PART 3

Improving the Delivery System

Operating systems must be constantly maintained and updated. Technological changes, competitive changes, service-product changes, and customer taste changes all conspire to create an environment where the operation cannot be “left alone.” Even where all of the elements above are stable, operations will deteriorate over time unless it is given care and attention.

There are specific techniques and mental models for the care and attention of service operations that are covered in this section: Process analysis, service quality management, and applying six-sigma methodologies to the service sector.

CHAPTER 9

Analyzing Processes

LEARNING OBJECTIVES *The material in this chapter prepares students to:*

- Diagnose and fix problems in processes.
- Create process flow diagrams and Gantt charts.
- Identify bottlenecks in processes.
- Understand the procedures behind simulating services.
- Run a service simulation.
- The simulation software SimQuick is described on the Student CD.

Regardless of the functional area, be it marketing, finance, operations, or any other, the actual work done can usually be described as a group of processes. If resources are used to produce outputs, then generally a process has been used. Examples of processes include scheduling a media campaign, writing a contract, executing a trade, approving a loan, and billing a customer.

This chapter looks at the process of analyzing and improving processes. The first half of the chapter will demonstrate two simple visual tools that help in improving processes: process flow diagrams and Gantt charts. The second half discusses the more complex task of simulating processes. The Student CD makes use of process simulation software.

The Need for Process Analysis in Services

The simple tools introduced in this chapter are well known to manufacturers. A formal responsibility of many industrial engineers is to maintain process flow diagrams for any complex manufacturing processes. In services, however, this aspect is quite often neglected—to their detriment. Within many service firms a single process can involve several different departments. Because of the lack of a formal description of a process, these different departments are often unaware of how their actions impact other parts of a service. We provide some examples of these complex service processes.

Consider a New York City cop who gets a flat tire on his patrol car. Although police are allowed to carry lethal weapons, have wide latitude in investigating criminal activity, and can pass physical tests of endurance and strength, they evidently cannot be trusted to change a tire. In the mid-1990s, the following process was necessary (*New York Daily News*, 1996):

1. Officer fills out a tire replacement request (TRR) form.
2. Tire Integrity Unit reviews the TRR.

3. Officer picks up tire at an approved vehicle maintenance facility.
4. City-approved vendor replaces tire.
5. Used tire is returned to the police garage.
6. Precinct commander signs off on TRR.
7. Tire Integrity Unit compares original and signed TRR forms and files them.

The estimated annual police officer salaries spent for tire changing amounted to $500,000.

On a more serious note, consider the arrest-to-arraignment system in New York City in 1988 (Larson, Cahn, and Shell, 1993):

1. Arrest is made and detainees are placed in patrol car by arresting officer (AO).
2. Detainees are transported to precinct by AO (average time: one hour after arrest).
3. Prisoner searched, fingerprinted, and arrest report generated.
4. Detainees are transported to central booking by AO and placed in a large holding cell (average cumulative time: five hours).
5. Detainee searched and given a bail interview. Fingerprints faxed to state capital for positive ID and return of detainee's rap sheet (average cumulative time: 15 hours).
6. AO gives a statement to an Assistant District Attorney (average cumulative time: 14 hours). (AO must be present and wait—often for several hours—for an available Assistant District Attorney.)
7. The last of steps 5 and 6 completed and additional paperwork performed (average cumulative time: 18 hours).
8. Detainee transported back to precinct holding cell. Arraignment scheduled. Detainee transported to courthouse holding pen (average cumulative time: 39 hours).
9. Detainee arraigned and bail set (average cumulative time: 44 hours).

It is generally considered unreasonable to hold a defendant more than 24 hours without a court hearing to determine probable cause, but in New York the average was 44 hours. However, 44 hours was only an average—many people were held far longer. Because of the cumbersome nature of this process some detainees were being held more than 100 hours—while making new friends in crowded holding cells—before arraignment.

The Los Angeles Police Department also went through a thorough process analysis. A few of the less productive processes included work scheduling: Each month, each officer spent three hours requesting days off for the next month. Also, forms were required from so many different entities that arresting a juvenile drunk driver required manually writing the suspect's name 70 times (Bailey, 1996).

Hopefully, readers will have little experience with the aforementioned institutions. However, one is likely to encounter insurance companies and retail banks. Table 9.1 demonstrates the relative back-office productivity of three firms with a similar customer

TABLE 9.1: *Productivity in the Insurance Industry*

Firm	Percentage of General Expenses/Premiums
Connecticut Mutual	20.5
Phoenix Mutual	15.7
Northwestern Mutual	6.9

Source: Van Biema and Greenwald (1997).

mix. Northwestern Mutual is credited with spending approximately one-third the amount of money on comparable processes that Connecticut Mutual spends. Possible results of this process efficiency include far more profitability at Northwestern Mutual if prices are the same, or an ability of Northwestern Mutual to charge significantly less for their products than the competition.

The amount of time required to open a checking account at a retail bank is illustrated in Table 9.2. Virtually all the large banks in the United States were included in this study, comprising approximately 75% of the banking assets in the country. If one were to try to open an account during a lunch hour, the best bank in the study would detain a customer only 24 minutes. Going to the slowest bank in the study on a lunch hour, however, would constitute an effective diet plan, as the 59 minutes required at the bank could send an employee on a lunch hour running back to work hungry. This disparity is especially surprising in the retail banking industry, because many employees move from bank to bank, which eliminates "trade secrets." To find out how a competitor opens accounts, a bank can simply send in an employee or hire a "mystery shopper" to do so.

The question is begged: How does this happen? Clearly, there is no centrally planned "evil genius" who gloats with the thought of LAPD officers writing a suspect's name 70 times, or who desires to hold detainees in New York holding cells for four days. In large part, processes become this way due to a slow, incremental buildup of process steps over time combined with the ignorance of some departments about the pressures they put on other groups. Departments frequently only know what their part of the process is and not what other parts of the process even do. This departmental myopia is compounded by the lack of anyone being in charge of a process. Instead, employees are usually in charge of a functional area, and many functional areas must get along for a process to work.

For example, in the New York arrest-to-arraignment system, the problem only became known when the *New York Times* ran a front-page article entitled, "Trapped in the Terror of New York's Holding Pens." Data did not exist on the total time detainees spent in the system, because no one was in charge of the system as a whole. Fixing the system required coordinating the NYPD, NYC Department of Corrections, District Attorney's offices, New York State Office of Court Administration, the State Department of Criminal Justice, the Legal Aid Society, the Criminal Justice Agency, and various bar associations. Solving the problem involved, first, describing the entire process, the topic of this chapter. As will be shown later, once a process is properly described in the visual format of process flow diagrams, departments realize more easily the totality of the issues, and the process flow diagram can become a central document for improvement. In this specific case, a number of changes were made, resulting in cutting the average time to 24 hours and saving approximately $10 million per year for the system in reduced overtime pay and other costs.

TABLE 9.2: ***Retail Banking Processes***

Time required to open a checking account with a $500 cashiers' check and no prior banking relationship

	Activity Time	Customer Time (in minutes)
Best Bank	27	24
Average	54	42
Worst Bank	70	59
Worst 20 Banks	≥ 60	≥ 48

Source: Frei and Harker (1999).

In the more mundane case of retail banks opening new accounts, many of the banks were unaware of their own processes and purchased the information that researchers gathered from the banks' own systems!

Process Flow Diagrams

The first step in analyzing and improving processes is to build a process flow diagram. This simple-to-construct, simple-to-understand visual tool describes a process. The standard tools of the trade are the symbols shown in Figure 9.1. Process flow diagrams are common; many appear in prior chapters of this book. Arrows are typically used to show direction of flow of products, information, customers, or whatever is of interest. Diamonds are used to denote decisions; one arrow often enters a diamond, then two or more arrows exit the diamond to denote decision results. Activities are represented by rectangles and inventory or delays are often represented by inverted triangles. Figure 9.1 shows only the most common images used. A more robust set of icons is standard equipment in many word-processing packages.

Process flow charts technically describe processes. However, they serve three primary "soft" managerial functions beyond technical description that will be described here.

Use 1: Process Communication

The process flow chart is the language used to communicate processes. Merely constructing a process flow chart can be enough to get a process improvement project underway. Consider Figure 9.2, a diagram of the steps involved in ordering inventory for the emergency room of a West Texas hospital. Figure 9.2 is in absurdly small print, since the original, normally-sized, document occupies six pages. The managerial purpose behind the original construction of Figure 9.2 was to communicate a feel, rather than precise process steps—to let hospital management know that, due to interdepartmental meddling, the inventory ordering process had become absurdly complex. The sheer bulk of unfolding the six-page document had the desired effect, and drew managerial attention to the problem.

Figure 9.3 also serves that purpose. This figure describes the check-out process at a Blockbuster Video store. This potentially simple process became the complex network shown as more and more marketing programs were added (see the Service Operations Management Practices: Blockbuster Video Links Process to Profits).

FIGURE 9.1: *Most Common Flowchart Tools*

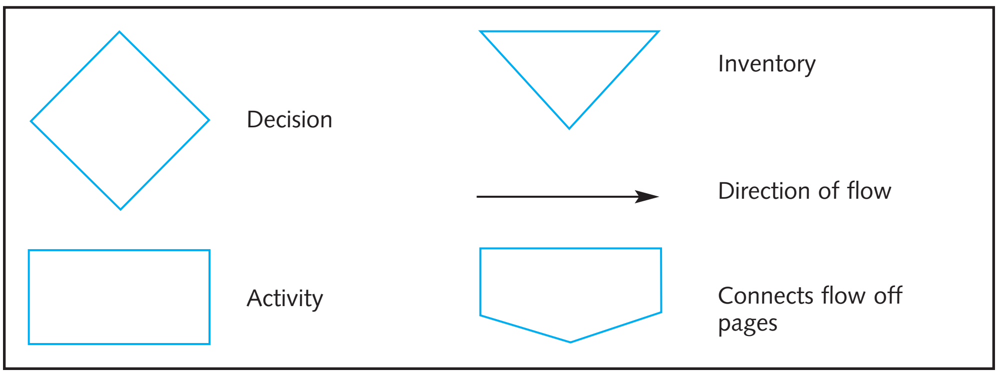
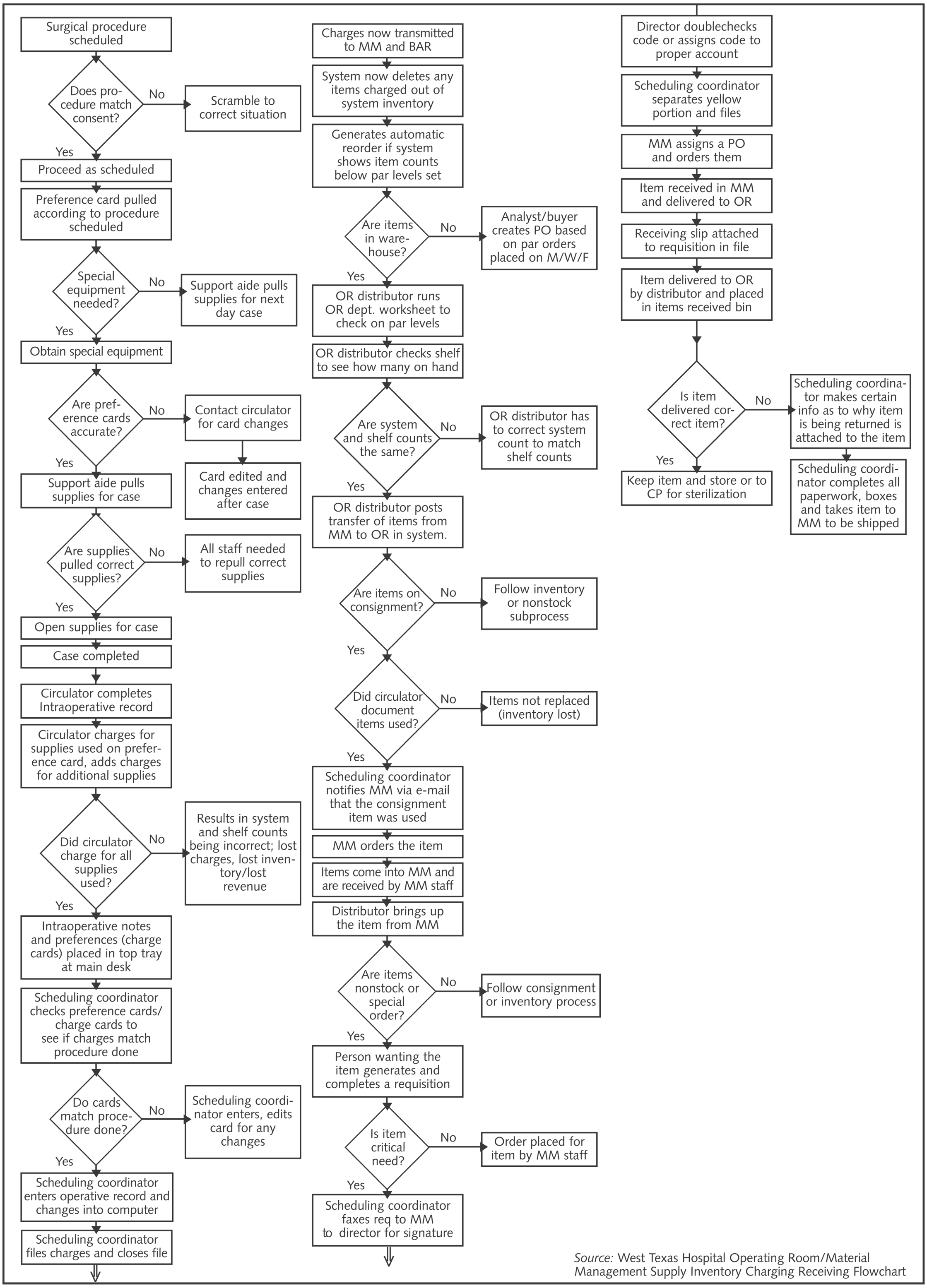


FIGURE 9.2: *Sample Inventory Ordering Flowchart*



Source: West Texas Hospital Operating Room/Material Management Supply Inventory Charging Receiving Flowchart

SERVICE OPERATIONS MANAGEMENT PRACTICES

Telecommunications Operation Without True Communication

In the early 1990s when AT&T wanted to increase the efficiency of its lockbox operation (processing incoming payments), the company decided to start by documenting its current process. Representatives of the two separate operations were selected to the newly formed "process team" and brought together at an off-site location. Many of the employees on the team had been processing the incoming payments for this company for more than 20 years.

Chaos erupted when two employees almost came to blows over how one particular process was supposed to flow. It turned out that these two employees, who sat literally only three feet apart for more than 20 years, carried out the same process *differently* for all those years!

It should also be noted that using the precise and correct symbols in describing a process is not always necessary—the key point is whether the nature of the process is communicated. For example, Figure 9.2 is not technically correct. It contains actions that seemingly end the process, because they have no arrows extending outward, but really are imbedded actions in the process. Often the most significant benefit of creating a process flow diagram is simply drawing attention to a process.

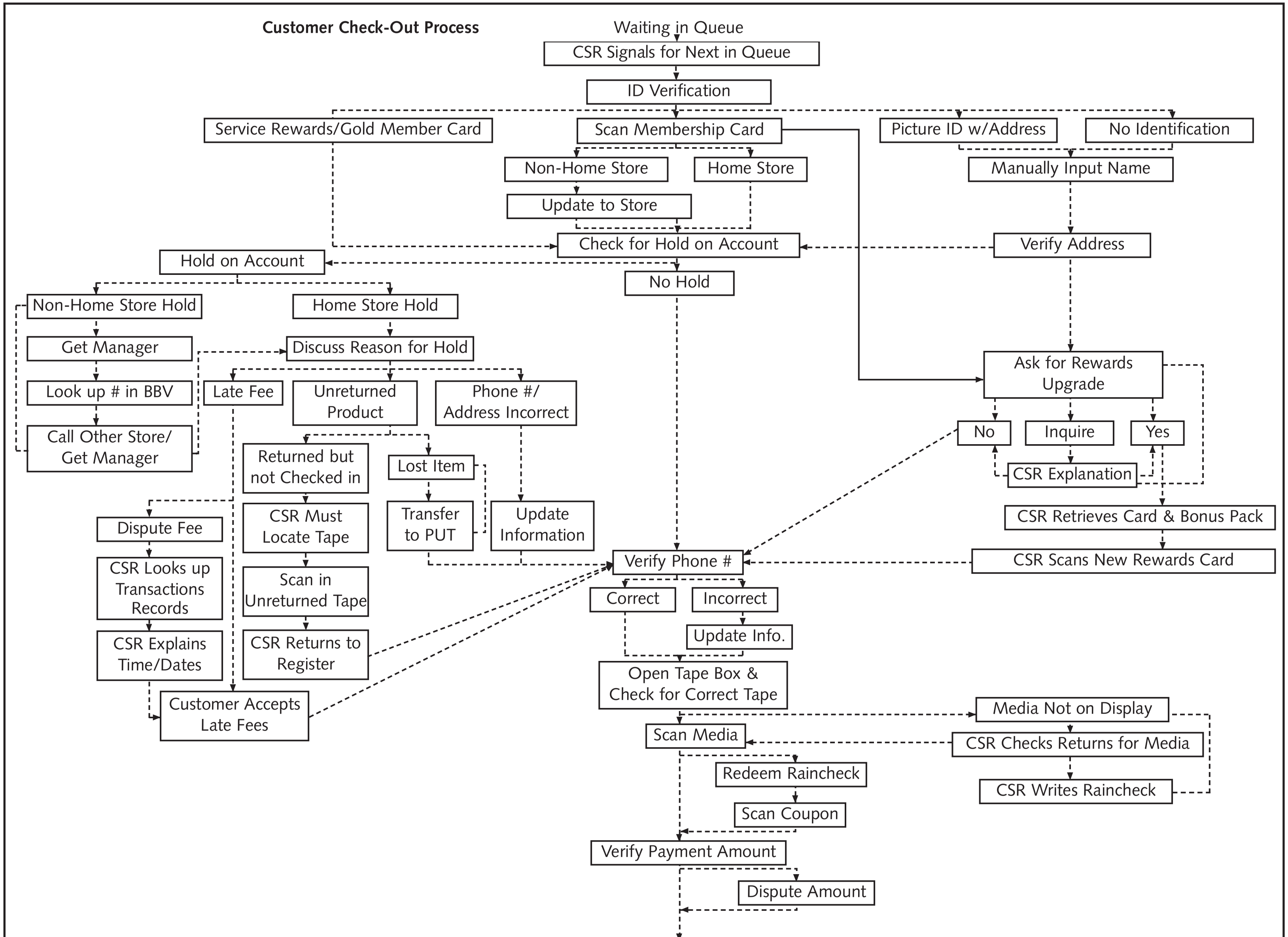
To demonstrate the next two managerial uses of process flow charts, consider the simplified process depicted in Figure 9.4, the back-office processes involved in creating an insurance policy. First, a lengthy, handwritten information form filled out by the salesperson/customer is reviewed for accuracy and entered into a computer system (30 minutes). The information is fed to an underwriter, who is responsible for assessing risk, pricing, and determining whether the insurance company should accept the policy (40 minutes). Finally, the policy writer converts the information into a formal, written policy for the customer (10 minutes). Let us assume that an individual worker is at each station and that each activity takes specialized training and cannot be performed by the other workers. The overall time the process takes, from beginning to end, is 30 + 40 + 10 = 80 minutes. Some call this time the *throughput time*, others call it *cycle time*. In this text it will be referred to as throughput time.

The comparison of throughput time to the actual time taken brings us to our second "soft" use of process flow charts.

Use 2: Focusing Managerial Attention on the Customer

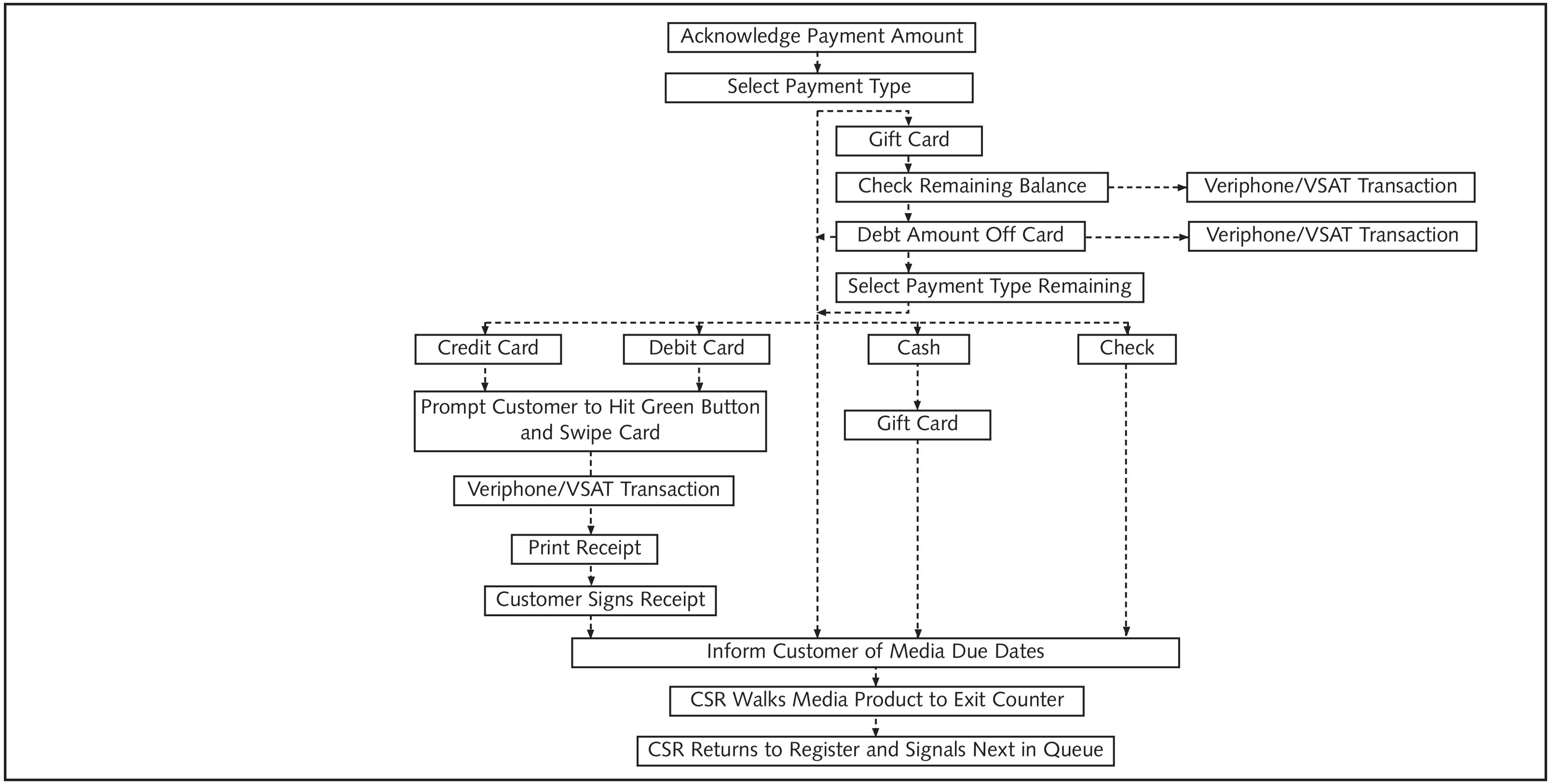
In Figure 9.4 the throughput time is 80 minutes, but the actual elapsed time for the customer is a week. Though this particular example is fictitious, it is representative. It is not unusual for the so-called value-added time that a service firm actually works for a customer to be 5% or less of the total time it takes for the customer to be served (Blackburn, 1991). Reasons for this discrepancy between throughput time and actual

FIGURE 9.3: *Check-out Process at Blockbuster Video*



Note: Process disguised for reasons of confidentiality.

FIGURE 9.3: *Check-out Process at Blockbuster Video (continued)*



Source: S. Evangelist, B. Godwin, J. Johnson, V. Conzola, R. Kizer, S. Young-Helou, and R. Metters, "Linking Marketing and Operations at Blockbuster, Inc.," *Journal of Service Research*, 5(2), 2002, copyright © *Journal of Service Research.*

SERVICE OPERATIONS MANAGEMENT PRACTICES

Blockbuster Video Links Processes to Profits

The nightmare conversation for management at Blockbuster Video: "Let's go to Blockbuster and rent a movie." "Ugh, remember the line at the checkout last Friday? I bet we were there 30 minutes." "You're right, it's too much of a hassle. Let's see what's on the tube instead."

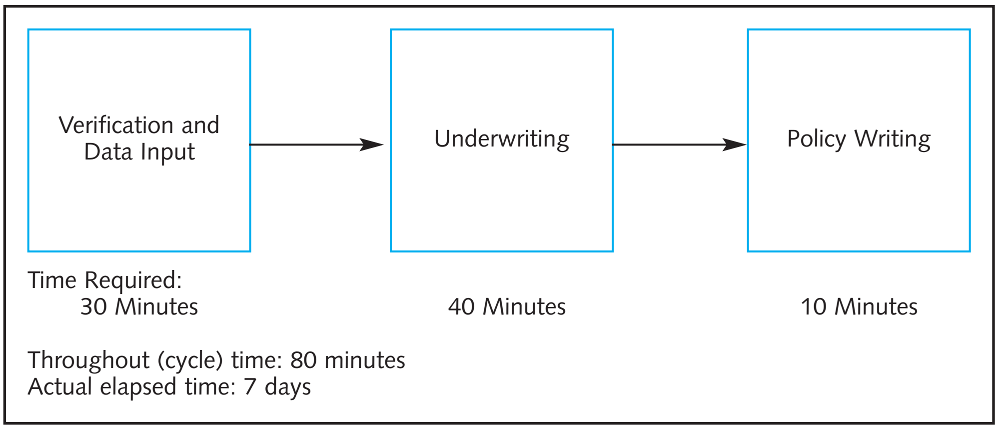
The check-out process at a Blockbuster Video store would seem simple. You give them the cash, they give you the movies, right? Well, not exactly. Due to different marketing programs (e.g., Rewards™ program, "raincheck" program for movies not in stock), different payment methods (e.g., gift cards, credit cards, debit cards, cash, checks), and holds on accounts for various reasons (e.g., late fees for forgotten movies), the check-out process has become amazingly complex (Figure 9.3). Because of the complexity, it takes longer to check out each customer. The reason it took 30 minutes to check out is that you were 15th in line, and the reason 15 customers were in line in the first place is because the customers in front of them took so long to check out.

With the help of marketing models from Walker Information and analysis from IBM, Blockbuster was able to link the time it takes at the check-out counter to customer loyalty, and link customer loyalty to repurchase behavior, then link repurchase behavior to financial results.

How much did they increase profits by using process analysis? Sorry, that answer is confidential, but now every marketing program that impacts the check-out counter is added to Figure 9.3. The times for these programs are assessed, and their effects on profitability become part of the program justification.

elapsed time include unbalanced work flow (no work comes in for a week, then three weeks' of work comes in on one day); batching of work, which makes the first customer's information wait until all customers in the batch are finished; inefficient hand-offs between departments, where work sits in in-boxes or e-mail systems for days before it is touched, just to name a few.

FIGURE 9.4: *Idealized Back-Office Insurance Policy Process*



Typically, departmental managers and workers focus on how to make their own tasks more efficient and do not consider the effect of their actions on the whole process. However, laying out the entire process in the customer's time frame, rather than their own, refocuses efforts toward the customer. This beneficial effect is also seen in the description of the NYPD arrest-to-arraignment process discussed earlier, where the times given in the steps were in terms of customer time, rather than activity time.

Use 3: Determining What to Work On and When to Stop Improving Process Steps

Suppose one were to suggest an improvement to the process in Figure 9.4. By changing the input automation, the data entry stage will take only 20 minutes, rather than 30. The change will be costly to install, but it will cut the work time of that station by one-third. Although such a labor savings sounds seductive, it should not be implemented in this case. In fact, the only changes that should be considered are changes to the underwriting process. To show why, let us start out by determining the capacity of this system. How many policies can be finished in a typical eight-hour day? A naïve calculation would state that because the throughput time is 80 minutes to finish one, and 8 hours = 480 minutes, then 480/80 = 6 policies per day can be finished. A Gantt chart, however, shows that the six policies per day solution is not a good one (see Figure 9.5, part A). A Gantt chart delineates the responsibilities of each person or piece of equipment in the specific time frames they are needed. The times that are actually being worked are in the rectangular boxes, while the spaces between the boxes represent idle time for that person. Part A shows that if a new policy is worked on once an old policy is finished, six policies a day may be done, but a lot of idle time also occurs. Physically, better solutions to the problem come from squeezing the idle time out and getting the rectangular boxes closer together. The best solution is shown in Figure 9.5, part B, where 12 policies per day can be written. In this solution, all three workers are working simultaneously on different policies. Note that even in this best solution, the data entry and policy writing jobs still have blank space, or idle time. (It may appear from the picture that only 11 policies could be written, because the underwriter has to wait 30 minutes for the first policy, and 11 more would take 30 + 11(40) = 470 minutes. However, on a daily basis the underwriter would start work in the morning on the last policy finished by data entry the night before.)

The capacity of the system is directly related to the length of the longest activity. In this case underwriting is the longest, requiring 40 minutes. This longest activity is usually called the *bottleneck*, because the bottleneck process regulates the flow of a service system like the neck of a bottle regulates flow of a liquid. The bottleneck process time and capacity are related by the following simple equation:

$$\text{Capacity} = 1/\text{Bottleneck time}$$

In this case, the bottleneck is 40 minutes, so

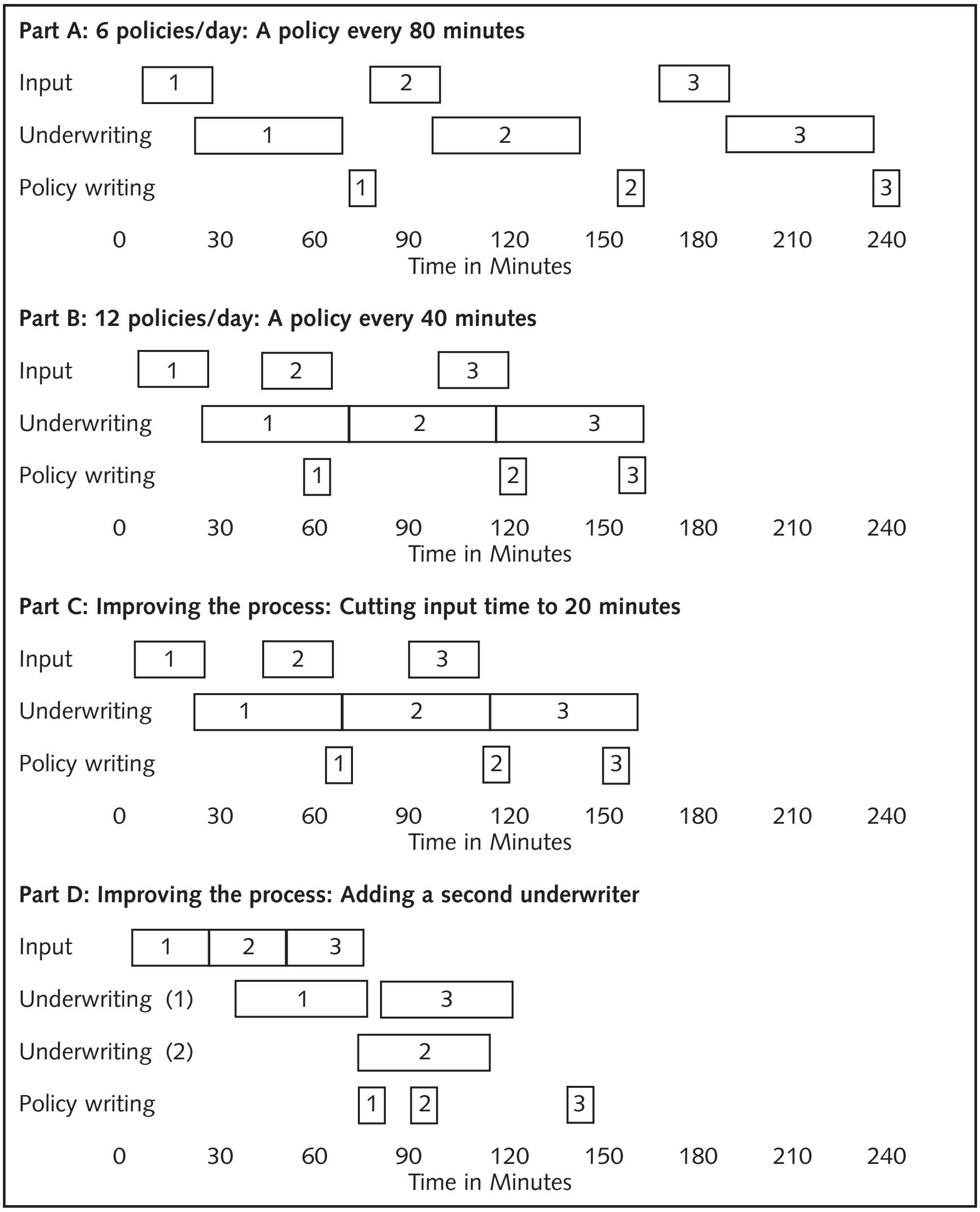
Capacity: Policies/Day = 1 policy/40 minutes × 480 minutes/day = 12 policies/day.

The bottleneck time is also referred to as "cycle time" or, less frequently, "takt time." Here, we will refer to it as cycle time.

A Gantt chart is a good visual style to see how bottlenecks affect capacity, but simple numerical calculations are an alternative means. To determine system capacity, take the smallest capacity of any process. For this example,

Input:	1 policy/30 minutes × 480 minutes/day = 16 policies/day
Underwriting:	1 policy/40 minutes × 480 minutes/day = 12 policies/day

FIGURE 9.5: *Gantt Chart of Insurance Process*



Policy writing: 1 policy/10 minutes × 480 minutes/day = 48 policies/day

so underwriting is the bottleneck.

Besides determining capacity, the bottleneck is important because it indicates what to work on and what to leave alone. To get back to improving the system by reducing data input time, consider Figure 9.5, part C, a Gantt chart mirroring a 10-minute reduction in input time. Here, a policy still exits the system every 40 minutes. All that is accomplished by reducing the input task time is that idle time in the input position has increased.

To improve the system one must attack the bottleneck process. Here, it might be wise to hire a second underwriter. Logic might dictate that if capacity with one underwriter is 12 policies per day, then capacity with two underwriters would be 24 policies per day. However, the reality is different. Figure 9.5, part D shows what happens when two underwriters are on the job. The capacity of the underwriting function is now 24 policies per day, but underwriting is no longer the bottleneck. Now, data input is the bottleneck at 16 policies a day. So, by doubling the capacity of the bottleneck, an improvement of 4/12 or 33% is garnered. In fact, any improvement beyond cutting the time per policy down below 30 minutes is wasted. In other words, useful improvement reaches a limit, a time to stop improving, and that limit can only be found by considering the process as a whole.

Consider multiple improvements. Now that data input is the bottleneck process, it might be time to go back to the original improvement envisioned. If the process includes two underwriters and the data input process only takes 20 minutes, the capacities of the processes are:

Input: 1 policy/20 minutes × 480 minutes/day = 24 policies/day

Underwriting: 2 policies/40 minutes × 480 minutes/day = 24 policies/day

Policy writing: 1 policy/10 minutes × 480 minutes/day = 48 policies/day

so underwriting and data input are jointly the bottleneck and the system capacity is 24 policies per day.

Process Simulation

Simulation is a useful tool for analyzing and improving service processes. Unlike tangible products, usually service designers cannot build a prototype of a service and use this model in field tests to understand the service's performance. Likewise, if one considers making some changes to a service process and would like to measure performance improvements (i.e., worker or technology utilization, waiting time, capacity planning, or scheduling), it is difficult to run pilot tests on the service due to disruptions to the real business, employee reactions, and other implementation costs. As an alternative, simulation allows designers to develop and perform experiments on a model of a real system.

Simulation offers several other advantages. First, it often leads to better understanding of a real system and is far more general than mathematical models such as waiting time theory (see Chapter 14). Second, it allows compression of years of experience into just a few seconds or minutes of computer time. Third, simulation can answer what-if questions and can be used to analyze transient (nonsteady state) conditions. On the other hand, it may take multiple simulation runs and scenarios to evaluate a service system, with no guarantee of an optimal solution.

Most simulation models are built on a computer either with commonly available programs, such as Microsoft Excel, or more specialized simulation packages such as SimQuick, ServiceModel™, MedModel™, or Crystal Ball™. The process example described in this chapter uses an Excel-based simulation. An example of process improvement with SimQuick is covered on the CD. More advanced process modeling requires specialized packages.

Access your Student CD now for the simulation example with SimQuick.

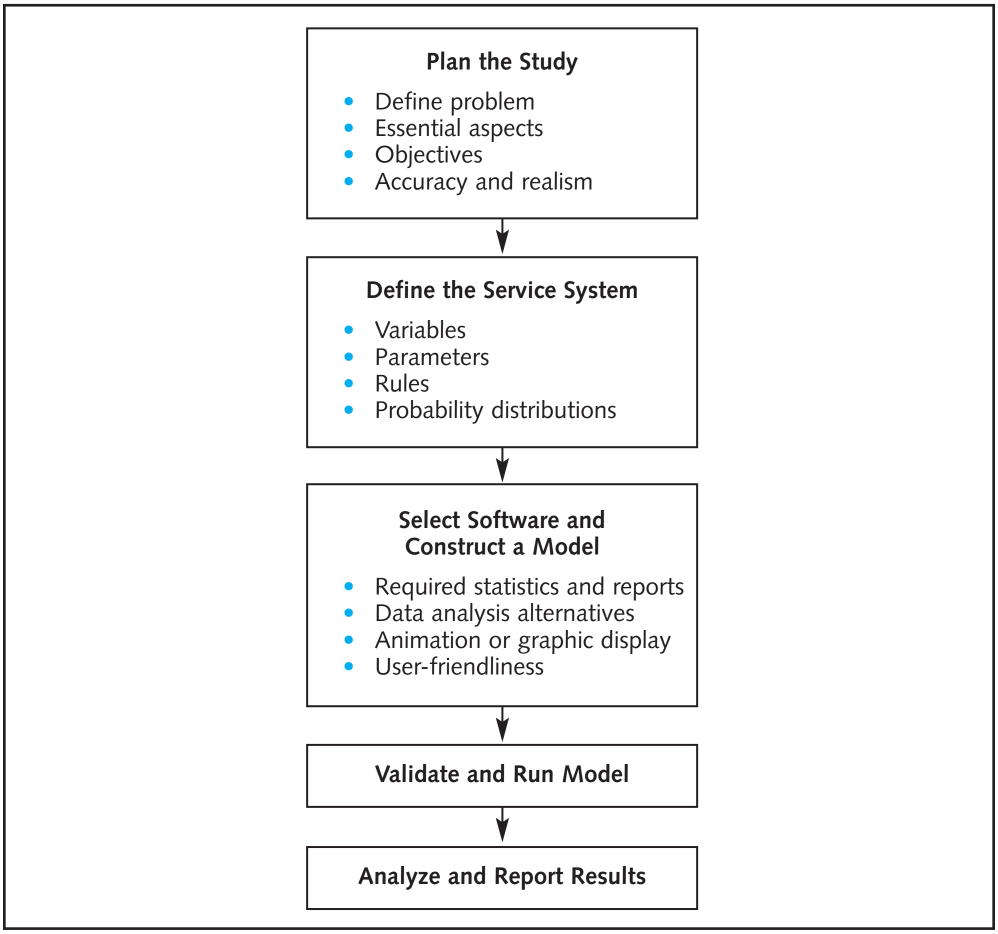
Steps for Conducting a Simulation Study

A good simulation project should include five crucial steps as shown in Figure 9.6. The five steps are: (1) plan the study, (2) define the service system, (3) select appropriate software and build the model, (4) validate the model and run experiments, and (5) analyze and report results.

Plan the Study

To build a simulation model, the modeler must *define* the objective and constraints of the project. Can the existing system be modeled? What is the objective of the study? What are the essential aspects of the process that need to be included in the model? Typical objectives involve performance and capacity analysis such as average waiting time for customers at a ski resort, throughput time for an insurance claim, or average employee utilization at different stages of a process. Models can also be used for capability and sensitivity analysis of service systems or for comparison studies. For example, one may want to evaluate how one service process design performs compared to another. Typically one evaluates an existing process or proposed new system and then makes changes to the model with the goal of reducing customer waiting time or throughput and increasing or balancing employee utilization throughout a process.

FIGURE 9.6: *Major Phases in a Simulation Study*



Several trade-offs occur in the planning state. Increasing the accuracy and realism of a model will increase its complexity, level of detail, and software required to model the system, which in turn requires more development time, expertise, and money. Depending on the financial implications of the model results, these increases may be justified. For example, simulations of work distribution and policies for a large call-in center may justify the building of detailed realistic models due to the potential for increases in customer satisfaction, investments in costly technology, or substantial labor cost reductions. On the other hand, evaluations of replacing several employees with an automation technology may require only a simple simulation.

Define the System

Once the modeler identifies the objectives of the project, the service system can be defined in detail. During this phase, one must determine the relevant variables, variable characteristics, and system rules, and collect data that emulate the input variables in the model. The first step is to *specify* variables, parameters, rules, and probability distributions. What variables within and outside of management's control need to be addressed in the model? For example, daily customer demand is often uncontrollable while the number of employees scheduled, their break times, seating capacity, and hours of operations can be controlled by management. For certain processes, the customer or employee must go through a fixed sequence of activities. This sequence is one of the parameters of the system. The previously mentioned process flow diagram is a useful tool for specifying the sequence. What are the rules of the system? Although some processes operate according to rules like first-come, first-served, other systems might include high-priority customers or paperwork that preempts other items. Finally, those variables not under management's control usually behave according to some probability distribution. From historic records, the modeler can construct empirical frequency, normal, exponential, or any appropriate distribution of the variable's behavior. Often, models of new services must rely on best-guess estimates of variable behavior. An example of the data collection for improving queue lines at Snowbird Ski resort is illustrated in the Service Operations Management Practices: Example of Data Collection for Snowbird Ski Resort Improvement.

Select Appropriate Software and Build the Model

After all pertinent information is obtained the appropriate software should be selected. As mentioned previously, the required software will depend on the modeler's needs, time, and programming skills to realistically replicate the service. In addition, desirable features for software include the following capabilities:

- Generates standard statistics such as worker utilization, wait time, and throughput or cycle time.
- Allows a variety of data analysis alternatives for both input and output data.
- Provides animation for graphic display of the customer or product flow through the system.
- Demonstrates user-friendliness for both clients and consultants (templates, control panels, and standard or custom output reports).

Usually, a model is built progressively by adding layers of detail to a simple structure. With this method, the modeler can debug each stage and compare the elementary model with the existing system or similar systems before adding more complex elements. By using a progressive or incremental expansion approach, the modeler can begin building the system while data collection occurs.

SERVICE OPERATIONS MANAGEMENT PRACTICES

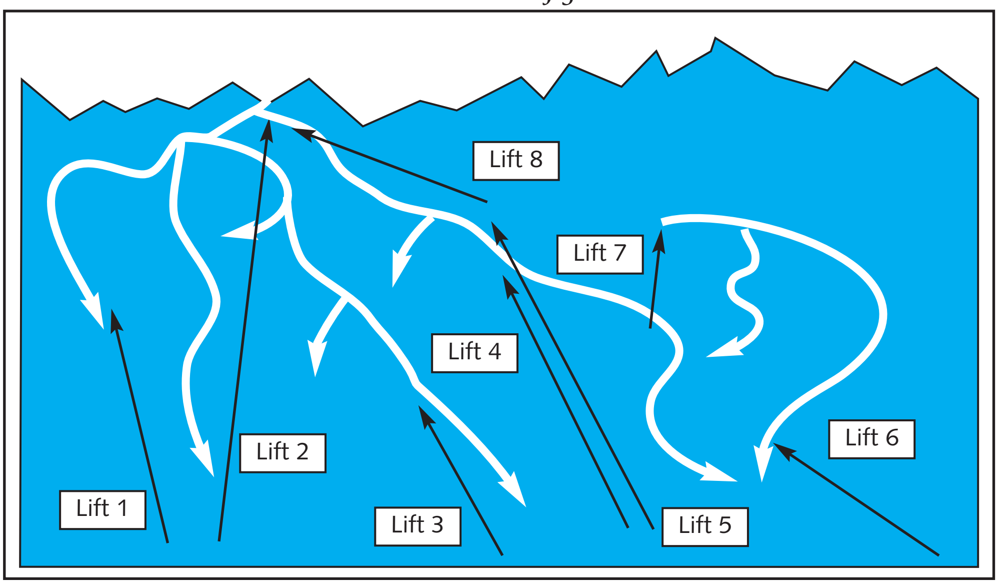
Example of Data Collection for Snowbird Ski Resort Improvement

For a simulation study on ski lift waiting time and process improvement at Snowbird Resort in Utah, the research team required extensive data collection. Snowbird's eight ski lifts all experience queuing; movement between queues is probabilistic based on ski terrain ability levels. At most resorts, terrain is classified as beginner, intermediate, and advanced. Figure 9.7 illustrates the ski resort network configuration. The data collection phase involved many steps, but one of the biggest challenges was obtaining estimates of (1) daily network flow patterns for different customer classes, and (2) time for travel between lifts as a function of customer class.

To estimate network flow, the probability of customers going between lifts as a function of their ability or customer class, a survey was administered to 500 randomly selected skiers during their lunch breaks or after skiing. The survey asked skiers to outline their previous choices of lifts and connecting runs for either the morning or the afternoon period. This information was summarized to develop an empirical frequency distribution matrix for the probability of each customer class skiing between lifts at the existing resort. A sample matrix for beginners is provided in Table 9.3.

For estimating the travel time between service facilities, data were collected on 10 different days during the ski season. The observers averaged 10 observations per day for a total of 100 observations. Skiers were observed on two of the eight possible lifts each day. The observer randomly selected a customer departing a lift and followed the

FIGURE 9.7: *Ski Resort Service Network Configurations*



SERVICE OPERATIONS MANAGEMENT PRACTICES

customer until arrival at the next lift. The observer noted skier ability (beginner to advanced), run choice, weather and ski terrain conditions, and time for travel between facilities. Additionally, a group of expert skiers provided information on the minimum times possible between facilities. The data were used to form a truncated normal distribution equation for the time between each lift. For example, the time to ski from the top of lift 2 to the bottom of the same lift provided a mean of 20 minutes and a standard deviation of 2 minutes.

The research team then used these data as part of a large model simulating the waiting line characteristics of the resort. Because of the available data, the researchers and managers could evaluate the performance of the resort when the marketing programs attempted to lure more beginning skiers or operations wanted to change the lifts from old two-seat chairs to new high-speed quad (four-seat) chairs.

TABLE 9.3: *Empirical Probability Distribution for Beginner Skier*

From	To Lift							
Lift	1	2	3	4	5	6	7	8
1	45	5	20	15	10	5	0	0
2	30	15	20	15	10	5	2.5	2.5
3	0	0	50	20	20	10	0	0
4	0	0	10	35	35	10	10	0
5	0	0	10	30	35	10	10	5
6	0	0	0	30	30	40	0	0
7	0	0	15	20	20	20	20	5
8	0	0	16	17	17	10	15	25

Validate the Model and Run Experiments

During the building stage, the model should be periodically validated to see how it corresponds to the real system. *Validation* generally refers to testing the model to make sure it adequately represents the real system. The modelers should constantly ask themselves whether the results appear reasonable and address any discrepancies between the real system and the model.

Once the model is validated, then the experimental process can begin. During this phase, a number of scenarios are developed to address changes to the variables of the system. For each scenario, the modeler must determine the appropriate run length (length of the simulation run), number of replications of each run, random number streams (different or the same for each run), whether start-up bias is present, and if so how to create similar initial conditions for each scenario, and termination conditions for each run. Possible experiments might address changes to parameters, variables, decision rules, starting conditions, or run length.

It is important to run the simulation for long enough that the system achieves steady state so that if the simulation experiment is repeated the results remain constant. For businesses that will experience start-up bias (i.e., when the doors open and queues take some time to form), the simulation data are not collected until enough time passes to allow for steady state to occur. For example, if the simulation is run for 2,000 hours then the first 200 hours of data may not be used in the final statistics.

For certain environments, it is important to capture the start-up conditions or fluctuations in queue patterns throughout a day or week. If so, these experiments are repeated multiple times with different random number streams. Again, depending on the environment, it may be necessary to capture several thousand repeated simulation runs' worth of statistics and collect mean, standard deviation, and confidence interval statistics for different periods of the day. In this case, it is necessary to collect a sufficiently large sample for statistical hypothesis testing. For more details on simulation experiments, refer to Law and Kelton (1991).

Analyze and Report Results

The final results will lead to conclusions about the service system. These conclusions depend on the degree to which the model reflects the real system (validity) and the statistical design of the simulation. To support the conclusion-generating process, many simulation packages come with analysis and results reporting capabilities. But keep in mind, the only true test of a simulation is how well the real system performs after the results of the study are implemented.

Manual Simulation Example

To illustrate the general concepts behind simulation, we will use a wholesale bakery example.

Albert's Wholesale Bagels receives a delivery of fresh dough once every day from a central bakery. The management wants to insure that Albert's never runs out of dough but would like to examine the trade-off between spoilage of excess dough versus good customer service. Albert collected historic data for the previous six months and the resulting discrete probability distributions are provided in Table 9.4.

The daily supply delivery varies according to demand from other shops but ranges between 4 and 9 batches. Every day, Albert receives between 1 and 5 orders from customers. Each customer order requires from 1 to 4 batches of dough. Using this information, we will simulate daily performance of the system.

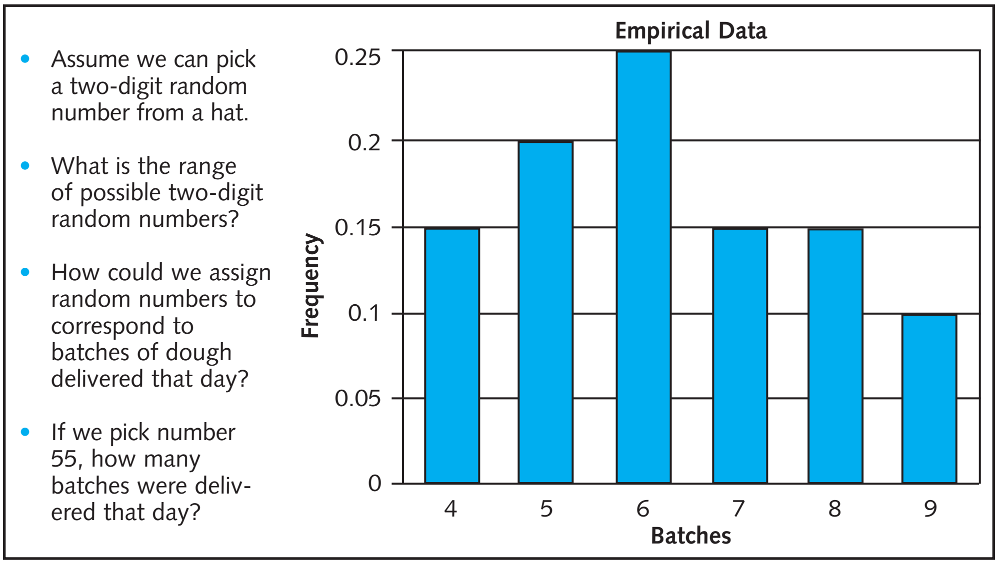
Step 1:

We begin by using random numbers to simulate daily delivery quantities as shown in Figure 9.8. Assume, we pick a two-digit random number from a hat of all possible

TABLE 9.4: *Empirical Frequency Distributions for Albert's Wholesale Bagels*

Delivery Quantities		Customer Order Distribution		Demand Per Customer Order	
Batch/Day	Probability	Orders/Day	Probability	Batch	Probability
4	0.15	1	0.25	1	0.40
5	0.20	2	0.25	2	0.30
6	0.25	3	0.30	3	0.20
7	0.15	4	0.15	4	0.10
8	0.15	5	0.05		
9	0.10				

FIGURE 9.8: *Using Random Numbers to Simulate Delivery Quantities*



two-digit numbers: 100 possible two-digit numbers ranging from 00 to 99. In Excel, we can generate a list of random numbers between 0 and 1 by entering the formula = RAND( ) in any cell. Then, we use only the first two digits of each number. Alternatively, we can use Excel's Random Number Generator as follows:

- Go to **Tools**
- Select **Data Analysis**
- Select **Random Number Generators**
- In **Number of Variables**, type 1
- In **Number of Random Numbers**, type in the number needed for your problem (Ex.: 30, 100)
- In **Distribution**, select Discrete
- In **Output range**, indicate the cell location where you want your list of random numbers to appear on the spreadsheet.

The results are shown in Table 9.5.

Step 2:

To simulate the number of batches in the daily delivery for day 1, we use the first random number in Table 9.5 and determine its corresponding delivery amount as shown in Table 9.6. The first number, 55, corresponds to a delivery of 6 batches. Assuming that the bakery started with 0 batches, 6 batches are now available for customer orders as shown in Table 9.7.

Step 3:

To simulate the number of orders received from customers on day 1, we use the second random number in Table 9.5 and determine its corresponding customer orders as shown in Table 9.8. The second number, 36, corresponds to 2 customer orders as shown in Table 9.7.

Step 4:

To simulate each of the two customers' demands, we use the third and fourth numbers in our random number list (Table 9.5) and their corresponding demand from

TABLE 9.5: *Random Number Examples*

#	Random Numbers between 0 and 100		
1	55	25	45
2	36	26	34
3	99	27	8
4	21	28	20
5	88	29	10
6	50	30	53
7	50	31	9
8	11	32	40
9	34	33	24
10	39	34	3
11	64	35	85
12	21		
13	51		
14	30		
15	30		
16	40		
17	66		
18	97		
19	87		
20	96		
21	3		
22	13		
23	48		
24	12		

Table 9.9. The first customer's random number is 99, which corresponds to a 4-batch order; the second customer's random number is 21, which corresponds to a 1-batch order. The results are shown in Table 9.7, and we see that at the end of the day, 1 batch of dough remains in inventory.

Step 5:

Repeating steps 2 through 4 for subsequent days, the results are shown in Table 9.7 for two additional days.

TABLE 9.6: *Random Numbers and Batches Delivered*

Delivery Amount	Probability	Random Number
4	0.15	00–14
5	0.20	15–34
6	0.25	35–59
7	0.15	60–74
8	0.15	75–89
9	0.10	90–99

TABLE 9.7: *Albert's Bagel Shop Simulation*

Day 1

Batches Delivered	Random #	Amount	Batches Remaining
	55	6	6
Customer Order Amount	Random #	Amount	
	36	2	
Customer 1 Demand	Random #	Amount	
	99	4	2
Customer 2 Demand	Random #	Amount	
	21	1	1

Day 2

Batches Delivered	Random #	Amount	Batches Remaining
	88	8	9
Customer Order Amount	Random #	Amount	
	50	3	
Customer 1 Demand	Random #	Amount	
	50	2	7
Customer 2 Demand	Random #	Amount	
	11	1	6
Customer 3 Demand	Random #	Amount	
	34	1	5

Day 3

Batches Delivered	Random #	Amount	Batches Remaining
	39	6	11
Customer Order Amount	Random #	Amount	
	64	3	
Customer 1 Demand	Random #	Amount	
	21	1	10
Customer 2 Demand	Random #	Amount	
	51	2	8
Customer 3 Demand	Random #	Amount	
	30	1	7

TABLE 9.8: *Random Numbers and Customer Orders*

Customer Order	Probability	Random Number
1	0.25	00–24
2	0.25	25–49
3	0.30	50–79
4	0.15	80–94
5	0.05	95–99

TABLE 9.9: *Random Numbers and Customer Demand*

Customer Demand	Probability	Random Number
1	0.40	00–39
2	0.30	40–69
3	0.20	70–89
4	0.10	90–99

Summary

As both consumers and providers of services we are involved in processes several times each day. Often, these processes are needlessly complex or do not suit the purposes of the business for a variety of reasons. The subject of this chapter, process analysis, is the starting point in process improvement.

Usually, the first step in process analysis is a simple process flow chart. Complex process analysis of the sort done by Blockbuster or analyses accomplished through such simulation packages as SimQuick begin with process flow charts. However, this simple tool provides sufficient reasons for its use. The process flow chart and Gantt chart are easy-to-use, visually oriented tools that can accomplish the basic goals of communicating what a process is across departments or to upper management. They help in focusing managerial attention on the customer, and they aid in determining what to work on and when to stop improving process steps.

To understand processes of sufficient complexity, though, or to determine what the effect of changes might do to that process, requires simulation. The basic steps and expected outcomes of simulation were presented in this chapter. Thanks to modern computing power, a number of user-friendly yet powerful simulation tools are available. This chapter demonstrated improving processes by using Excel. The simulation software SimQuick is covered in the CD.

Review Questions

1. Why are visual tools helpful when attempting to change an interdepartmental process?
2. What are the benefits of creating process flow diagrams?
3. How are Gantt diagrams helpful?
4. What is the relationship between the time it takes to perform a bottleneck process and system capacity?
5. What are the main steps in constructing any process simulation?

Problems

9.1 Complete the spreadsheet simulation problem for seven days at Albert's Wholesale Bagels. What are your conclusions about the existing system?

9.2 You decide to change the delivery system for Albert's Wholesale Bagels and deliver on average two fewer batches per day. The resulting probability distribution follows:

Batch/Day	Probability
2	.15
3	.20
4	.25
5	.15
6	.15
7	.10

Redo the simulation with the same random number set. Does your change improve the performance of the system?

9.3 Using SimQuick, set up a two-agent call-in center problem as described in the chapter and run it for 120 time units and 20 simulations. Add another agent and repeat the process. What changes does the additional agent make in the service levels of the organization?

9.4 Using SimQuick, set up the two-agent call-in center problem with automation handling 40% of all calls as described in the chapter. Run this simulation for 120 time units and 20 simulations. Next, repeat the experiment with 50%, 60%, and 70% of customers using the automation. At what point can you eliminate an agent?

Selected Bibliography

Bailey, J. 1996. The LAPD Is Treated to a Business Analysis, and It Comes Up Short. *The Wall Street Journal* (June 11), A1.

Blackburn, J. 1991. *Time-Based Competition*. Business One Irwin, Homewood, IL.

Evangelist, S., Godwin, B., Johnson, J., Conzola, V., Kizer, R., Young-Helou, S., and R. Metters. 2002. Linking Marketing and Operations at Blockbuster, Inc. *Journal of Service Research*, 5(2).

Frei, F. and P. Harker. 1999. Measuring the Efficiency of Service Delivery Processes. *Journal of Service Research*, 1(4), 300–312.

Hartvigsen, D. 2004. *SimQuick: Process Simulation with Excel*, 2nd ed. Prentice Hall

Larson, R., M. Cahn, and M. Shell. 1993. Improving the New York City Arrest-to-Arraignment System. *Interfaces*, 23(1), 76–96.

Law, A., and W. Kelton. 1991. *Simulation Modeling and Analysis*, 2nd ed. McGraw-Hill, New York.

Van Biema, M., and B. Greenwald. 1997. Managing Our Way to Higher Service-Sector Productivity. *Harvard Business Review*, 75(4), 87–95.