DATA 604 HW1

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```r
library(ggplot2)
```

DES textbook problems: 1.1, 2.1, 2.2, 2.4, 2.5, 2.7, 2.8

Due to problems loading some of the Excel spreadsheets, some responses are executed in R.

1.1:

Name several entities, attributes, activities, events, and state variable for each of the following systems

a. Cafeteria:

```
+ entities - customers, servers, cashiers, tables, chairs
+ attributes - rate of service bey servers/chashiers, number of seats
at a table
+ activities - waiting in line, being served food, serving food,
waiting to cash out, sitting at a table eating, cashing out a customer
+ events - arriving customer, leaving customer, customer arriving at
checkout
+ state variable - number of people waiting, number of people at
tables, number of customers, number of servers, number of cashiers,
number of open chairs
```

b. Grocery store

```
+ entities - customers, cashiers, checkout lanes
+ attributes - customers paying with cash, customers paying with card
card, items allowed in a lane, paper or plastic bags, number of items
per customer, rate of checkout by cashier
+ activities - waiting in line, waiting to cash out, cashing out a
customer
+ events - arriving customer, leaving customer, customer arriving at
checkout
+ state variable - number of people waiting, number of customers,
number of cashiers, number of checkout lanes
```

c. Laundromat

```
+ entities - customers, washing machines, dryers
+ attributes - run time of washing machines, run time of drying
machines
+ activities - washing clothes, switching clothes from washer to dryer,
waiting for clothing to dry, waiting for washer or dryer
```

```
+ events - arriving customer, leaving customer, wash cycle starts, wash cycle stops, dry cycle starts, dry cycle stops
+ state variable - number of people waiting, number of dryers in use, number of washers in use
```

d. Fast-food restaurant

```
+ entities - customers, servers, cashiers, cook, tables, chairs
+ attributes - customers take-out or to-go, speed of cook, speed of cashier
+ activities - waiting in line, being served food, serving food, cooking food, waiting to cash out, sitting at a table eating, cashing out a customer
+ events - arriving customer, leaving customer, customer arriving at checkout
+ state variable - number of people waiting, number of people at tables, number of people doing take-out, number of cashiers, number of chairs, number of tables, number of cooks
```

e. Hospital emergency room

```
+ entities - patients, admitting nurses, doctors, EMT, beds
+ attributes - patients per doctor, triage time of nurse, severity of patient injury
+ activities - arriving at ER, nurse assessment, patient exam by doctor, treating the patient, waiting in receiving area
+ events - arriving at ER, triage start/end, treatment start/end, exam start/end, patient discharged
+ state variable - number of patients arriving, number of busy nurses, number of busy doctors, number of beds available
```

f. Taxicab company with 10 taxis

```
+ entities - taxis, riders, dispatcher
+ attributes - rider capacity of cab, speed of dispatcher, distance of cab ride
+ activities - waiting for cab, riding in cab, paying driver, driving to pick up rider
+ events - rider calls dispatcher, taxi goes to pick up rider, ride starts, ride ends
+ state variable - number of people waiting, number of people at tables
```

g. Automobile assembly line

```
+ entities - workers, machines, materials
+ attributes - inventory of material, speed of machines, speed of workers, breakdown rate of machines
+ activities - building, monitoring machines
+ events - start assembly, end assembly, building, machine breakdown
+ state variable - machine status, material inventory high or low
```

2.1:

Consider the following continuously operating job shop. Interarrival times of jobs are distributed as follows:

```
##   Time_Between_Arrivals Prob
## 1                     0 0.23
## 2                     1 0.37
## 3                     2 0.28
## 4                     3 0.12
```

Processing times of jobs are normally distributed, with mean 50 mins and SD 8 mins. Construct a simulation table and perform a simulation for 10 new customers. Assume that when the simulation begins, there is one job being processed (to be completed in 25 mins) and another job in the queue that will take 50 mins. What is the average time in the queue for the 10 new jobs? What was the average processing time of the 10 new jobs? What was the max time in the system for the 10 new jobs?

```
set.seed(1500)

# DF of jobs already in queue
in_queue <- data.frame(job=c(-1, 0), #first two jobs
                           inter_arrive_h=c(0,0),
                           inter_arrive_m=c(0,0),
                           arrive_m=c(0,0),
                           srvc_time_m=c(25, 50), # 25 min job and 50
min job
                           srvc_begin_time=c(0, 25),
                           wait_m=c(0,25),
                           srvc_end_time=c(25, 75),
                           total_time=c(25,75))
# DF for new 10 jobs
new_ten <- data.frame(job=seq(1, 10),
                      inter_arrive_h=c(0, sample(seq(0, 3), # details
from table
                                                size=9,
                                                prob=c(.23, .37, .28,
.12),
                                                replace=TRUE)),
                      inter_arrive_m=rep(NA, 10),
                      arrive_m=rep(0, 10),
                      srvc_time_m=rnorm(10, mean=50, sd=8),
                      srvc_begin_time=rep(0, 10),
                      wait_m=rep(0, 10),
                      srvc_end_time=rep(0, 10),
                      total_time=rep(0, 10))

# Convert time between arrivals from hours to minutes and find arrival
times.
new_ten$inter_arrive_m <- new_ten$inter_arrive_h*60
```

```
new_ten$arrive_m <- cumsum(new_ten$inter_arrive_m) # cumulative sum

# Merge the DFs by row
new_table <- rbind(in_queue, new_ten)

# Compute final times
for(i in seq(3, nrow(new_table))) # row 3 forward are the simulated
records
{
  new_table[i,]$srvc_begin_time <- max(new_table[i,]$arrive_m,
new_table[i-1,]$srvc_end_time)
  new_table[i,]$wait_m <- new_table[i,]$srvc_begin_time -
new_table[i,]$arrive_m
  new_table[i,]$srvc_end_time <- new_table[i,]$srvc_begin_time +
new_table[i,]$srvc_time_m
  new_table[i,]$total_time <- new_table[i,]$srvc_end_time -
new_table[i,]$arrive_m
}

# Remove unnecessary hours column
drop <- "inter_arrive_h"
new_table <- new_table[ , !(names(new_table) %in% drop)]

# Show the simulation table
new_table

##    job inter_arrive_m arrive_m srvc_time_m srvc_begin_time    wait_m
## 1   -1              0        0    25.00000          0.0000  0.000000
## 2    0              0        0    50.00000         25.0000 25.000000
## 3    1              0        0    57.12032         75.0000 75.000000
## 4    2            120      120    59.82831        132.1203 12.120321
## 5    3            180      300    48.57218        300.0000  0.000000
## 6    4              0      300    36.85853        348.5722 48.572178
## 7    5             60      360    53.58040        385.4307 25.430708
## 8    6             60      420    50.27648        439.0111 19.011111
## 9    7             60      480    44.74127        489.2876  9.287587
## 10   8            120      600    40.01024        600.0000  0.000000
## 11   9            180      780    54.96180        780.0000  0.000000
## 12  10            180      960    52.93330        960.0000  0.000000
##    srvc_end_time total_time
## 1        25.0000   25.00000
## 2        75.0000   75.00000
## 3       132.1203  132.12032
## 4       191.9486   71.94863
## 5       348.5722   48.57218
## 6       385.4307   85.43071
## 7       439.0111   79.01111
## 8       489.2876   69.28759
## 9       534.0289   54.02886
## 10      640.0102   40.01024
```

```
## 11      834.9618   54.96180
## 12     1012.9333   52.93330
```

```r
colnames(new_table)
```

```
## [1] "job"             "inter_arrive_m"  "arrive_m"
"srvc_time_m"
## [5] "srvc_begin_time" "wait_m"          "srvc_end_time"
"total_time"
```

a. What is the average time in the queue for the 10 new jobs?

```r
mean(new_table[3:12,6])
```

```
## [1] 18.94219
```

b. What was the average processing time of the 10 new jobs?

```r
mean(new_table[3:12,4])
```

```
## [1] 49.88828
```

c. What was the maximum time in the system for the 10 new jobs?

```r
max(new_table[3:12,8])
```

```
## [1] 132.1203
```

2.2:

A baker is trying to figure out how many dozens of bagels to bake each day. The probability distribution of the number of bagel customers is as follows:

```r
Customers_per_Day <- c(8,10,12,14)
Prob <- c(.35,.3,.25,.10)
table2.2a <- data.frame(rbind(Customers_per_Day,Prob))
table2.2a
```

```
##                     X1   X2    X3   X4
## Customers_per_Day 8.00 10.0 12.00 14.0
## Prob              0.35  0.3  0.25  0.1
```

Customers order 1,2,3, or 4 dozen bagels according to the following probability distribution:

```r
Dozens_per_Customer <- c(1,2,3,4)
Prob <- c(.4,.3,.2,.1)
table2.2b <- data.frame(rbind(Dozens_per_Customer,Prob))
table2.2b
```

```
##                      X1  X2  X3  X4
## Dozens_per_Customer 1.0 2.0 3.0 4.0
## Prob                0.4 0.3 0.2 0.1
```

Bagels sell for $8.40 per dozen. They cost $5.80 per dozen to make. All bagels not sold at the end of the day are sold at half price. Based on 5 days simulation, how many dozen (to the nearest 5 dozen) bagels should be baked each day?

Answer

News Dealer's inventory spreadsheet ("Example2.7NewsDealer.xls") was reconfigured to answer this question. The simulation table was adjusted to represent a maximum of 14 customers in a single day. I also adjusted cells to simulate the number of customers per day based on the probability distribution described in the prompt. I also specified that if the customer count was greater than the number of customers simulated, the number would be 0.

Resulting five day simulation of number of bagels ordered per day:

24 dozen bagels; 10 customers
27 dozen bagels; 10 customers
28 dozen bagels; 14 customers
24 dozen bagels; 10 customers
16 dozen bagels; 8 customers

If we were to base our decision about the number of bagels to supply on these five simulated days, we would need 30 dozen bagels (max of 14 customers to the nearest 5 dozen).

2.4:

Smalltown Taxi operates one vehicle during th 9AM to 5PM period. Currently, consideration is being given given to the addition of a second vehicle to the fleet. The demand for taxis follows the distribution shown:

```
Time_Between_Calls <- c(15,20,25,30,35)
Prob <- c(.14,.22,.43,.17,.04)
table2.4a <- data.frame(rbind(Time_Between_Calls,Prob))
table2.4a

##                       X1    X2    X3    X4    X5
## Time_Between_Calls 15.00 20.00 25.00 30.00 35.00
## Prob                0.14  0.22  0.43  0.17  0.04
```

The distribution of time to complete a service is as follows:

```
Service_Time_m <- c(5,15,25,35,45)
Prob2 <- c(.12,.35,.43,.06,.04)
table2.4b <- data.frame(rbind(Service_Time_m,Prob2))
table2.4b

##                  X1    X2    X3    X4    X5
## Service_Time_m 5.00 15.00 25.00 35.00 45.00
## Prob2          0.12  0.35  0.43  0.06  0.04
```

Simulate 5 individual days of operation of the current system and of the system with an additional taxicab. Compare the two systems with respect to the waiting times of the customers and any other measures that might shed light on the simulation.

Answer

Excel solution: Modified "Example2.5SingleServer.xls" example from text. First we set clock to end after 480 minutes (5pm). After 5 day simulation the mean wait time result was 35 minutes. This would seem to indicate that a second car would be useful. This conclusion was then tested using an adapted version of the "Example2.6AbleBaker.xls" spreadsheet. If we use "Able" as the preferred car (when available) and count service time of "Baker" (second cab) and subtract the result from 480 (max daily minutes) we get a total idle time for the second car that is pretty high: 450, 455, 365, 345, 410 mins. this means that adding a second car would likely decrease wait times, but much of the time it would be idle.

2.5

The random variables X, Y, and Z are distributed as follows:

$$X \sim N(\mu = 100, \sigma^2 = 100)$$

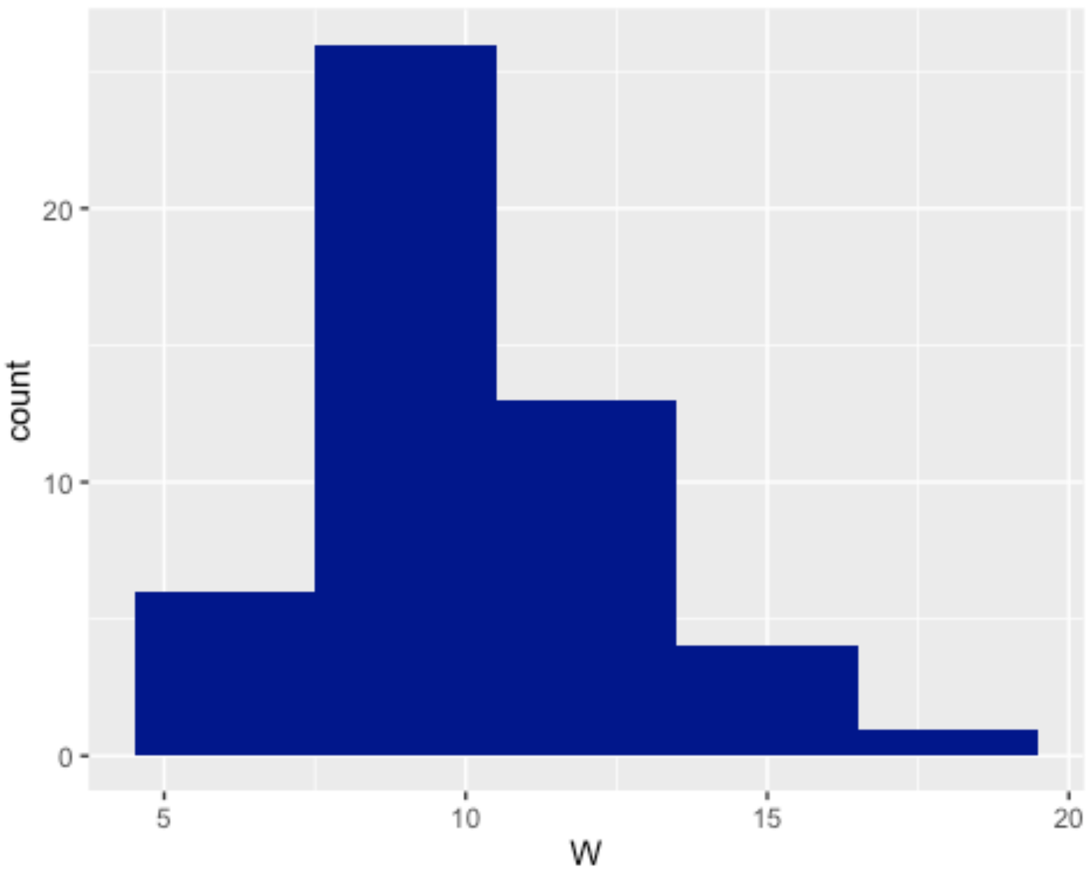
$$Y \sim N(\mu = 300, \sigma^2 = 225)$$

$$Z \sim N(\mu = 40, \sigma^2 = 64)$$

Simulate 50 values of the random variable

$$W = \frac{X + Y}{Z}$$

```r
set.seed(1111)
# 50 random
X <- rnorm(50,100,sqrt(100))
Y <- rnorm(50,300,sqrt(225))
Z <- rnorm(50,40,sqrt(64))
W <- (X+Y)/Z
q2.5 <- data.frame(X,Y,Z,W)
plot2.5 <- ggplot(q2.5) + geom_histogram(aes(x=W), binwidth=3,
fill="darkblue")
plot2.5
```



2.7:

Estimate, by simulation, the average number of lost sales per week for an inventory system that functions as follows:

a. Whenever the inventory level falls to or below 10 unites, an order is placed. Only one order can be outstanding at a time.
b. The size of each order is equal to 20 - I, where I is the inventory level when the order is placed.
c. If a demand occurs during a period when the inventory level is zero, the sale is lost.
d. Daily demand is normally distributed, with a mean of 5 units and a standard deviation of 1.5 unites. (Round off decimals to the closest integer during the simulation and, if a negative value results, give it a demand of zero.)
e. Lead time is distributed uniformly between zero and 5 days - integers only.
f. The simulation will start with 18 units in inventory.
g. For simplicity, assume that orders are placed at the close of the business day and received after the lead time has occured. Thus, if lead time is one day, the order is available for distribution on the morning of the second day of business following the placement of the order.
h. Let the simulation run for 5 weeks.

Answer:

Excel Solution: Modified "Example2.8RefrigInventory.xls" from the text.
a. Assume review period = 1 day. I adjusted the pending order only when the previous "days until order arrives" = 0 to prevent overlapping orders. Running the simulation 5 times results in lost sales: 3, 4, 1, 2, 6.
b. Assume the review period back to = 5 days. Max inventory adjusted to 20, and pending order column formula adjusted so the order would always be 20 - I. Running the simulation 5 times results in lost sales: 1, 11, 5, 0, 0.
c. Initially (a,b) number of shortages was used as a proxy to lost sales. To calculate a more explicit condition, I created a column in the spreadsheet to show when the inventory level was 0 and there was demand. The demand added as the number of lost sales. Running the simulation 5 times results in lost sales: 4, 4, 0, 5, 0.
d. Using the rules expressed in part c, adjustments were made to the original spreadsheet with new conditions: =IF(INT(1.5timesNORM.S.INV(rnd01())+5)>=0, INT(1.5timesNORM.S.INV(rnd01())+5),0) to create a normally distributed demand. Running the simulation 5 times results in lost sales: 238, 228, 163, 216, 174.
e. The original lead time formula is adjusted to =IF(D19=L6,discreteuniform(0,5),0). Running the simulation 5 times results in lost sales: 210, 133, 83, 260, 78.
f. The default max number of units was originally 11. This was adjusted to 20 in the original spreadsheet. Running the simulation 5 times results in 0 lost sales. g. No adjustments were needed.
h. The "length" of the simulation table is adjusted resulting in shortages: 20, 13, 3, 18, 2

2.8:

An elevator in a manufacturing plan carries exactly 400 kg of material. There are three kinds of material packaged in boxes that arrive for a ride on the elevator. these materials and their distributions of time between arrivales are as follows:

```
Material <- c("A","B","C")
Weight <- c(200,100,50)
Inter_Arrival_m <- c("5 +- 2 (uniform)", "6 constant", "P(2)=0.33 or
P(3)=0.67")
table2.8 <- data.frame(cbind(Material,Weight,Inter_Arrival_m))
table2.8

##   Material Weight        Inter_Arrival_m
## 1        A    200       5 +- 2 (uniform)
## 2        B    100             6 constant
## 3        C     50 P(2)=0.33 or P(3)=0.67
```

It takes the elevator 1 min to go up to the second floor, 2 minutes to unload, and 1 minute to return to the first floor. The elevator does not leave the first floor unless it has a full load. Simulate 1 hour of operation of the system. What is the average transit time for a box of material A (time from its arrival until it is unloaded)? What is the average waiting time for a box of material B? How many boxes of material C make the trip in 1 hour?

Answer: 2.8

I was unable to complete this question by either adapting an Excel spreadsheet, or through R code. I am looking forward to seeing a breakdown of this solution. I know I would basically need to define a function that would set conditions and times based on weight, but determining how to nest that function based on the different material distributions has proven itself to be a real challenge. I think more examples like this in both code and spreadsheet would be helpful as we move forward in class.