Practice Problems on Process Analysis Solutions

<u>Problems from Chase, Aquilano, Jacobs</u>

2. There are five steps in sequence. The bottleneck of this process is step 2, which takes the longest time (1.5 minutes per student). The bottleneck will govern the capacity. Therefore, Capacity
   = 1 student per 1.5 min * (60 min per hour) * (40 hours per week)
   = 1600 students per week
   Therefore, this line cannot produce the requested 2000 students per week.

3a. The market can only be served at 3 gal/hr, while the raw material is received at 4 gal/hr. Consequently, there is a 1 gal/hr buildup of inventory in the bathtub. After 50 hours (50 gal bathtub / 1 gal per hour build-up), the bathtub will overflow. Over production, too much inventory!

3b. We have 5 gal inventory to begin with. The next 5 gal will come 2 hours later. The market demand is 3 gal/hr, so after 1 hour 40 minutes (5 gal / (3 gal/hr) = 1.667 hr), stock-out will occur for 20 minutes before the next 5 gal supply arrives. We lose 1 gal demand during that 20 minutes stock-out period.

4a. <u>Old method</u>: One operator per project: 10 projects per 8 hours = 1.25 projects/hour. The productivity (i.e., output per labor-hour) of this option is 1.25 projects / labor-hour. <u>New method</u>: Two operators approach: The second operator is the bottleneck, and limits the system's capacity to a rate of 2 projects/hour (since 30 minutes is needed for each project in the second step). Every hour, 2 hours of labor is spent. (Although the first operator has some idle time, we assume that labor cost is sunk). Thus, productivity = 2 projects / 2 labor-hours = 1 project/labor-hour.

4b. With one operator, 1000 projects would take 1000 projects/1.25 project per hour = 800 hours or 100 days. With two operators, it would take 1000 projects/2 projects per hour = 500 hours or 62.5 days. The labor content for the first option is 800 hours. The second option requires 1000 hours of labor.

5. (This is a batch process, i.e., a process structured in between job shop and flow shop.) To produce 100 processors, we need 5 minutes of setup for A, then 0.2 *100 = 20 minutes of production of A, then 10 minutes of setup for B, then 0.1 *100 = 10 minutes of production of B. The total time required is 5 + 20 + 10 + 10 = 45 minutes. Thus, the output rate is 100 units per 0.75 hr = 133.3 units/hr.

7. Even though orders are taken from 7am to 7pm, the problem also states that "Wally promises that every order placed today gets shipped tomorrow. That means that the picking and packing operation must finish all orders before they go home."

a. The maximum output every hour is limited by the bottleneck at order packing, which operates at 60 customers per hour. In terms of daily output, the maximum daily output is 1200 customers per day (they can take order 100 per hour from 7am to 7pm) since the pick and pack operations can work up to 24 hours to clear out their order backlog.

b. If we take the maximum of 1200 orders a day, then Pick Orders need to work 1200 orders/80 per hour = 15 hours, Pack Orders need to work 1200 orders/60 per hour = 20 hours.

c. Orders can be taken at a rate of 100/hours and can be picked at the rate of 80/hour so they build at the rate of 20/hour. Orders are taken for 12 hours. Thus, maximum orders waiting for picking = 20/hour * 12 hours = 240 orders.

d. Orders can be picked at a rate of 80/hours and can be packed at the rate of 60/hour so they build at the rate of 20/hour. Orders are picked for 15 hours. Thus, maximum orders waiting for packing = 20/hour * 15 hours = 300 orders.

(b. revisited) If we take the maximum of 1200 orders then Pick Orders need to work 1200 orders/80 per hour = 15 hours, Pack Orders need to work 1200 orders/120 per hour = 10 hours. However, Packing has to wait for the orders to be picked so it still need to work 15 hours.

(c. revisited) This answer does not change.

(d. revisited) Orders can be picked at a rate of 80/hours and can be packed at the rate of 120/hour so there is no inventory buildup. Maximum orders waiting for packing = 0.

1. State in your own words what Little's Law means. Think of an example that you have observed where Little's Law applies.

   Little's Law shows the relationship between throughput rate, flow time, and inventory. Specifically, it shows flow time equals amount of inventory divided by the throughput rate. Little's Law is useful for examining the performance of a process. Many examples have been discussed in class.

2. On a typical weekday in January, 4,200 customers visit the Ypsilanti Wal-Mart. It is estimated that, on average, there are 350 customers in the store. Assuming that the store is open 14 hours a day, how much time does the average customer spend in the store?

   Solution:
   - Since the average number of customers in the store is 350, I=350.
   - 4,200 customers go through the system in a 14 hr. day. Thus, the throughput rate (R) is 4200 customers/day or 4200/14 = 300 customers/hr.
   - Applying Little's Law (I=R*T) the time an average customer spends in the store is: T=I/R = 350/300 = 1.17 hours = 70 minutes

3. In 2006, Shouldice Hospital admitted 14,965 patients. In 2007, a 20% increase in admissions is expected. Currently the hospital has 390 beds. Assume the hospital operates 365 days a year (and, please assume one patient per bed!).

   a) If the average patient stays in the hospital 8 days, how many beds were empty, on average, in 2006?

   Solution:
   - Average stay, T = 8 days
   - 14,965 patients went through the system in a year. This implies R=14,965/365 = 41 patients/day.
   - Thus the number of patients in the hospital on average is I=R*T= 41*8 = 328, and the number of average empty beds is (390-328)=62.

   b) On average, how many beds do you expect to be empty in 2007?

   Solution:
   - The number of beds needed will also increase by 20 % to a total of 393.6, implying that not enough beds are available.

4. The total number and gender mix of employees in a certain company remains constant. Due to turnover, on average the company hires 150 men and 200 women each year. It is estimated that on average a woman stays 50% longer than a man. What proportion of the employees are women?

Solution:

- Since the total number and gender mix of employees remains constant, the throughput rate of this system equals the input rate (rate of hiring).
- Let m denote men and w women. We have R(m) = 150 men/year and R(w) = 200 women/year.
- Women stay 50% longer, which implies that T(w) = 1.5*T (m).
- The number of women is: I(w) = R(w)*T(w) = 200 * 1.5*T(m) = 300*T(m).
- The number of men is: I(m) = R(m)*T(m) = 150 * T(m).
- Consequently, the number of women is the double of the number of men, and therefore, 2/3 of the employees are women.

5. The Internal Revenue Service Department of Tax Regulations writes regulations in accord with laws passed by Congress. On average, the department completes 300 projects per year. The *Wall Street Journal* reports that, as of October 11, 1997, the number of projects currently "on the Department's plate" is 588. Nevertheless, the department head claims that average time to complete a project is under six months. Do you have any reason to disagree? Why or why not?

   Solution:

   - Inventory I = 588 projects
   - Throughput R = 300 projects/yr (we assume a stable system).
   - Thus, average flow time T = I / R = 588 / 300 = 1.96 yr.
   - This is much larger than six months. So we should disagree with the department head's statement.

6. A bank finds that the average number of people waiting in line during lunch hour is 10. On average, during this period 2 people per minute leave the bank after receiving service. On average, how long do bank customers wait in line?

   Solution:

   - Average inventory I = 10 people
   - Throughput R = 2 people/min (we assume a stable system).
   - Thus, average flow time T = I / R = 10 / 2 min = 5 min.

7. At the drive-through counter of a fast-food outlet, an average of 10 cars waits in line. The manager wants to determine if the length of the line impacts potential sales. Her study reveals that, on average, 2 cars per minute try to enter the drive-through area, but 25% of these cars are dismayed by the long line and simply move on without entering the line and placing orders. Assume that no car entering the line leaves without service. On average, how long does a car spend in the drive-through line?

   Solution:

   - Average inventory I = 10 cars.

- Cars attempt to enter the drive through area at a rate of 2 cars/min. However 25% of cars leave when they see a long queue. Thus, cars enter the drive through at a flow rate R = 75% * 2 cars/min = 1.5 cars/min.
- Average flow time T = I / R = 10 / 1.5 min = 6.67 min.

8. Checking accounts at a local bank carry an average balance of $3,000. The bank turns over its balance six times a year. On average, how many dollars flow through the bank each month?

   Solution:
   - Average inventory I = average balance = $3,000
   - Inventory Turns = 6 per year.
   - Average flow time T = 1 / turns = 1/6 year = 2 months.
   - Throughput R = I / T = 3,000 / 2 = $1,500 / month