity, or equipment usage, for example) to identify problems in operations. Gathering relevant data uses information technology support to create and manage the data, and is often the most time-consuming aspect of process improvement work. Organizations that already have some database information on operations and IT support may want to consider ME. If easily accessible data are not currently available, ME improvement results will be slow to occur. Lean, with its focus on waste and cultural change, requires the least data of the three primary methods. Using the Lean method, organizations can make certain improvements with little operational data.

Implementing the Methods

Most organizations that have successfully implemented these methods adopted the following practices:

- **Involve front-line staff.** Caregivers who are working daily with patients are the best source for identifying problems. Because caregivers work directly with patients and must eventually implement the changes, they should be involved in the process improvement from initiation to implementation.
- **Make objectives clear and available.** Post objectives on the wall in prominent places (lunch rooms, for example) so that staff members know what their organization is trying to achieve.
- **Obtain management support.** Mid- and senior-level management provide the necessary resources and set priorities for operations improvement. Organizational change will not occur or be sustained unless senior leadership is supportive and involved in the change process. Certainly the cultural change expected by Lean will not occur without a high level of support.
- **Emphasize communications and team effort.** Providing health care services requires staff to work as an organized group focused on a common goal. Health care providers who have employed operations improvement methods have found it critical to get full involvement of physicians, nurses, administration, etc. to achieve sustained results.
- **Provide necessary resources.** Process improvements can often be accomplished with internal staff and without capital purchases. However, some resources are required. In particular, staff must have the necessary time to devote to improvement projects. In the case of Lean, Kaizen (change) meetings with staff can take a week or more of full-day training with 10 or more staff. Data are also needed to quantify problems, make logical choices, and measure success. IT support can be an issue since existing computer systems are often designed to support clinical and financial needs rather than operational ones.
- **Provide training.** Even if outside consultants are used, internal staff must understand the methods for ongoing use. Many training sources are available from colleges, private providers, and professional societies. Training can be limited to a

specific tool or a broad set of methods. Generally, the trained individual must be involved in ongoing use of the methods in order to maintain effectiveness.

Implementing these practices will ensure that results will be meaningful. Operations improvement leads to significant cost savings, increased capacity, and a motivated workforce. As noted in Section II, the savings can be great.

VIII. How to Decide

Some organizations have successfully used a combination of these methods; they need not be used in isolation. However, if an organization is initiating its first operation improvement program, the organization should consider one single method to avoid being overextended.

Selecting the "best" method requires first defining the specific goals for improvement:

- Definition of the long-term goals;
- Type of problem to be addressed (cultural change, capacity increase, patient satisfaction improvement, cost reduction, etc.);
- Experience in such operations improvement, internally or from related organizations;
- Size of the institution;
- Budget and time available; and
- IT services and data availability.

If the overall performance goals are not well defined and understood, then methods like Balanced Scorecards, Baldrige, and ISO 9000 can provide an initial structure. Once goals are defined, the organization can select an approach that best addresses those goals, given the organization's limitations such as cost or time constraints, for example.

- **If immediate savings are imperative,** then Lean may be the best way to find cost savings and get prompt results.
- **If the organization wants to develop a continuously improving quality service,** then Six Sigma may be best.
- **If the organization needs to design a new system,** then management engineering skills may be needed.
- **If the organization needs tools to control and monitor change and has the money for a consultant or new staff,** then management engineering provides the most comprehensive solution.
- **If the organization lacks a clear set of operational goals,** then a Balanced Scorecard, Baldrige, or other overview should be undertaken first.

Need for Quick Results or Long-Term Improvement

If quick results are a priority, then the Lean method offers advantages: waste can be eliminated within a day after learning Lean's waste-identifying methods. Lean can be used to reduce gross waste in selected areas.

Long-term sustained improvement requires broad organizational support and trained staff. Training takes time. Some providers have found that training large segments of their staff is, in fact, best so that many people are working toward improvement as part of their regular duties. Six Sigma offers a clear set of training levels and certifications. Others, however, feel that an organization needs a stronger intervention than training alone.

Need for an Expert

Experts in these methods are valuable to the organization in getting the process started, training staff, and helping sustain the effort. The availability of a local "expert" (from a local university or an independent consultant) may be a useful in selecting an approach. Having an expert available for the long term can help the organization sustain improvement by offering an independent view. Budgets may determine if staff can be hired or a consultant afforded. Internal staff can be a good resource if they have available time and the necessary expertise. Consultants and academic institutions can offer training as well as experience. Also consider financial grants that support operations improvement work.

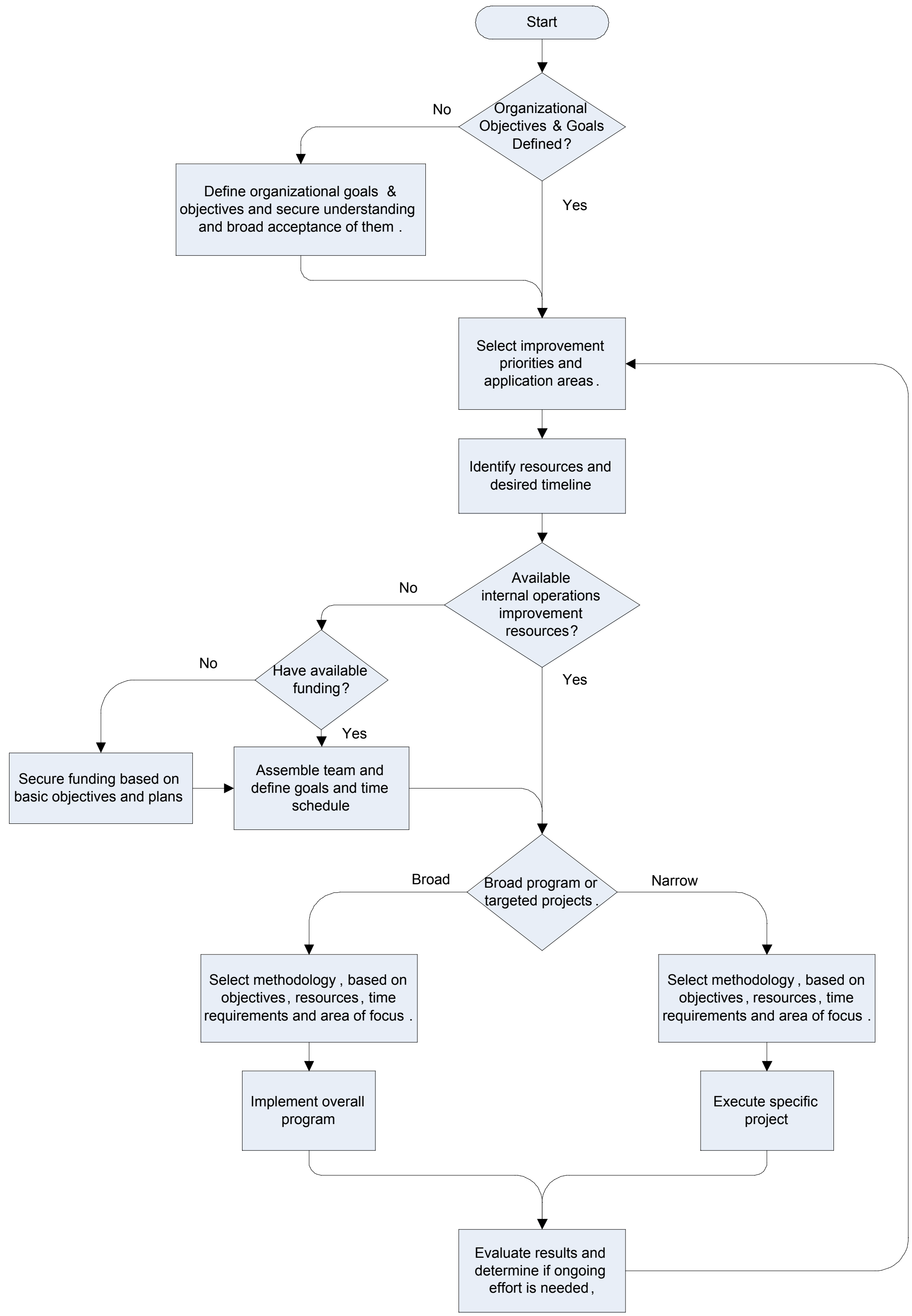
Several professional organizations are available to assist in operations improvement. The Institute for Healthcare Improvement provides training and seminars for specific functional areas, such as surgery, as well as broad-based programs for systems and quality improvement.[26] Several organizations exist to support Lean, Six Sigma, and management engineering. Conferences and seminars are provided by the Society for Health Systems and the Healthcare Information and Management Systems Society.[27,28]

Size of an organization is generally not the key consideration. Most hospitals and clinics, of all sizes, have similar problems with waste, efficiency, and consistency.

Selecting the right method—or combination of methods—requires first defining the specific improvement goals, assessing the resources needed to implement and train staff, and committing to the method requirements to ensure successfully implementing and sustaining improvement. (See Figure 5.)

The methods discussed in this paper have helped health care organizations reduce costs, improve efficiency, and increase patient satisfaction. These methods cover a range of techniques and work processes and can be effective in your organization, depending on the organization's objectives and resources available.

Figure 5. Choosing a Path



Source: Belson, David, Ph.D., University of Southern California, Los Angeles, 2009.

Appendix: Terminology

Below are terms and tools used by the operations improvement methods in health care; commonly used terms are denoted by the following codes: (L) = Lean, (S) = Six Sigma, (IE) = Industrial Engineering or Management Engineering.[29] There are more terms used in operations improvement work than those listed here, which are given as representative examples. Italicized terms are defined in separate listings.

A

Affinity Diagrams. A team-based method of organizing information, such as causes of a problem. Typically, brainstormed ideas are written on "sticky notes" that are stuck to a wall and progressively organized into logical groupings by the participants.

Alpha Risk. Also known as Producer's Risk. The probability of committing a Type I error; generally, the risk of incorrectly concluding that there is a difference. (S)

Andon Board. A visual control device in a work area, typically a lighted overhead display, giving the current status of operations and alerting team members to emerging problems. (L)

B

Balanced Production. The outcome of a system in which all operations or cells produce at the same cycle time. In a balanced system, the cell cycle time is less than Takt Time. (L)

Balanced Scorecard. A strategy used to drive performance and accountability. Under this system the organization develops performance measures in each of four categories:

- Financial – the traditional focus of performance
- Customer (generally a patient) – the present and future needs and expectations
- Business Processes – the efficiency of the operations
- Learning and Growth – developing the knowledge and expertise in the organization

Benchmarking. A strategy for improving systems involving comparing a system used in your organization with the equivalent system elsewhere. This system may be at a competing organization, or in another industry that is particularly effective with the system concerned, or even in another division of your own organization. Benchmarking may also be conducted in a more narrow way, such as comparing a certain metric to the same measurement elsewhere or to an average value from similar organizations.

Beta Risk. Also known as Consumer's Risk. The probability of committing a Type II error; generally, the risk of incorrectly concluding that there is no difference. (S)

Bottleneck. Any resource whose capacity is equal to, or less than, the demand placed on it.

Brainstorming. A problem-solving conference technique in which participants announce suggestions in rapid sequence. The brainstorming objective is to uncover a large number of possible problem solutions. Brainstorming enhances group creativity by encouraging group members to generate as many novel ideas as possible on a given topic, with no one allowed to criticize or evaluate ideas while the meeting is in session.

C

Cause and Effect Diagrams. Also known as Ishikawa diagrams. Graphical tools used to list and categorize possible causes of a problem. The diagram looks like a fish skeleton and is sometimes called a "fishbone diagram". The categories most often selected are Methods, Equipment, Personnel, and Materials, but other categories may be selected as appropriate.

Confidence Interval. A range describing where the true population parameter lies with a certain degree of confidence. For example, a 95 percent confidence interval for the mean estimates that the true mean lies within the confidence interval with 95 percent confidence (with 5 percent alpha risk). (S)

Constraint. Anything that limits a system from achieving higher performance, or throughput.

Continuous Flow. Refers to a system where items are produced and moved from one processing step to the next one at a time. Each process makes only the one piece that the next process needs, and the transfer batch size is one. Also called "single-piece flow" or "one-piece flow." (L)

Control Chart. A graph that monitors variance in a process over time and alerts the business to unexpected variance that may cause defects. (S)

Control Limits. Natural process limits, determined from historical data of how the process will run if undisturbed. The control limits are often set at the historical mean or target ±3 time the historical standard deviation for the process. (S)

Current State Map. A diagram that helps visualize the current production process and identify sources of waste. (L)

D

Defect. A process output that does not meet specification. (S)

DFSS. Design For Six Sigma. Also known as DMADV. A systematic methodology using tools, training, and measurements to enable us to design products and processes that meet customer expectations and that can be produced at Six Sigma quality levels. (S)

DMADV. Define, Measure, Analyze, Design, Verify. Also known as DFSS. (S)

DMAIC. Define, Measure, Analyze, Improve, Control. A Six Sigma process improvement method for continued improvement. It is a systematic, scientific, fact-based, closed-loop process that eliminates unproductive steps, often focuses on new measurements, and applies technology for improvement. (S)

DOE. Design of Experiments. An efficient experimental strategy that allows the investigation of multiple factors at multiple levels while minimizing the experiments or test required.

F

FMEA. Failure Mode and Effects Analysis. A method for evaluating risk in which each potential failure mode is evaluated for. (S)

Five-S. Term for five processes used to create a workplace suited for good visual control and lean production. (1) *Sort* means to separate needed tools, parts, and instruction from unneeded materials and to remove the latter. (2) *Simplify* means to neatly arrange and identify parts and tools for ease of use. (3) *Scrub* means to conduct a cleanup campaign. (4) *Standardize* means to conduct Sort, Simplify, and Scrub at frequent intervals to maintain a workplace in perfect condition. (5) *Sustain* means to form the habit of always following the first Ss. (L)

Flow. An objective of Lean production, and one of the important concepts that passed directly from Henry Ford to Toyota. Ford recognized that ideally production should flow continuously all the way from raw material to the customer, and envisioned realizing that ideal through a production system that acted as one long conveyor. (L)

Future State Map. A blueprint for Lean implementation. The future state map reflects your organization's vision, and forms the basis of your implementation plan by helping you design how the process should operate. (L)

G

Gantt Chart. A diagram showing the work breakdown of tasks for a project against time. The vertical axis shows the activities and the horizontal axis the time they take (in days, weeks, months etc.) (IE)

Gainsharing. The term used to denote any plan for sharing productivity gains with employees, including small group and individual incentives and other pay-for-performance practices. (IE)

J

Just-in-Time (JIT). A system design for producing and delivering the right items at the right time, in the right amounts. The key elements of Just-in-Time are *Flow, Pull, Standard Work, and Takt Time.* The idea is to produce or keep inventory to a minimum, producing materials or work only when necessary and at the latest possible moment. (L)

K

Kaizen. Generally refers to a team approach to quickly tearing down and rebuilding a process layout to function more efficiently. (L)

Kanban. A signaling device that gives instruction for production or conveyance of items in a pull system. It is a message that can be in paper or electronic form. It can also be used to perform *Kaizen* by reducing the number of Kanban in circulation, which highlights line problems. (L)

L

Lead Time. The total time a customer must wait to receive a product after placing an order. When scheduling and production systems are running at or below capacity, lead time and throughput time are the same. When demand exceeds the capacity of a system, there is additional waiting time before the start of scheduling and production, and lead time exceeds throughput time. (L)

Lean. A term describing business processes that require less human effort, capital investment, floor space, materials, and time in all aspects of operation. (L)

Learning Curve. A plot of productive output or unit work times of an individual or group as a function of time or output per unit time; used to predict the learning rate in starting up a new job or project. A learning curve is usually exponential and flattens out with time. (IE)

M

Mean. The arithmetic average of a set of values. The sum of a set of values divided by the number of values.

Median. The middle value found after a set of values has been rank ordered. If there is an even number of values, then it is the average of the middle two numbers.

Mistake-Proofing. Also known as fool-proofing, error-proofing, or *Poka Yoke.* A control method that makes it unlikely or impossible for an error to occur. (L)

Mode. The most frequently occurring value in a data set.

Muda. Waste. Anything that interrupts the flow of products and services through the value stream and out to the customer is designated waste. (L)

N

Noise Variable. A nuisance or uncontrolled factor that adds variation to a process or product. (S)

Non-Value Added. Describes activities or actions taken that add no real value to the product or service, making such activities or action a form of waste. (L)

Normal Performance. The work output of a qualified employee considered acceptable in relation to standards and pay levels, agreed upon with or without measurement by management or between management and the workers or their representatives. An acceptable amount of work produced by a qualified employee following a prescribed method under standard safe conditions, with an effort that does not incur cumulative fatigue from day to day. The base performance level above which incentive bonus is paid. (IE)

O

One Best Way. The concept that for every job there is an optimal work method that can be developed and specified. A concept originated by Frank and Lillian Gilbreth. (IE)

P

Pareto Diagram. A graphical tool that focuses on the efforts or problems that have the greatest potential for improvement by showing relative frequency or size (or both) in a descending bar graph. Based on the Pareto principle, which states that 20 percent of sources cause 80 percent of problems.

PDCA. Plan, Do, Check, Act. A cycle of steps used in Six Sigma quality improvement efforts to evaluate the effectiveness of improvement techniques. (S)

Plan: Senior management should use the visioning process in the context of its business plan. HP translates business plans to action plans that are meaningful to all levels of the organization.

Do: Answer “who”, “what”, and “how” for the total number of tiers in an organization, keeping in mind that the fewer the number of tiers, the better. The Do stage is also the time to bring management together and provide them with a basic understanding of HP mechanics.

Check: Periodically review measurements and note what was learned that can help in the future.

Act: Make the necessary adjustments to plans and priorities in order to ensure the success of the strategy breakthroughs.

Poisson Distribution. A probability function that is used for charts for defects.

Poka-Yoke. A mistake-proofing device or procedure to prevent a defect during order-taking or manufacture, for example, a screen for order input developed from traditional ordering patterns that questions orders falling outside the pattern. In this case, the devices or procedure would case suspect orders to be examined, which would often lead to the discovery of inputting errors or buying based on misinformation. A manufacturing example might be a set of photocells in parts containers on an assembly line that would prevent components from progressing to the next stage with missing parts. (L)

Process Map. A diagram representing a sequence of processes, such as the activities done to complete a particular objective. Process maps might show a flow of work, organizational relationships, or the movement of materials or data.

Productivity. The ratio of output to total inputs. The ratio of actual production to standard production, applicable to either an individual worker or a group of workers. (IE)

Pull. One of the three elements of Just In Time processing. In a pull system, workers at the downstream process take the product they need and pull it from the producer; this customer's pull is a signal to the producer that the product is sold. The pull system links accurate information with the process to minimize waiting and overproduction. (L)

Push. A system that requires a product to be pushed into a process, regardless of whether it is needed. The pushed product goes into inventory and, lacking a pull signal from the customer indicating that it has been bought, more of the same product could be overproduced and put in inventory. (L)

Q

QFD. Quality Function Deployment. A visual decision-making procedure for multi-skilled project teams which develops a common understanding of the voice of the customer and a consensus on the final engineering specifications of the product; the outcome of the QD process should have the commitment of the entire team. QFD integrates the perspectives of team members from different disciplines, ensures that their efforts are focused on resolving key trade-offs in a consistent manner against measurable performance targets for the product, and deploys these decisions through successive levels of detail. The use of QFD eliminates expensive backflows and rework as projects near launch.

R

Reengineering. The engine that drives time-based competition. To gain speed, firms must apply the principles of reengineering to rethink and redesign every process and move it closer to the customer. (IE)

Regression Equation. A prediction equation that allows values of inputs to be used to predict the value of outputs.

Root Cause Analysis. The study of the original reason for nonconformance with a process. When the root cause is removed or corrected, the nonconformance will be eliminated. (S)

S

Sample Size. The amount of data an experimenter needs to answer a statistical question. Varies with alpha risk, beta risk, & the associated difference to be detected. (S)

Scatter Plots. Graphs of data points used to show the relationship between two variables. (S)

Sensei. An outside master or teacher who assists in implementing Lean practices. (L)

Seven Wastes. Taiichi Ohno's original catalog of the wastes commonly found in physical production. These are overproduction ahead of demand, waiting for the next processing stop, unnecessary transport of materials, over-processing of parts due to poor tool and product design, inventories more than the absolute minimum, unnecessary movement by employees during the course of their work, and production of defective parts. (L)

Single-Piece Flow. A system or process in which products proceed, one complete product at a time, through various operations in design, order taking, and production, without interruptions, backflows, or scrap. (L)

Spaghetti Diagram. A diagram that shows the movement (usually of people) during a process. Its purpose is to identify potential improvements to the layout to remove unnecessary movement. (L)

Specification Limits. Requirements based on customer requirements or expectations. (S)

Standard Deviation. The square root of the Variance.

Standard Work. A precise description of each work activity specifying cycle time, Takt Time, the work sequence of specific tasks, and the minimum inventory of on-hand parts needed to conduct the activity. (L)

Standard Time. A unit time value for the accomplishment of a work task determined by the proper application of appropriate work measurement techniques by qualified personnel. Generally established by applying appropriate allowances to normal time. (IE)

Statistical Process Control. The application of statistical methods to analyze data and study and monitor process capability and performance.

T

Takt Time. Available production time divided by the rate of customer demand. For example, if patients demand 240 services per day and providers operate at 480 minutes per day, Takt Time is two minutes; if patients want two new services per month, Takt Time is two weeks. Takt Time sets the pace of production to match the rate of customer demand and becomes the heartbeat of any Lean system. Takt is derived from the German word "Taktzeit," which translates to cycle time. (L)

Theory of Constraints. A management philosophy that stresses the removal of constraints to increase throughput while decreasing inventory and operating expenses.

Throughput Time. The time required for a product to proceed from concept to launch, order to delivery, or raw materials into the hands of the customer. This includes both processing and queue time.

Type I Error. Finding an imagined difference where none actually exists. (S)

Type II Error. Failing to find a difference when one actually exists. (S)

V

Value. A capability provided to a customer at the right time at an appropriate price, defined in all cases by the customer. (L)

Value Stream Mapping. A graphical tool that highlights the sources of waste and eliminates them by implementing a future state value stream that can become reality within a short time. (L)

Variance. A statistical measure of the variability of a single data point. Or, a change in a process or business practice that may alter its expected outcome. (S)

Visual Control. The placement in plain view of all tools, parts, production activities, and indicators of production system performance so everyone involved can understand the status of the system at a glance. (L)

VOC. Voice of the Customer. (S)

W

Waste. Anything that uses resources but does not add real value to the product or service. (L)

Work Measurement. A generic term used to refer to the setting of a time standard by a recognized industrial engineering technique, such as time study, standard data, work sampling, or predetermined motion time systems. Another word for work measurement is "ergonometrics". (IE)

Work Sampling. An application of random sampling techniques to the study of work activities so that the proportions of time devoted to different elements of work can be estimated with a given degree of statistical validity. (IE)

Z

Z-score. The distance of a particular value from the sample mean in units of standard deviations.

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25. In 2005, ABET formally changed its name from the Accreditation Board for Engineering and Technology to ABET, Inc.

26. The Institute for Healthcare Improvement
20 University Road, 7th Floor
Cambridge, MA 02138
www.ihi.org/ihi/contactus.aspx

27. Society for Health Systems, www.iienet.org/shs.

28. Healthcare Information and Management
Systems Society
230 East Ohio Street, Suite 500
Chicago, IL 60611-3270
www.himss.org

29. From the Industrial Engineering Terminology publication, an official standard of the American National Standards Institute.

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