4.8 Exercises

4-1 Travelers arrive at the main entrance door of an airline terminal according to an exponential interarrival-time distribution with mean 1.6 minutes, with the first arrival at time 0. The travel time from the entrance to the check-in is distributed uniformly between 2 and 3 minutes. At the check-in counter, travelers wait in a single line until one of five agents is available to serve them. The check-in time (in minutes) follows a Weibull distribution with parameters $\beta = 7.78$ and $\alpha = 3.91$. Upon completion of their check-in, they are free to travel to their gates. Create a simulation model, with animation (including the travel time from entrance to check-in), of this system. Run the simulation for 16 hours to determine the average time in system, number of passengers completing check-in, and the average length of the check-in queue.

4-2 Develop a model of a simple serial two-process system. Items arrive at the system with a mean time between arrivals of 10 minutes, with the first arrival at time 0. They are immediately sent to Process 1, which has a single resource with a mean service time of 9.1 minutes. Upon completion, they are sent to Process 2, which is identical to (but independent of) Process 1. Items depart the system upon completion of Process 2. Performance measures of interest are the average numbers in queue at each process and the total time in system of items. Using a replication length of 10,000 minutes, make the following four runs and compare the results (noting that the structure of the model is unchanged, and it's only the input distributions that are changing):

- Run 1: exponential interarrival times and exponential service times
- Run 2: constant interarrival times and exponential service times
- Run 3: exponential interarrival times and constant service times
- Run 4: constant interarrival times and constant service times

4-3 Modify the Exercise 4-1 check-in problem by adding agent breaks. The 16 hours are divided into two 8-hour shifts. Agent breaks are staggered (i.e., one agent goes on break, and immediately upon return, the next agent goes on break, until all agents have had their breaks), starting at 90 minutes into each shift. Each agent is given one 15-minute break. Agent lunch breaks (30 minutes) are also staggered, starting 3.5 hours into each shift. The agents are rude and, if they're busy when break time comes around, they just leave anyway and make the passenger wait until break time is over before finishing up that passenger (since all agents are identical, it's not necessary for the same agent to finish up that passenger). Compare the results of this model to those of the model without agent breaks.

4-4 Two different part types arrive at a facility for processing. Parts of Type 1 arrive with interarrival times following a lognormal distribution with a log mean of 11.5 hours and log standard deviation of 2.0 hours (note that these values are the mean and standard deviation of this lognormal random variable itself); the first arrival is at time 0. These arriving parts wait in a queue designated for only Part Type 1's until a (human) operator is available to process them (there's only one such human operator in the facility) and the processing times follow a triangular distribution with parameters 5, 6, and 8 hours. Parts
of Type 2 arrive with interarrival times following an exponential distribution with mean of 15.1 hours; the first arrival is at time 0. These parts wait in a second queue (designated for Part Type 2’s only) until the same lonely (human) operator is available to process them; processing times follow a triangular distribution with parameters 3, 7, and 8 hours. After being processed by the human operator, all parts are sent for processing to an automatic machine not requiring a human operator, which has processing times distributed as triangular with parameters of 4, 6, and 8 hours for both part types; all parts share the same first-come, first-served queue for this automatic machine. Completed parts exit the system. Assume that the times for all part transfers are negligible. Run the simulation for 5,000 hours to determine the average total time in system (sometimes called cycle time) for all parts (lumped together regardless of type), and the average number of items in the queues designated for the arriving parts. Animate your model, including use of different pictures for the different part types, and use resources that look different for busy vs. idle.

4-5 During the verification process of the airline check-in system from Exercise 4-3, it was discovered that there were really two types of passengers. The first passenger type arrives according to an exponential interarrival distribution with mean 2.41 minutes and has a service time (in minutes) following a gamma distribution with parameters $\beta = 0.42$ and $\alpha = 14.4$. The second type of passenger arrives according to an exponential distribution with mean 4.4 minutes and has a service time (in minutes) following $\text{Gamma}(3,\text{ExpMean }= 0.54) + \text{ Erlang}(5, 15)$ (i.e., the expression for the service time is $3 + \text{ERLA}(0.54, 15)$). A passenger of each type arrives at time 0. Modify the model from Exercise 4-3 to include this new information. Compare the results.

4-6 Parts arrive at a single workstation system according to an exponential interarrival distribution with mean 21.5 seconds; the first arrival is at time 0. Upon arrival, the parts are initially processed. The processing-time distribution is $\text{TRIA}(16, 19, 22)$ seconds. There are several easily identifiable visual characteristics that determine whether a part has a potential quality problem. These parts, about 10% (determined after the initial processing), are sent to a station where they undergo a thorough inspection. The remaining parts are considered good and are sent out of the system. The inspection-time distribution is $\text{NQ(95,000)}$ plus a $\text{WEIB}(48.5, 4.04)$ random variable, in seconds. About 14% of these parts fail the inspection and are sent to scrap. The parts that pass the inspection are classified as good and are sent out of the system (so these parts didn’t need the thorough inspection, but you know what they say about hindsight). Run the simulation for 10,000 seconds to observe the number of good parts that exit the system, the number of scrapped parts, and the number of parts that received the thorough inspection. Animate your model.

4-7 A proposed production system consists of five serial automatic workstations. The processing times at each workstation are constant: 11, 10, 11, 11, and 12 (all times given in this problem are in minutes). The part interarrival times are $\text{UNIF}(13.0, 15.1)$. There is an unlimited buffer in front of all workstations, and we will assume that all transfer times are negligible or zero. The unique aspect of this system is that at Workstations 2 through 5 there is a chance that the part will need to be reprocessed by the workstation that
precedes it. For example, after completion at Workstation 2, the part can be sent back to the queue in front of Workstation 1. The probability of revisiting a workstation is independent in that the same part could be sent back many times, with no change in the probability. At present, it is estimated that this probability, the same for all four workstations, will be between 5% and 10%. Develop the simulation model and make six runs of 10,000 minutes each for probabilities of 5, 6, 7, 8, 9, and 10%. Using the results, construct a table (put this table inside your doe file using an Arena Text box) of the average cycle time (system time) against the probability of a revisit. Also include the maximum cycle time for each run in your table.

4-8 A production system consists of four serial automatic workstations. The first part arrives at time zero, and then (exactly) every 9.8 minutes thereafter. All transfer times are assumed to be zero and all processing times are constant. There are two types of failures: major and jams. The data for this system are given in the table below (all times are in minutes). Use exponential distributions for the uptimes and uniform distributions for repair times (for instance, repairing jams at Workstation 3 is UNIF(2.8, 4.2)). Run your simulation for 10,000 minutes to determine the percent of time each resource spends in the failure state and the ending status of each workstation queue.

<table>
<thead>
<tr>
<th>Workstation Number</th>
<th>Process Time</th>
<th>Major Failure Means</th>
<th>Jam Means</th>
<th>Uptimes</th>
<th>Repair</th>
<th>Uptimes</th>
<th>Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.5</td>
<td>475</td>
<td>20, 30</td>
<td>47.6</td>
<td>2, 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>8.3</td>
<td>570</td>
<td>24, 36</td>
<td>57</td>
<td>2.4, 3.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8.6</td>
<td>665</td>
<td>28, 42</td>
<td>66.5</td>
<td>2.8, 4.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>8.6</td>
<td>475</td>
<td>20, 30</td>
<td>47.5</td>
<td>2, 3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4-9 An office that dispenses automotive license plates has divided its customers into categories to level the office workload. Customers arrive and enter one of three lines based on their residence location. Model this arrival activity as three independent arrival streams using an exponential interarrival distribution with mean 10 minutes for each stream, and an arrival at time 0 for each stream. Each customer type is assigned a single, separate clerk to process the application forms and accept payment, with a separate queue for each. The service time is UNIF(8, 10) minutes for all customer types. After completion of this step, all customers are sent to a single, second clerk who checks the forms and issues the plates (this clerk serves all three customer types, who merge into a single first-come, first-served queue for this clerk). The service time for this activity is UNIF(2.65, 3.33) minutes for all customer types. Develop a model of this system and run it for 5,000 minutes; observe the average and maximum time in system for all customer types combined.

A consultant has recommended that the office not differentiate between customers at the first stage and use a single line with three clerks who can process any customer type. Develop a model of this system, run it for 5,000 minutes, and compare the results with those from the first system.
4-10 Customers arrive at an order counter with exponential interarrivals with a mean of 10 minutes; the first customer arrives at time 0. A single clerk accepts and checks their orders and processes payments, taking UNIF(7.9, 10) minutes. Upon completion of this activity, orders are randomly assigned to one of two available stock persons (each stock person has a 50% chance of getting any individual assignment) who retrieve the orders for the customers, taking UNIF(16, 20) minutes. These stock persons only retrieve orders for customers who have been assigned specifically to them. Upon receiving their orders, the customers depart the system. Develop a model of this system and run the simulation for 5,000 minutes, observing the average and maximum customer time in system.

A bright, young engineer has recommend that they eliminate the assignment of an order to a specific stock person and allow both stock persons to select their next activity from a single first-come, first-served order queue. Develop a model of this system, run it for 5,000 minutes, and compare the results to the first system.

4-11 Using the model from Exercise 4-2, set the interarrival-time distribution to exponential and the process-time distribution for each Process to uniform on the interval \([9 - h, 9 + h]\). Setting the value of \(h\) to 1.732, 3.464, and 5.196, compute the (exact) variance of this distribution and make three different runs of 100,000 minutes each and compare the results. Note that the mean of the process time is always 9 and the distribution form is always the same (uniform); the standard deviation (and thus the variance) is the only thing that’s changing.

4-12 Using the model from Exercise 4-11, assume the process time has a mean of 9 and a variance of 4. Calculate the parameters for the gamma distribution that will give these values. Make a 100,000-minute run and compare the results with those from the \(h = 3.464\) case of Exercise 4-11. Note that here both the mean and the variance are the same—it’s only the shape of the distribution that differs.

4-13 Parts arrive at a single machine system according to an exponential interarrival distribution with mean 20 minutes; the first part arrives at time 0. Upon arrival, the parts are processed at a machine. The processing-time distribution is TRIA(11, 16, 18) minutes. The parts are inspected and about 24% are sent back to the same machine to be reprocessed (same processing time). Run the simulation for 20,000 minutes to observe the average and maximum number of times a part is processed, the average number of parts in the machine queue, and the average part cycle time (time from a part’s entry to the system to its exit after however many passes through the machine system are required).

4-14 Using the model from Exercise 4-13, make two additional runs with run times of 60,000 minutes and 100,000 minutes and compare the results with those of Exercise 4-13.

4-15 Items arrive from an inventory-picking system according to an exponential interarrival distribution with mean 1.1 (all times are in minutes), with the first arrival at time 0. Upon arrival, the items are packed by one of four identical packers, with a single queue “feeding” all four packers. The packing time is TRIA(2.75, 3.3, 4.0). Packed boxes are then separated by type (20%, international and 80%, domestic), and sent to
shipping. There is a single shipper for international packages and two shippers for domestic packages with a single queue feeding the two domestic shippers. The international shipping time is TRIA(2.2, 3.3, 4.8), and the domestic shipping time is TRIA(1.7, 2.0, 2.7). This packing system works three 8-hour shifts, five days a week. All the packers and shippers are given a 15-minute break two hours into their shift, a 30-minute lunch break four hours into their shift, and a second 15-minute break six hours into their shift; use the Wait Schedule Rule. Run the simulation for two weeks (ten working days) to determine the average and maximum number of items or boxes in each of the three queues. Animate your model, including a change in the appearance of entities after they’re packed into a box.

4-16 Using the model from Exercise 4-15, change the packer and domestic shipper schedules to stagger the breaks so there are always at least three packers and one domestic shipper working. Start the first 15-minute packer break one hour into the shift, the 30-minute lunch break three hours into the shift, and the second 15-minute break six hours into the shift. Start the first domestic shipper 15-minute break 90 minutes into the shift, the 30-minute lunch break 3.5 hours into the shift, and the second 15-minute break six hours into the shift. Compare the new results to those from Exercise 4-15.

4-17 Using the Input Analyzer, open a new window and generate a new data file (use File > Data File > Generate New) containing 50 points for an Erlang distribution with parameters: ExpMean equal to 12, k equal to 3, and Offset equal to 5. Once you have the data file, perform a Fit All to find the “best” fit from among the available distributions. Repeat this process for 500, 5,000, and 25,000 data points, using the same Erlang parameters. Compare the results of the Fit All for the four different sample sizes.

4-18 Hungry’s Fine Fast Foods is interested in looking at their staffing for the lunch rush, running from 10 AM to 2 PM. People arrive as walk-ins, by car, or on a (roughly) scheduled bus, as follows:

- Walk-ins—one at a time, interarrivals are exponential with mean 3 minutes; the first walk-in occurs EXP(3) minutes past 10 AM.
- By car—with 1, 2, 3, or 4 people to a car with respective probabilities 0.2, 0.3, 0.3, and 0.2; interarrivals distributed as exponential with mean 5 minutes; the first car arrives EXP(5) minutes past 10 AM.
- A single bus arrives every day sometime between 11 AM and 1 PM (arrival time distributed uniformly over this period). The number of people on the bus varies from day to day, but it appears to follow a Poisson distribution with a mean of 30 people.

Once people arrive, either alone or in a group from any source, they operate independently regardless of their source. The first stop is with one of the servers at the order/payment counter, where ordering takes TRIA(1, 2, 4) minutes and payment then takes TRIA(1, 2, 3) minutes; these two operations are sequential, first-order-taking then payment, by the same server for a given customer. The next stop is to pick up the food ordered, which takes an amount of time distributed uniformly between 30 seconds and
2 minutes. Then each customer goes to the dining room, which has 30 seats (people are willing to sit anywhere, not necessarily with their group), and partakes of the sublime victuals, taking an enjoyable TRIA(11, 20, 31) minutes. After that, the customer walks fulfilled to the door and leaves. Queueing at each of the three "service" stations (order/pay, pickup food, and dining room) is allowed, with FIFO discipline. There is a travel time of EXPO(30) seconds from each station to all but the exit door—entry to order/pay, order/pay to pickup food, and pickup food to dining. After eating, people move more slowly, so the travel time from the dining room to the exit is EXPO(1) minute.

The servers at both order/pay and pickup food have a single break that they "share" on a rotating basis. More specifically, at 10:50, 11:50, 12:50, and 1:50, one server from each station goes on a 10-minute break; if the person due to go on break is busy at break time, the station will be shut down until he or she finishes serving the customer but still has to be back at the top of the hour (so the break could be a little shorter than 10 minutes).

Staffing is the main issue facing Hungry's. Currently, there are six servers at the order/pay station and two at the pickup food station throughout the 4-hour period. Since they know that the bus arrives sometime during the middle two hours, they're considering a variable staffing plan that, for the first and last hour would have three at order/pay and one at pickup food, and for the middle two hours would have nine at order/pay and three at pickup food (note that the total number of person-hours on the payroll is the same, 32, under either the current staffing plan or the alternate plan, so the payroll cost is the same). What's your advice?

In terms of output, observe the average and maximum length of each queue, the average and maximum time in each queue, and the total number of customers completely served and out the door. Make plots of the queues to get into order/pay, pickup food, and the dining room. Animate all queues, resources, and movements between stations. Pick from a .plb picture library a humanoid picture for the entities (different for each arrival source), and make an appropriate change to their appearance after they've finished eating and leave the dining room. Also, while you won't be able to animate the individual servers or seats in the dining room, pick reasonable pictures for them as well.

4-19 In the discussion in Section 4.2.5 of Arena's Instantaneous Utilization vs. Scheduled Utilization output values, we stated that if the Resource has a fixed Capacity (say, \( M(t) = c > 0 \) for all times \( t \)), then Instantaneous Utilization and Scheduled Utilization will be the same. Prove this.

4-20 In the discussion in Section 4.2.5 of Arena's Instantaneous Utilization vs. Scheduled Utilization output values, we stated that neither of the two measures is always larger. Prove this; recall that to prove that a general statement is not true you only have to come up with a single example (called a counterexample) for which it's not true.

4-21 Modify your solution for Exercise 4-7 to include transfer times between part arrival and the first workstation, between workstations (both going forward and for reprocessing), and between the last workstation and the system exit. Assume all part transfer times are UNIF(2,5). Animate your model to show entity movement and run for 10,000 minutes using a reprocess probability of 8%.
4-22 Management wants to study Terminal 3 at a hub airport with an eventual eye toward improvement. The first step is to model it as it is during the eight hours through the busiest part of a typical weekday. We’ll model the check-in and security operations only, i.e., once passengers get through security they’re on their way to their gate and out of our model. Passengers arrive one at a time through the front door from curbside ground transportation with interarrival times distributed exponentially with mean 0.5 minute (all times are in minutes unless otherwise noted). Of these passengers, 35% go left to an old-fashioned manual check-in counter, 50% go right to a newfangled automated check-in counter, and the remaining 15% don’t need to check in at all and proceed directly from the front door to security (it takes these latter types of passengers between 3 and 5 minutes, uniformly distributed, to make the walk from the front door to the entrance to the security area; the other two passenger types move instantly from their arrival to the manual or automated check-in counter as the case may be). There are two agents at the manual check-in station, fed by a single FIFO queue; manual check-in times follow a triangular distribution between 1 and 5 minutes with a mode of 2 minutes. After manual check-in, passengers walk to the security area, a stroll that takes them between 2 and 5.8 minutes, uniformly distributed. The automated check-in has two stations (a station consists of a touch-screen kiosk and an employee to take checked bags; view a kiosk-employee pair as a single unified unit, i.e., the kiosk and its employee cannot be separated), fed by a single FIFO queue, and check-in times are triangularly distributed between 0.5 and 1.5 with a mode of 1. After automated check-in, passengers walk to the security area, taking between 1 and 3 minutes, uniformly distributed, to get there (automated check-in passengers are just quicker than manual check-in passengers at everything). All passengers eventually get to the security area, where there are six stations fed by a single FIFO queue; security-check times are triangularly distributed between 1 and 6 with a mode of 2 (this distribution captures all the possibilities there, like x-ray of carry-ons, walking through the metal detector, bag search, body wanding, shoes off, laptop checking, etc.). Once through the security check (everybody passes, though it takes some longer than others to do so), passengers head to their gates and are no longer in our model. Simulate this system for an 8-hour period and look at the average queue lengths, average times in queue, resource utilizations, and average total time in system of passengers (for all passenger types combined). Animate your model, including queues, resources, and passengers walking to security. Put in plots that track the length of each of the three queues over the eight-hour simulation (either three separate plots or three curves in a single plot).

4-23 Modify Model 4-1 to include a packing operation for “shipped” parts (those that pass the initial inspection and don’t need rework) before they exit the system; don’t count parts as having left the system until they’re packed. Packing takes between 2 and 4 minutes, distributed (continuously) uniformly, and there’s a single packer named Brett to do this. Also, add a similar but separate packing operation for “salvaged” parts, where the packing-time distribution is the same and there’s a separate packer named AJ for these. Leave the run conditions the same as for Model 4-1. In addition, collect statistics on entities and compare the total system time (for both part types) between the two models.
4-24 In the results from Exercise 4-23, you might have noticed that AJ doesn’t have much to do. So say goodbye to him, and send salvaged parts to Brett for packing, along with the shipped parts. Both types of parts have the same priority for Brett, but they reside in separate queues. (HINT: It’s okay in Arena to have multiple places where entities are trying to seize on the same resource.) Compare the results to those obtained from Exercise 4-23.

4-25 Compare the results for Model 4-1, Exercise 4-23, and Exercise 4-24, looking at the total times in system of the three different exit possibilities (shipped, salvaged, and scrapped). In an attempt to make the comparison more statistically meaningful, make 100 replications of each. Make a table or graph summarizing your results, and discuss with respect to the relative structures of these three models. What suggestions would you have for further investigation of these differences?

4-26 Modify Model 4-1 so that, in both inspections, only half of what had failed before now really fail, and the others have returned for a re-do and the preceding operation (i.e., to the Sealer and Rework for the first and second inspections, respectively). The re-done parts still have to be re-inspected with the same probabilities for what happens to them there as for parts arriving there for the first time. There’s no limit on the number of re-dos in either place. (HINT: Explore the Help topic in the Decide modules and think about a three-sided coin.) Compare the results (making 100 replications) to Model 4-1, looking at the total times in system of the three different exit possibilities (shipped, salvaged, and scrapped).

4-27 An acute-care facility treats non-emergency patients (cuts, colds, etc.). Patients arrive according to an exponential interarrival-time distribution with a mean of 11 (all times are in minutes). Upon arrival they check in at a registration desk staffed by a single nurse. Registration times follow a triangular distribution with parameters 6, 10, and 19. After completing registration, they wait for an available examination room; there are three identical rooms. Data show that patients can be divided into two groups with regard to different examination times. The first group (55% of patients) has service times that follow a triangular distribution with parameters 14, 22, and 39. The second group (45%) has triangular service times with parameters 24, 36, and 59. Upon completion, patients are sent home. The facility is open 16 hours each day. Make 200 replications of one day each and observe the average total time patients spend in the system.

4-28 Modify your solution from Exercise 4-27 to include lunch breaks for the doctors who staff the examination rooms. There are three doctors on duty for the first 3.5 hours of each eight-hour shift. For the next 90 minutes, the doctors take rotating 30-minute lunch breaks, resulting in only two doctors being available at any point during these 90 minutes. If all three doctors are busy with patients when the 90-minute lunch period begins, they wait until the first patient among the three is done, and that doctor takes the first 30-minute lunch break; each doctor gets a full 30-minute lunch, so if the 90-minute lunch period starts a little late, it also ends that much late. After all the lunch breaks end, all three doctors are available until the end of their eight-hour shift, at which point the second eight-hour shift begins with the same staffing and lunch (maybe call it dinner).
rules. Note that the eight hours in a doctor’s shift include the 30-minute lunch break. Compare your results to those from Exercise 4-27.

4-29 Further study of the facility in Exercise 4-28 reveals that after registration, 5% of arriving patients are told to go immediately to a nearby emergency room (the emergency room is outside the boundaries of this model). These patients immediately leave the system, and never go to an examination room. Modify your solution from Exercise 4-28 to include this new feature and compare your results to those from Exercise 4-28. Do not include patients who are sent to the emergency room in your system-time statistics.

4-30 Patients arrive at a 24-hour, 7-days-a-week outpatient clinic with interarrival times being distributed as exponential with mean 5.95 (all times are in minutes); the first patient arrives at time zero. The clinic has five different stations (like nodes in a network), where patients might be directed for service before leaving. All patients first sign in with a single receptionist; sign-in times have a triangular distribution with parameters 1, 4, and 8. From there, they might go to the nurses’ station (probability 0.9888) or to one of three exam rooms (probability 0.0112). The table below gives the five stations, service times at those stations, and transition probabilities out of each station into the next station for a patient (including out of the sign-in station, just described as an example):

<table>
<thead>
<tr>
<th>Station</th>
<th>Service Time</th>
<th>Next Station Probability (blank entries are zero probability)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sign In</td>
<td>TRIA(1, 4, 8)</td>
<td>Sign In 0.9888</td>
</tr>
<tr>
<td>Nurses’ Station</td>
<td>TRIA(2, 5, 7)</td>
<td>Nurses’ Station 0.0112</td>
</tr>
<tr>
<td>Exam Room</td>
<td>TRIA(4, 7, 13)</td>
<td>Exam Room 0.9167</td>
</tr>
<tr>
<td>Lab and X-ray</td>
<td>TRIA(15, 23, 38)</td>
<td>Lab and X-ray 0.0833</td>
</tr>
<tr>
<td>Check Out</td>
<td>TRIA(3, 5, 8)</td>
<td>Check Out 0.4652</td>
</tr>
</tbody>
</table>

All patients eventually go through the check-out station and go home. Note that it is possible that, after a visit to an exam room, a patient is directed to an exam room again (but may have to queue for it). After a patient checks in but is queueing for either the nurses’ station or an exam room, regard that patient as being in the waiting room (and those patients leaving an exam room but again directed to an exam room are also regarded as being in the waiting room). There are three identical exam rooms, but only one resource unit at each of the other four stations. Queues for each station are first-in, first-out, and we assume that movement time between stations is negligible. Run a simulation of 30 round-the-clock 24-hour days and observe the average total time in system of patients, the average number of patients present in the clinic, as well as the throughput of the clinic (number of patients who leave the clinic and go home over the 30 days); also make a plot of the number of patients present in the clinic, and display a throughput counter. If you could afford to add resources, where is the need most pressing? (See Exercises 6-24 and 6-25 for better ways to address this question.)
This is a modification of a model developed by Bretthauer and Côté (1998) and Bretthauer (2000). The latter does an analytical evaluation and optimization under the assumption that this is a Jackson network of queues, where service times also have exponential distributions (not triangular or other kinds of distributions). The advantage of simulating instead is that the model can be more general and thus possibly more valid; for instance, we do not have to assume exponential service times if the data suggest otherwise. The disadvantage of simulation is that we do not get exact answers, so we must do proper statistical analysis of the output (see Chapter 6). (Thanks to Professor Jim Morris of the University of Wisconsin-Madison for suggesting these papers and this exercise.)