5-18. Under what conditions can the basic single-server and multiple-server models be used to analyze a multiple-phase waiting line system?

5-19. Why do waiting lines form at a service facility even though there may be more than enough service capacity to meet normal demand in the long run?

5-20. Provide an example of when a first-in, first-out (FIFO) rule for queue discipline would not be appropriate.

5-21. Under what conditions will the single-channel, single-phase queuing model with Poisson arrivals and undefined service times provide the same operating characteristics as the basic model with exponentially distributed service times?

5-22. What types of waiting line systems have constant service times?

5-23. Compare traditional car rental services with zipcar and car2go. Each of these has a different service concept. Explain.

PROBLEMS

5-1. McBurger's fast-food restaurant has a drive-through window with a single server who takes orders from an intercom and also is the cashier. The window operator is assisted by other employees who prepare the orders. Customers arrive at the ordering station prior to the drive-through window every 3.6 minutes (exponentially distributed) and the service time is 2.4 minutes (exponentially distributed). Determine the average length of the waiting line and the waiting time. Discuss the quality implications of your results. If you decide that the quality of the service could be improved, indicate what things you might do to improve quality.

5-2. The ticket booth on the Tech campus is operated by one person, who is selling tickets for the annual Tech versus State football game on Saturday. The ticket seller can serve an average of 12 customers per hour (Poisson distributed); on average, 8 customers arrive to purchase tickets each hour (Poisson distributed). Determine the average time a ticket buyer must wait and the portion of time the ticket seller is busy.

5-3. The Minute Stop Market has one pump for gasoline, which can service 10 customers per hour (Poisson distributed). Cars arrive at the pump at a rate of 5 per hour (Poisson distributed).
  a. Determine the average queue length, the average time a car is in the system, and the average time a car must wait.
  b. If, during the period from 4:00 P.M. to 5:00 P.M., the arrival rate increases to 12 cars per hour, what will be the effect on the average queue length?

5-4. The Universal Manufacturing Company produces a particular product in an assembly-line operation. One of the machines on the line is a drill press that has a single assembly line feeding into it. A partially completed unit arrives at the press to be worked on every 8 minutes, on average, according to an exponential distribution. The machine operator can process an average of 10 parts per hour (Poisson distributed). Determine the average number of parts waiting to be worked on, the percentage of time the operator is working, and the percentage of time the machine is idle.

5-5. The management of Universal Manufacturing Company (Problem 5-4) likes to have its operators working 90% of the time. What must the assembly line arrival rate be in order for the operators to be as busy as management would like?

5-6. The Peachtree Airport in Atlanta serves light aircraft. It has a single runway and one air traffic controller to land planes. It takes an airplane 8 minutes to land and clear the runway (exponentially distributed). Planes arrive at the airport at the rate of 5 per hour (Poisson distributed).
  a. Determine the average number of planes that will stack up waiting to land.
  b. Find the average time a plane must wait in line before it can land.
  c. Calculate the average time it takes a plane to clear the runway once it has notified the airport that it is in the vicinity and wants to land.
  d. The FAA has a rule that an air traffic controller can, on the average, land planes a maximum of 45 minutes out of every hour. There must be 15 minutes of idle time available to relieve the tension. Will this airport have to hire an extra air traffic controller?

5-7. The National Bank of Union City currently has one outside drive-up teller. It takes the teller an average of three minutes (exponentially distributed) to serve a bank customer. Customers arrive at the drive-up window at the rate of 12 per hour (Poisson distributed). The bank operations officer is currently analyzing the possibility of adding a second drive-up window at an annual cost of $20,000. It is assumed that arriving cars would be equally divided between both windows. The operations officer estimates that each minute's reduction in customer waiting time would increase the bank's revenue by $2000 annually. Should the second drive-up window be installed? What other factors should be considered in the decision besides cost?

5-8. During registration at Tech every quarter, students in the Department of Management must have their courses approved by the departmental advisor. It takes the advisor an average of five minutes (exponentially distributed) to approve each schedule, and students arrive at the advisor's office at the rate of 10 per hour (Poisson distributed). Compute L, Lq, W, Wq, and ρ. What do you think about this system? How would you change it?

5-9. All trucks traveling on Interstate 40 between Albuquerque and Amarillo are required to stop at a weigh station. Trucks arrive at the weigh station at a rate of 120 per eight-hour day (Poisson distributed), and the station can weigh, on the average, 140 trucks per day (Poisson distributed).
  a. Determine the average number of trucks waiting, the average time spent at the weigh station by each truck, and the average waiting time before being weighed for each truck.
  b. If the truck drivers find out they must remain at the weigh station longer than 15 minutes on the average, they will start taking a different route or traveling at night, thus depriving the state of taxes. The state of New Mexico estimates it loses $10,000 in taxes per year for each extra minute (over 15) that trucks must remain at the weigh station. A new set of scales would have the same service capacity as the present set of scales, and it is assumed that arriving trucks would line up equally behind the two sets of scales. It would cost $50,000 per year to operate the new scales. Should the state install the new set of scales?

5-10. In Problem 5-9(a), suppose arriving truck drivers look to see how many trucks are waiting to be weighed at the weigh station. If they see four or more trucks in line, they will pass by the station and risk being caught and ticketed. What is the probability that a truck will pass by the station?

5-11. In Problem 5-8, the head of the Management Department at Tech is considering the addition of a second advisor in the college advising office to serve students waiting to have their schedules approved. This new advisor could serve the same number of students per hour as the present advisor. Determine L, L_q, W, and W_q for this altered advising system. As a student, would you recommend adding the advisor?

5-12. Annie Campbell is a nurse on the evening shift from 10:00 P.M. to 6:00 A.M. at Community Hospital. She is responsible for 15 patients in her area. She averages two calls from each of her patients every evening (Poisson distributed), and she must spend an average of 10 minutes (negative exponential distribution) with each patient who calls. Nurse Smith has indicated to her shift supervisor that although she has not kept records she believes her patients must wait about 10 minutes on average for her to respond and she has requested that her supervisor assign a second nurse to her area. The supervisor believes 10 minutes is too long to wait, but she does not want her nurses to be idle more than 40% of the time. Determine what the supervisor should do.

5-13. Wallace Publishers has a large number of employees who use the company's single fax machine. Employees arrive randomly to use the fax machine at an average rate of 20 per hour. This arrival process is approximated by a Poisson distribution. Employees spend an average of two minutes using the fax machine, either transmitting or receiving