Appendix A

Term Project: Osric's Office Appliances and Decor

Osric Ormondsey owns Osric's Office Appliances and Decor (OOA&D). Osric has a highly successful career decorating the offices of top business executives. He employs a number of subcontractors and technicians so that he can provide a complete turnkey service, including telecommunications (telephone, fax, high-speed data link, and so on). His success is largely due to the speed with which he responds to a customer's request; he has been known to completely redecorate a large executive suite in only two days.

Osric's customers frequently comment effusively about the skills of his two telecommunications technicians, in the light of their many bad experiences with technicians of the local telephone company. Osric realizes that he can expand his business by adding a telecommunications division. He decides to hire the best technicians he can find, offer them an exorbitant salary plus bonuses, and advertise their services to the executives whose offices he has decorated. The executives realize that it is far more effective for their companies to pay Osric's high rates for a highly skilled technician who arrives within an hour or two and fixes the problem quickly than to wait two or three days for an incompetent technician to come and make the problem worse.

Osric's idea has succeeded beyond his wildest dreams. His technicians are in constant high demand, so much so that the waiting time for an OOA&D technician is sometimes more than two days, despite the fact that Osric has technicians on call 24 hours a day. This is unacceptable to both Osric and his customers, so Osric tries to rectify the situation. He has been unable to hire enough technicians with the necessary high level of skills, so he has decided to ration their services. Specifically, he decides to prioritize his customers so that, when someone calls to request service, Osric can decide where to put them on the waiting list for a technician.

Each customer company has a five-digit customer number and is assigned a priority.

Priority 4: A company that has hired Osric to decorate an executive office.

Priority 3: A company that has had three or more previous telecommunications service calls.

Priority 2: A company that has had one or two previous telecommunications service calls.

Priority 1: A company calling for service for the first time.

When someone calls for service, the assistant asks the caller for his or her company's customer number. If the customer does not know the customer number, the assistant asks for the company name. If the name is not found, the software assumes that this is a new customer. A new customer is assigned a number only if it is put on the waiting list (see the following).

When there is a request for service, the company is added to the waiting list. The companies on the waiting list are sorted by priority, and by date and time of call within priority.

Osric's technicians work 8-hour shifts. He currently has seven technicians on the day shift and two on each of the two night shifts, but this could change. Osric has observed that the durations of the service calls are normally distributed with a mean of 5.5 hours and a standard deviation of 9.8 hours. However, the shortest time for a job was 1.9 hours, and the longest time was 23.1 hours.[1] At 8 A.M. a technician is assigned to each of the top seven companies on the waiting list, and similarly at 12 noon, provided that there are no incomplete jobs, as described in the next paragraph.

If a job is completed within its assigned 4-hour block, the customer is charged for the 4-hour block and the technician returns to OOA&D. If a job has not been completed by 12 noon, the same technician is assigned a further 4-hour block to complete it, reducing the number of technicians available for new jobs.

Osric provides service 24 hours a day. At night, however, the assistant on duty does not accept new service requests; his or her sole task is to supervise the night technicians. At 4 P.M. the assistant on duty checks if there are jobs that have not been completed. If so, he or she calls each company to ask if they want a night technician to continue the job (at double rates), or whether they want the same technician to continue in the morning. Because there are fewer night technicians than day technicians, it may not be possible to honor all requests for night service. Accordingly, the assistant calls the companies with outstanding jobs in waiting list order, that is, by priority, and by date and time of call within priority.

[1] Many programming languages support pseudorandom number generators. In Java, function nextGaussian generates numbers from a distribution that is normally distributed with mean 0 and standard deviation 1. In C++, function rand generates numbers uniformly distributed between 0 and 1; the Box-Muller transformation can then be used to generate normally distributed pseudorandom numbers (see G. E. P. Box and M. E. Muller, "A Note on the Generation of Random Normal Deviates," *Annals of Mathematical Statistics* **29** (1958), pp. 610–11). Alternatively, many free Gaussian pseudorandom number generators for C++ can be downloaded from the Web, including gsl_ran_Gaussian in the GNU Scientific Library (GSL).

If x is a number generated from a distribution that is normally distributed with mean 0 and standard deviation 1, then $\mu + x \times \sigma$ will be from a distribution that is normally distributed with mean μ and standard deviation σ. Outliers (numbers that are too high or too low) can then be rejected.

Just in Case You Wanted to Know — Box A.1

Osric, the foppish courtier, appears for the first time in the final scene (Act V, Scene 2) of William Shakespeare's *The Tragedy of Hamlet, Prince of Denmark*, which is set in Kronberg Castle in Helsingør (Elsinore in English). I have always felt sorry for the actor playing Osric. He has nothing to do for the first three hours of the play, he has only one worthwhile line ("A hit, a very palpable hit"), and he is mercilessly mocked by Hamlet and Laertes. Tom Stoppard made Hamlet's friends Rosencrantz and Guildenstern the protagonists of his version of *Hamlet*, which he called *Rosencrantz and Guildenstern Are Dead*. In the same spirit, I have made Osric the protagonist of this term project.

Again, work is assigned and charged at night on the basis of 4-hour blocks. A night job can continue the following day, if necessary, at day rates. In this case, too, the same day technician as before will be assigned to the job.

After a company has been on the waiting list for 2 full day blocks, its priority is *temporarily* increased by 1 before technicians are assigned to their next job. As a result, Priority-4 customers usually get service within 4 hours, but new (Priority 1) customers may have to wait until the fourth day for service.

When a customer calls for service, the software product estimates how soon service will be available based on the time taken so far on each of the current jobs, the length of the current waiting list, and the average time to complete a job. It also gives a worst-case estimate, based on the time it will take if the company has to reach Priority 4 before receiving service. The assistant gives this information to the customer, and asks if the company is prepared to wait, if necessary. Each morning the assistant calls all the customers on the waiting list to inform them how soon they can expect service. Again, this information is computed by the product, using the information available at that time.

If a new company requests a service call, this must first be approved by a manager. Ordinarily, such approval will not be given if the number of customers on the waiting list exceeds twice the number of day technicians. Occasionally, however, Osric will want to add a specific new company to his customer list. Accordingly, decisions regarding new customers have to be made by a manager who will give an immediate response when called by the assistant.

When the technician has completed the service call, he or she hands the job card to the assistant, who enters the customer number and the number of day and night blocks that the job required. The software product first uses this information to update the company's priority, if applicable. Then the data are used to generate a bill to be mailed to the customer; the cost per block is $480 during the day, and $960 at night. Osric's billing address is Suite 16, Kronborg Castle, Helsingør, Sjælland, Denmark (see Just in Case You Wanted to Know Box A.1).

You are required to determine the effectiveness of Osric's scheme by simulating it. First, generate a job mix, that is, a set of jobs. For each job in the mix, specify the necessary attributes, including the time the call is made, the company priority, and the duration; other attributes will also be needed. As each job is called in, it is added to the queue. At the start of each block, jobs are removed from the queue and assigned to available technicians. When a job is finished, the technician is released, either to begin a job at the start of the second block of the shift or to go home.

In order to assess the effectiveness of the scheme, certain statistics need to be kept, including the average waiting time before a job is started; the average queue length; the percentage of time the queue is empty, both day and night; the number of blocks when a technician is idle (and hence no income accrues to OOA&D); and the number of jobs that cannot be continued at night because no technician is available.

Now, using the same job mix, determine the same statistics without Osric's scheme, that is, on a pure first-come–first-served basis, including new customers. Determine the average waiting time for customers with each priority. Repeat with different sets of jobs and different numbers of technicians. Decide whether Osric's scheme is cost effective for Osric, and whether it reduces the customers' waiting time.