Change and improvement are never easy. Even an apparently simple system becomes much more complex when change is contemplated or introduced. This chapter will use the two parts of the Model for Improvement presented in Part One (see Figure 1.4)—the three fundamental questions and the PDSA Cycle—to guide the reader in expanding the use of the model to more complex applications than those discussed in Part One. Figure 1.5 illustrated the wide variety of settings and levels of complexity in which this very simple framework can be used to guide improvement efforts. Mastering the methods for working on complex projects presented in this chapter will increase your ability to make improvements in some of the less-complex settings described in Part One.

What Are We Trying to Accomplish?

When the owners of the diner described in Chapter One decided to improve the lunch service, they were able to discuss and agree on the aim of the project over a cup of coffee. They might even have been able in this short period of time to come up with some ideas for changes. This was possible because so few people were involved in the effort, those initiating the effort were also doing the work, the system was relatively simple, and unintended consequences were easily identified.

As the scope of an improvement effort increases, the system becomes large or complex, more people become involved in or affected by the work of improvement, those initiating the effort may not be doing the work, and unintended consequences of the changes may be difficult to identify or anticipate. For these reasons, it is recommended that the answer to the question of what is to be accomplished be written down. This written statement of aim is sometimes referred to as a charter. The written document can be discussed and circulated for comment to a variety of people who have a stake in the work or the outcome of the project.
Charters can take many forms, but a charter that contains a general description of aim and some guidance for carrying out the work has proved useful, especially for projects that were initiated by someone other than those who are working on the project. The charter should explain in broad terms what is to be accomplished and why. The guidance section of the charter should include information that helps an individual or team begin to answer the fundamental questions about the improvement effort. Information that might be included are such things as suggestions for measures, aspects of the system on which to focus initially, boundaries within which the changes are to be developed, and recommendations for possible changes. If specific results are expected from the improvement effort, they should be included in the charter. Exhibit 4.1 contains examples of charters. Some additional examples are included in the case studies in Chapter Eight. The sample charters in Exhibit 4.1 address two issues that arise when setting the aim of an improvement initiative: the use of numerical goals and the removal of the current system as an alternative. Both of these issues will be addressed in Chapter Thirteen, but they are worthy of brief consideration in this chapter.

**Use of Numerical Goals**

Advice about the use of numerical goals in setting an aim for an improvement project ranges from “never use them” to “always provide one and let other people figure out how to achieve it.” This book’s authors recognize the abuses associated with numerical goals, including falsifying figures, unfairly holding people accountable for results that they are incapable of achieving, and achieving the goal at the expense of other parts of the system. We do not believe, however, that these instances of poor practice or abuse should preclude the use of numerical goals in ways that are beneficial.

We also recognize that some hardy souls need only the challenge of a numerical goal to find ways to actually improve the system. The existence of these few individuals does not justify the wholesale use of numerical goals without associated methods for achieving them. Our experience indicates that a middle ground between these two extremes is achievable and useful.

Numerical goals can be a convenient way to communicate expectations. Are small incremental improvements expected or are large breakthrough changes necessary? If the numerical goal is used well, it not only communicates the expectation; it also communicates the support that will be provided. Large changes to big systems usually require investment of time and sometimes capital.

Individuals and teams rarely will significantly exceed their own expectations of what is possible. Those providing the goal must convince the team that the goal is feasible. Means of doing this include:
Example 1: Medication System in a Hospital

General Description: Redesign the medication system to reduce errors, improve customer satisfaction, support care, and reduce costs.

Guidance:
1. A multitude of relatively small improvement projects have been completed on various processes in the medication system, resulting in some improvement, but the fragmented nature of the efforts prevented the optimization of the system as a whole. This project should address the system as a whole.
2. The system includes all processes inside the hospital relating to the use of medications, but it also extends outside the hospital to impact the continuum of care—for example, the patient’s primary-care physician.
3. The project should obtain significant results in reduction of errors, increase in customer satisfaction, and reduction of cost. Preliminary analysis of the opportunities for improvement indicates that at least a 50 percent reduction in errors and a 15 percent reduction in cost are achievable.

Example 2: Computer Support

General Description: Improve the process for supporting computer hardware and software needs in the organization. Emphasis should be placed on improved response time of software and response to customers’ requests.

Guidance:
1. An expected result is a documented process for support of hardware and software needs.
2. Some important measures of performance are:
   - Response time to requests for software support
   - Down time
   - Response time to customers with software needs

Exhibit 4.1. Examples of Charters.

- Observing other organizations that have accomplished similar goals
- Providing some basic concepts or ideas that, if pursued, could feasibly result in achieving the goal
- Drawing out ideas from participants themselves by asking questions like “What would it take to get a 50 percent reduction in time to ship an order?”
- Showing data on current faults of the system and computing the performance levels of the system if these faults were eliminated

Removing the Current System as an Alternative

Change is difficult. The current system pulls innovative changes toward more familiar ground like a giant magnet. What begins as a large change often results
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### Example 3: Budget for Capital Expenditures

**General Description:** Redesign the system for budgeting capital expenditures so that the system better supports the business initiatives of the company.

**Guidance:**

1. **The expected result of this project is a system that:**
   - is responsive to the strategic needs of the business units, manufacturing, and research.
   - deals effectively with the distribution of limited capital so that customers of the process feel that the distribution has occurred in an objective manner.
   - minimizes the time needed to operate the process.
   - minimizes the difference between the capital budgeted and the amount actually spent, except under unanticipated changes in the business environment.

2. **The boundaries for the project are:**
   - the capital planning system to be improved will have as an input an upper limit of expenditure defined by the CEO. The team is not asked to address the process of defining this upper limit.
   - the team will work on the mechanical part of approving appropriation requests for individual projects.
   - the current system is in need of significant redesign; the team should not be constrained by existing procedures.

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3. **Some boundaries for the activities are:**
   - existing and new software should be addressed.
   - the different hardware configurations of all customers should be accommodated.
   - initial focus should be on the software supporting the organization's primary products.

In only a small adjustment. Frequently, it is implicitly or explicitly assumed that if changes resulting in improvement cannot be developed, then remaining with the current system is an option. This is comforting to participants, but it inhibits improvement.

The charter can be used to prevent this assumption from being made by including the following:

- A statement of fact, such as, “remaining at the current level of twenty-one days is not an alternative if the custom business is to remain viable.”
- A numerical goal that clearly is not attainable with small changes to the current system.
- Some ideas for changes to be pursued if no better alternative is developed.
• Logical consequences that follow from failure to make the improvements, such as discontinuing the product or service.

• A statement that takes part of the present system away, such as, “Computer Services will delete the old version of the accounting package from all computers on the tenth of the month.”

**How Will We Know That a Change Is an Improvement?**

An effective answer to this question provides the foundation for the learning that is fundamental to effective improvement. Changes to large and small business, government, or social systems are frequently made without thoughtfully answering this question. Consequently, valuable opportunities to learn and to accelerate improvement are lost.

In simple systems it is often easy to discern that a change is an improvement by informally observing the system. In more complex systems, measurements or other types of data are almost always necessary to answer this question. For example, measures of improvement in redesigning a hospital’s medication system might be customer satisfaction, medication error rate, timeliness of administration, and costs associated with the system; measures for reducing labor costs in the lab might be hours of overtime, costs for temporaries, turnaround time, and accuracy; and measures for developing a new flooring tile might be whether it holds a shine, its ease of installation, its durability, and its visual attractiveness. Some guidelines for developing such measures are:

1. Make sure that the interests of the customer of the product or process are strongly represented in the list of measures.

   A company that makes garage door openers had to decide what their customers would call good quality. They knew from their 800-number survey that ease of installation was one of the measures of quality. They constructed a simple three-question form for their customers to fill out about the experience they had had during installation. They put the three questions on the back of the warranty registration card. As the company made changes to make the installation easier, they expected the responses to the three questions to show improvement.

2. It is useful to look at data collected both before and after a change; however, this is not always necessary, or possible. Often, looking at data collected after a change is enough to justify calling the change an improvement.
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Sally was quite happy. The chart of the number of errors showed that they were producing consistently fewer than ten errors per week in statements sent to customers. From their weekly meetings the previous year she knew that they used to produce more than fifteen errors per day. Although she did not know precisely the effect of the changes that were made, she was confident that it was substantial. The data that had been collected since the latest changes would serve as the baseline against which to assess changes in the future.

3. In many situations, the data needed to measure the impact of a change will not be available for a long time. When this is the case, select a surrogate or intermediate measure that is related to the measure(s) you most want to impact.

| The leaders of a large health care organization wanted to make some changes that would result in the reduced occurrence of lung cancer. They decided to start a clinic for helping people to stop smoking. Obviously, what they wanted was to see the rate of lung cancer go down. It would take many years, however, for this result to be detectable. They decided to focus on an intermediate measure, one that could be measured immediately, one that they strongly believed is related to a reduction in lung cancer. They decided to measure the success rate of people trying to quit smoking (specifically, the percentage of people who went through the workshops who were still not smoking six months after the program). |

| The process are |

4. Multiple measures are almost always required, in order to provide a balance among competing interests and to help to assure that the system as a whole is improved. Try to keep the list to six or fewer measures—certainly fewer than ten. Strive to develop a list that is useful and manageable, not perfect.

| A state’s secondary education system was interested in increasing the scores that its high school students achieved on the Scholastic Aptitude Test, necessary for admission to most colleges. Some people were concerned that some high schools would achieve the aim by discouraging the poorer-performing students from taking the test and thus hurting their chances of going to college. To accommodate this concern, the percentage of students taking the exam was included in the list of measures. |

Levels of Measurement

Item 3 of the previous list described intermediate measures. Intermediate measures are actually part of a hierarchy of measurement. To facilitate learning while
improving a complex system, the use of different levels of measurement is particularly helpful. In simple systems, two to four cycles may be all that are needed to accomplish the aim. In complex systems, many more cycles will usually be needed. The need for multiple cycles raises two questions: (1) How can we learn from each cycle if it takes many cycles to achieve the results we want? and (2) How can we assure that the cycles will actually combine to provide real improvement at the system level? These questions can be answered by responding to the question, How will we know that a change is an improvement? at several levels. These are (1) global or outcome measures, (2) intermediate measures, and (3) process measures.

**Global Measures** Global measures are measures of the big system under study. They relate directly to the aim of the project. Improvement in these measures signifies accomplishment of the aim.

To support one of the initiatives in its strategic plan—to improve quality and reduce cost—a computer manufacturing company chartered a team to change how suppliers of components are brought into the new-product process. Jed, the project leader, chose five measures relating to quality and cost of the computer.

Global measures facilitate learning from a sequence of cycles by providing evidence that the sequence of changes are actually having an impact at the system level.

**Intermediate Measures** An intermediate measure is related to the global measure, but improvement in the intermediate measure is not sufficient to ensure the accomplishment of the aim. Intermediate measures could be thought of as indicators of progress.

Jed realized that it would take a year or more to see improvements in the measures of quality and cost of the computer. He chose the average number of vendors per component as one of several intermediate measures to help guide the learning as they worked through the project. Having fewer vendors was not the aim of the project. However, the company believed strongly that reducing the number of vendors was a prerequisite for close cooperation on improvement efforts.
Intermediate measures are chosen by making a rational argument—supported by research, experience, or common sense—that improvements in the intermediate measures will eventually lead to improvements in the global measures and accomplishment of the aim of the project.

**Process Measures** In large systems, the global and intermediate measures most often assess the impact of several cycles. Process measures, usually associated with a specific cycle, are often used to determine if the cycle was carried out as planned.

As part of the new working relationship with suppliers, key technical people from the supplier companies were invited to participate in the design of the components for the computer. In the past, the suppliers were given little say about the design of the components, even though they had potentially valuable expertise. Jed and the team decided to run a cycle to test the theory that suppliers could contribute to the design of components. One of the process measures they used was the number of suggestions from suppliers that were actually included in the design of the components.

Unambiguously classifying global, intermediate, and process measures is not the aim of this discussion. The important lesson is that a variety of measures will be needed to guide the learning and action as a project progresses, especially for improvement of complex systems. Some data should be collected and plotted over time for the life of the project, and others will be used only for a short time as part of a PDSA cycle.

**What Changes Can We Make That Will Result in Improvement?**

Answering this question requires developing possible changes. For relatively simple systems, a list of changes may be developed and tested almost immediately. For larger, more complex systems, or for any efforts that require fundamental design or redesign, it is advantageous to answer the question in two parts. First, provide some broad concepts for the system design, sometimes referred to as concept design. Second, provide more detail on the actual changes that will be made to the components of the system.

A teaching hospital associated with a leading medical school was concerned about the performance of the system of ordering, distributing, and administering medications to patients. Hospital management was also concerned that patients were having problems obtaining or properly using the medications once they left the hospital.
A multitude of relatively small improvement projects had been completed on various processes in the medication system over the preceding five years. This had resulted in some improvement, but the fragmented nature of the efforts prevented the optimization of the system as a whole. Management decided to charter a project to address the system as a whole. Their aim is presented in Example 1 in Exhibit 4.1. To decide whether the changes were improvements, they used a patient survey, measures of error rates, timeliness of administration of medications, and costs associated with the system.

A small core group of nurses, physicians, and pharmacists were responsible for providing a concept design to guide the overall project. Some of the major design concepts for accomplishing the aim were:

1. Patient service
   a. Standardize patient education regarding medications.
   b. Provide multilingual medication information.
   c. Follow-up on problematic cases after discharge from hospital.
   d. Provide information on where hard-to-obtain medications can be found in the community.

2. Clinical decision support: Many choices of medication are available for the complex problems experienced by the varied patients treated in this hospital. It is difficult for physicians to keep abreast of the existing choices and the latest developments in medication. Support physician decisions concerning medication by providing electronic information systems and by making pharmacists available to them for consultation.

3. Timely administration of medications
   a. Keep frequently used medications on the unit rather than in the pharmacy. Investigate the use of automated dispensing systems (similar to ATM machines at banks).
   b. For medications that must be ordered from the pharmacy, consider using fax and pneumatic tube systems.
   c. For appropriate drugs, the pharmacy should carry some inventory to be dispensed when ordered rather than having to produce a dose of the drug from each order.

4. Standardization
   a. Provide the same information about a medication in the same format to patients and clinicians on all units.
   b. Standardize times to administer drugs to patients.
   c. Standardize procedures for restricted drugs.

5. Error proofing
   a. Minimize the transcription of medication orders by providing online ordering systems.
   b. Use industrial error-proofing methods to reduce errors during the production of medications.
   c. Streamline and optimize inspection.

6. Optimize the mix of pharmacy tasks.
   a. Increase efficiency by centralizing and streamlining production.
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b. Take advantage of efficiencies to provide unit-based consulting.
c. Establish cooperative relationships with community pharmacists.

With some guidance from the hospital leadership, the core group chartered thirteen teams to build on the concept design. The teams developed and tested changes to components of the system that were consistent with the spirit of the concept design.

Chapter Five provides methods for developing changes. In addition, Chapters Ten, Eleven, and Twelve address developing changes for particular business goals.

The Plan–Do–Study–Act Cycle

The PDSA Cycle is the primary means for turning the ideas into action and for connecting action to learning. Using the cycle effectively takes some discipline and effort. Figure 4.1 provides some detail on what should be considered in each phase of the cycle.

Jed and his team planned a cycle to evaluate the participation of supplier experts during the early concept design phase for a new computer. This cycle was part of their project to increase the quality and lower the cost of their computers and associated products through better supplier relations. In theory, the idea of including suppliers in the design phase was appealing. However, it did take more work, it made the meeting arrangements more complex, and it required additional time for technical people from the suppliers. The team wanted to learn about the return on this investment.

The plan for the cycle was to invite suppliers to three upcoming design meetings. Each meeting was concerned with a different product, so only one or two people would be at all three of the meetings. In some cases, more than one supplier for the same component would be at a meeting. The team was interested in seeing the effect of having competitors at the same meeting. Two members of the team were assigned to attend all three meetings to observe and record their observations. In particular they were to record (1) attendance from the suppliers and their level of technical expertise, (2) ideas that came from the suppliers and that would be pursued in the design, and (3) the willingness of suppliers to perform further investigative work after the meeting. In addition, a survey questionnaire would be sent to each person who attended the meeting to get their general impressions of the meeting and the usefulness of including suppliers at this phase in the design of a new product.

The data for the three meetings would be studied at a meeting of the improvement team. Based on the results, they would take some action, such as changing the criteria
Jed and his team thoughtfully planned a cycle to learn from the three meetings. They did not just invite some suppliers to see how it would work. They realized that since only a few people would attend all three meetings, some important information would be lost, and if they simply asked the participants to comment on the meetings, much of the detail would be lost. Neutral observers were used to collect the data. The team also set aside some time to reflect on the results by studying the data from the three meetings. They planned to take action based on what they learned.

Contrast what Jed and his team did with a more-familiar scenario: have the meetings, hear some anecdotes about how the meetings went during a weekly staff meeting, decide whether to keep inviting suppliers, based on the most compelling anecdote, and regardless of the decision, neglect to set up a process to
carry out the decision. Although in this scenario action occurred, it should not be considered a cycle.

To be considered a PDSA Cycle, the following aspects of the activity should be easily identifiable:

1. The activity was planned, including a plan for collecting the data.
2. The plan was attempted.
3. Time was set aside to analyze the data and study the results.
4. Action was rationally based on what was learned.

Not all improvements require cycles; some just happen. However, most purposeful improvements will require answers to the three fundamental questions. Purposeful improvements in large or complex systems will almost always require one or more cycles. Exhibit 4.2 is a worksheet that has proved useful for establishing a degree of discipline and thoughtfulness in carrying out a cycle. Filling out a worksheet for each cycle is a convenient way of documenting the project.

The PDSA Cycle is a vehicle for learning and action. The three most common ways for using the cycle as part of an improvement effort are:

1. To build knowledge to help answer any one of the three questions
2. To test a change
3. To implement a change

The next sections clarify the use of the cycle as an aid to answering the three questions. (The use of the cycle to test a change is discussed in Chapter Six, and the use of the cycle for implementing a change is discussed in Chapter Seven.)

Using the Cycle to Build Knowledge

The PDSA Cycle is used when current knowledge or readily available background information are not sufficient to answer one or more of the three questions. The primary use of data in answering the question What are we trying to accomplish? is to determine why a particular aim should be chosen from among the many alternative initiatives. The data might be warranty claims, responses to a customer survey, an analysis of defects or complaints, plots of measurements over time, or documented comments from employees.

Several workers had complained to the plant manager that the glass bottles they had to use were "nothing but junk." They pointed out that they had to throw away hundreds of pounds of glass every day. By examining the reject records and by plotting the weight of rejected glass daily for three weeks, the operations manager was able to show the workers that the quality of the glass was better than they had expected. Once they began
Exhibit 4.2. Worksheet for Documenting a PDSA Cycle.

<table>
<thead>
<tr>
<th>PDSA Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle #</td>
</tr>
<tr>
<td>Plan</td>
</tr>
<tr>
<td>Do</td>
</tr>
<tr>
<td>Study</td>
</tr>
<tr>
<td>Act</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

The following example illustrates the use of a cycle to set the aim for an improvement effort.

A manufacturer of a garage door opener established an 800 telephone number to assist customers. As an input to their quality planning process, management planned a cycle.
to collect and analyze data from the calls to the 800 number according to the following procedure:

1. A summary of each call was logged for one week.
2. The calls were classified into six categories (installation, warranty, parts, new model, billing, and cosmetics).
3. The data were then collected for three more weeks by using a worksheet to record the time of each call and the category into which it could be classified. Space was provided for summaries of calls that did not fall into any of the six categories (other).
4. The analysis of the data was used as input to planning for improvement.

Figure 4.2 contains a Pareto chart (graphs that illustrate the relative frequency of occurrence of an activity) for calls for assistance received on the 800 number. Two aims were adopted as a result of analyzing the data presented in the figure: (1) to improve the ease of garage door installation and use of accompanying instructions, and (2) to make warranty information more understandable.

![Pareto Chart](image)

**Figure 4.2. Pareto Analysis of Calls from Customers.**

A cycle can also be used to answer the question, *How will we know that a change is an improvement?* A cycle might be run to determine a balanced set of measures. The cycle could consist of a survey of customers or interviews with a sample of people who have a stake in the system. Other cycles that might be completed to help answer this question include:
- Collecting baseline data on the performance of the system
- Testing the feasibility of using a new measurement device, such as a new color-measuring instrument
- Testing the clarity of survey questions
- Assessing the ability of workers to routinely collect data
- Testing the accuracy of a lab result

One way to answer the question, What changes can we make that will result in improvement? is to use existing knowledge or some creative activity, as discussed in Chapter Five. When the knowledge or ideas for specific changes are not available, one or more cycles can be used to build the knowledge necessary to develop the changes.

The following example illustrates the use of a PDSA Cycle to build knowledge to develop a change.

The management of a rapid rail transportation system in a large metropolitan area designed a cycle to help set priorities for improvement. The cycle included soliciting suggestions from riders of the subway as to how the system could be improved. More than eighteen hundred replies were received. The replies were analyzed in a variety of ways. One analysis took into account the relative merits of the suggestions by qualitatively choosing a subset of the suggestions for testing. The output of the analysis was simply a list of changes to be tested:

- Pay telephones on station platforms
- Better lighting in the stations
- More directional signs
- Farecard vending machines that accept $10 and $20 bills
- A twenty-four-hour telephone assistance line for riders
- Mailboxes at station entrances
- Use of credit cards to buy farecards
- Transit system information on display near the convention center
- Selling the family/tourist pass at all stations
- Indicators showing the color of the next scheduled train (by track)

Detailed design of the tests was then accomplished in subsequent cycles by small teams.

One caution: Make sure that when a cycle is run in order to build knowledge that the knowledge gained is subsequently translated into action. Do not forget
the A in PDSA. In each of the examples just provided, immediate action was taken based on what was learned.

**Using the Cycle Sequentially**

The Model for Improvement is based on a trial-and-learning approach to improvement. The PDSA Cycle is the vehicle for learning and for transforming that learning into action. In general, increased frequency and number of cycles results in increased improvement. We strongly advocate the rapid testing of changes on a small scale and the subsequent use of other cycles to scale-up the changes. In our experience, spending more time in the conference room trying to perfect the change before testing is not an effective way to make improvements. Too many uncertainties will exist. (This concept was discussed in Chapter One and illustrated in Figure 1.3.)

Although the use of small-scale, rapid cycles runs counter to intuition, it is an effective approach for the design or redesign of large or complex systems. The bigger the system is, the more uncertainties there will be and the less likely it will be that conference-room analysis will uncover them. A criticism of this approach is that for large systems all of these small cycles will not be coordinated and therefore will not result in real change to the system. This potential weakness is overcome by using a concept design (discussed earlier in this chapter) to set the context for all the smaller cycles. (Note: small cycle refers to the size of the test or the scope of the implementation. The change being tested could be very innovative and a significant departure from current practice—a very large change.) The concept design is refined and more detail is added as cycles for testing components of the design are completed.

For the redesign of large systems it is usually effective to run simultaneous sequences of cycles.

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Dave ran one of three major businesses within a manufacturing company. Dave, Ruth, Ellen, and Todd were working to fundamentally redesign the system for their custom products. The charter for their effort was the following:

**General description:** Reduce the time to get custom sampling tubes for air pollution monitoring from twenty-one days to fewer than seven days.

**Guidance:**
1. Surveys and discussions with customers indicate that providing customer orders within seven days would make our product extremely attractive to them. Customers who are making their own custom tubes would be willing to buy from us rather than make the tubes themselves if that type of reliable service were available.
2. The initial focus should be on custom products, but the team should also communicate changes that could benefit the system for standard products.
3. Remaining at the current level of twenty-one days is not an alternative if the custom business is to remain viable.

Within a year they were able to accomplish the charter, and business increased 30 percent. To accomplish their aim, they had to make improvements simultaneously in several areas: increase manufacturing efficiency, improve scheduling, streamline quality assurance, and redesign the price-quoting system. Each of these areas of focus included sequences of PDSA Cycles, as illustrated in Figure 4.3.

People frequently comment that the simultaneous approach to running cycles prevents one from knowing which changes actually produced the result. Some considerations when addressing this concern are:

1. Sometimes, even when the changes are improvements at the local process level and are not impacting the global measures, a simple cost-benefit analysis results in the changes being implemented.
2. Often, no one change or sequence of changes is responsible for the overall improvement. The newly redesigned system as a whole is producing the increased performance. Thus, investigations into what the one important change might be are often futile.
3. For situations in which the changes are expensive or it is desirable for other reasons to implement only those changes that affect overall system performance, various methods of testing are available. Changes can be “turned on and off” one at a time to see if the performance degrades. More sophisticated
experiments can be designed so that the effect of more than one change at a time can be evaluated. (Such experiments are briefly described in Chapter Six.)

**Using Data in a Cycle**

The use of data in a cycle to facilitate learning and action is an important aspect of the approach presented in this book.

Sally was a midlevel manager in a large corporation. Her department was responsible for the processing of hundreds of complex forms every day. To improve the performance of her group, Sally purchased new high-speed computers and new software. She was quite sure that these changes had resulted in improvement of the department's performance. Some of the clerks complained that the new programs were too hard to use, but others talked about how fast the new computers were "once you learned the new system." Sally’s boss argued that errors were still being made and that her department’s work was backed up worse than before they had "invested all that money."

The problem Sally faced could have been greatly reduced if her plan for the change (new computers and new software) had included the use of data collection and analysis. Data could have been used to answer the fundamental question, How will we know that a change is an improvement? Instead, Sally relied on observation, memory, and feelings to judge the success of the changes being implemented in her department. But people will always disagree on what they have observed. Human beings filter the information they get from their observations. In fact, what people "observe" is strongly affected by other recent observations. For example, salespeople often show a customer an expensive item first so that the cost of the item the customer originally asked about will seem less expensive. The consideration of data both reduces the impact of subjectivity and brings independence to the analysis.

For the purposes of this discussion of improvement efforts, data may be defined as documented observations or measurements. Observations play an important role in change efforts. The only difference between observations and data is that data are thoughtfully documented. The documentation can take the form of activities recorded on videotape or in a photograph; ideas and feelings written in a diary; and words, letters, or numbers written on paper or in an electronic file. Documentation of observations and measurements provides a more balanced and objective view of the behavior of the systems you are trying to improve.

Most people think of data as numbers that result from measurement of such factors as time, cost, or length—elements of the physical world. The idea of data
is often associated with the physical sciences. People engaged in improvement efforts, however, are also interested in data about personal behavior and experience.

Data about personal experience can be obtained indirectly by recorded observation (written or visual) or by counting the frequency of certain behaviors. Some examples of observations of behavior that could be recorded and analyzed are being tardy or absent, making repeat purchases, volunteering answers in a seminar, searching for a salesperson in a store, signaling for service in a restaurant, paying attention to a product displayed in a store, volunteering for a task, and committing unsafe acts. These observations can be quantified by using classifications or counts of the observed behavior during some fixed period of observation.

Data about personal experience can also be obtained directly by asking people about their feelings or by asking them to record their feelings at specified or random times. So-called "attitude surveys" are another example of obtaining this type of data. In efforts to determine whether changes to products are improvements, aesthetic characteristics would fall into the category of personal experience.

Ranking or rating scales can be used to obtain data on personal experience. Figure 4.4 contains three such rating scales. The following are some examples of questions and statements that could be used with the scales:

**Examples of Questions Used with the Poor-Excellent Scale**
- How would you rate your health in the last four weeks?
- How would you rate the courtesy shown to you during your stay at this hotel?
- How would you rate the landscaping around this building?
- How would you rate the relationship you have with our project manager?

**Examples of Questions Used with the Worse-Better Scale**
- How would you rate your overall health now compared to four weeks ago?
- How would you rate the new process for taking orders compared to the old one?
- How would you rate the appearance of floor tile A compared to tile B?
- How would you rate the new sick-leave policy versus the old one?
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Examples of Statements Used with the Agree-Disagree Scale
- Our attorneys exhibit the highest integrity.
- Our instructions for assembly of the bookcase are easy to follow.
- It is easy to find what you are looking for in our catalogue.
- Conscientious efforts were made to relieve your anxiety during your stay in the hospital.

The response to the question can be put anywhere on the scale. It need not be limited to the five discrete labels. The scales are provided to establish a basic level of measurement for almost any application. These scales, along with common measurements of such factors as time and cost, will allow those who are trying to improve quality in service or administrative applications to use continuous data as readily as their manufacturing counterparts.

Some Suggestions for the Proper Collection of Data Data are usually collected as part of the PDSA Cycle. The object of the cycle may be to build knowledge or to test or implement a change. The following are some suggestions for the proper collection of data:
1. Explicitly state the questions to be answered by the data. Data are collected to facilitate learning. The data collection will be most efficient if the questions to be answered by the data are stated ahead of time. This is why part of the planning phase of a cycle includes identifying the questions to be answered by the data to be collected in the cycle. Deciding how the data will later be analyzed (perhaps by sketching some "dummy" tables and graphs that will be used to present the results of the analysis) provides those planning the cycle with a way to check that they are collecting the data necessary to answer the pertinent questions.

2. Use sampling to collect the data. It is often better to study a sample rather than all available items. For example, rather than using a simple check sheet to record every call to an 800 number, analyze every twentieth call in more detail. Much can be learned from small samples, especially if they are collected over time. Sampling reduces both the cost and the workload. Reducing the burden of collecting a large amount of data also enables people to do a better job of measuring and studying the items selected. Studying a sample therefore often provides better information than studying all of the items that are available.

3. Design and test a form for collecting the data. Using a form that has been carefully designed and tested to collect the data will make the collection process easier and reduce the opportunity for error. The form should contain the necessary instructions for collecting the data and definitions of terms.

4. Train those who will collect the data and give them understandable instructions. In most cases the collection of data to aid improvement efforts calls for some new tasks for those collecting the data. Do not assume that people will know how to do the necessary tasks. Provide training that includes the reasons for collecting the data and the importance of the data. The specific process of measurement or recording should be reviewed and practiced.

5. Record what went wrong during the data collection. The data will be collected during the Do phase of the PDSA Cycle. Every collection of data will have some problems, some things that did not go as planned. Be sure to include in the instructions to those collecting the data that they record these occurrences and not hide them. The people analyzing the data must then assess the impact of these unexpected occurrences on the conclusions drawn from the data.

The Display and Analysis of Data. Of the many ways to analyze data, visual displays provide a particularly useful form of analysis. Figure 4.5 contains examples of five basic types of data displays: a run chart, which plots observations over time; a histogram, which plots observations to show their distribution; an ordered bar chart known as a Pareto diagram, which illustrates relative frequency of occurrence; a scatter diagram, which plots observations to show the relationship between two sets of data; and a map, which plots data across locations.
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Figure 4.5. Various Types of Data Displays.
As noted earlier, good data analysis begins with clarifying what question is being asked of the data. Are you trying to predict future performance, determine the extent of a problem, find out where you should focus your efforts, or determine a relationship? The question you want to answer will not only guide you to the appropriate data to collect but will also guide you to the appropriate type of data display.

Graphs that are useful for learning, communication, and improvement should:

- Show all the data (at least in the first analysis)
- Separate sources of variation
- Emphasize comparisons and relationships
- Minimize text, markings, colors, and so on that are not directly related to the data
- Label data to provide enough explanation for self-interpretation
- Be simple enough for the appropriate people to learn from quickly
- Avoid fancy embellishments such as huge splashy fonts, art deco backgrounds, or 3-D displays (unless, of course, the data is three-dimensional)

Of all the displays in Figure 4.5, the plot of data over time plays the central role when making improvements. Change is a prerequisite for improvement, and people experience change as a time-related phenomenon. Often, the answer to the question, How will we know that a change is an improvement? is that one or more measures will either increase or decrease over time. By plotting data over time, patterns that indicate improvement can be discerned.

One of the pioneers in the use of time plots for purposes of improvement was Walter Shewhart. His work dates back to the 1920s. When plotting data over time Shewhart observed two situations. In some cases the patterns in the data were predictable. (See the time plot before the new system was installed in Figure 4.5.) Shewhart theorized that this predictability indicated that the system was stable and that only a fundamental change to the system would alter the pattern. In other cases, the pattern of variation over time was not predictable from historical patterns. The system was unstable. To Shewhart this indicated the presence of specific circumstances that should be identifiable (such as the installation of a new system). Based on these observations, Shewhart used statistical theory to develop a means of understanding variation in systems based on patterns of variation over time. His method is based on the following definitions:

*Common causes:* those causes that are inherently part of the process (or system) over time. They affect everyone working in the process, and affect all outcomes.
A process that has only common causes affecting the outcomes is called a stable process, or one that is in a state of statistical control. In a stable process, the cause system of the variation remains essentially constant over time. This does not mean that there is no variation in the outcomes of the process, that the variation is small, or that the outcomes meet the requirements. It only implies that the variation is predictable within statistically established limits. In practice, this indicates that a fundamental change to the system is needed for improvement.

A process whose outcomes are affected by both common causes and special causes is called an unstable process. An unstable process is not necessarily one with large variation. Rather, the magnitude of the variation from one period to the next is unpredictable. If special causes can be identified and removed, the process becomes stable. Its performance becomes predictable. In practical terms this implies that improvement can occur by identifying the special causes and taking appropriate action, which often means much less change than for a stable system. Once a change is made, plotting data over time helps to determine whether the change is an improvement.

In addition to providing the basic concepts, Shewhart also encouraged the plotting of data over time, and developed the control chart method for determining whether variation in a system is dominated by common or special causes. Although there are many situations in which the statistical formality of control charts is useful, often it is adequate to rely on run charts, or simple plots over time (see Figure 4.5). Statistically minded readers are encouraged to learn and apply Shewhart control charts.

**Conclusion**

This chapter has expanded on the options presented in Part One of the book by discussing ways to apply the Model for Improvement to large and complex systems. Concepts introduced were the use of a written charter to state aims and provide guidance for achieving them; the use of various levels of measurement; the idea of using a concept design and a sequence of cycles to guide fundamental system design or redesign; the value of using simultaneous sequences; and the effective use of data.

**Special causes**: those causes that are not part of the process (or system) all the time or do not affect everyone, but arise because of specific circumstances.