COIS 4470H Modelling and Simulation
Assignment 2
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Question 1 – Inventory System

Language : Python

C_HOLDING = $25/week
C_SHORTAGE = $700/week
C_SETUP = $1000/week
C_UNIT = $8000/week

Part a and b

S = 80

s	0	5	10	15	20	25	30	35	40
Average Holding Cost/week	854.5	917.5	917.5	955.75	1060.0	1144.5	1208.0	1262.25	1277.5
Average Shortage Cost/Week	797.99	371.0	371.0	343.0	175.0	14.0	0.0	0.0	0.0
Average Setup Cost/Week	320.0	340.0	340.0	350.0	390.0	440.0	470.0	500.0	510.0
Sum of Three Costs/Week	1972.49	1628.5	1628.5	1648.75	1625.0	1598.5	1678.0	1762.25	1787.5

Part c – Optimal Number of 's'

Optimal Value for s = 25

Ideally, when the business has the LEAST cost, that is the optimal number, which is s=25. The higher the s is, the higher the holding cost, even though shortage cost is 0.00. Similarly, the lower it is, the higher the shortage cost, heavier orders.

Part d and e– NO Backorder and different Set up Costs based on Number of Orders + unsatisfied customers

$$C\_SetUp = \begin{cases} 1000 \text{ if order } \leq 70 \\ 1200 \text{ if order } > 70 \end{cases}$$

s	0	5	10	15	20	25	30	35	40
Average Holding Cost/week	23.75	854.25	854.25	902.5	1020.0	1130.0	1197.5	1256.75	1272.5
Average Shortage Cost/Week	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average Setup Cost/Week	10.0	406.0	406.0	410.0	434.0	472.0	490.0	506.0	514.0
Sum of Three Costs/Week	33.75	1260.25	1260.25	1312.5	1454.0	1602.0	1687.5	1762.75	1786.5
Unsatisfied Customers	2849	266	266	248	143	20	6	2	4

Optimal Number s = 30

The number of unhappy customers are low while also the total cost is low.

Part f – additional demand

s	0	5	10	15	20	25	30	35	40
Average Holding Cost/week	23.75	700	805	810.25	1003.75	1117.5	1181	1250.5	1215.5
Average Shortage Cost/Week	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average Setup Cost/Week	10.0	574	562	566	520	508	520	506	530
Sum of Three Costs/Week	33.75	1274	1367	1376.25	1523.75	1625.5	1701	1756.5	1745.5
Unsatisfied Customers	13956	1069	628	684	128	25	4	2	4

Optimal Number s = 30

The number of unhappy customers are low while also the total cost is low.

Question 2: 3 Die Experiment Monte Carlo Simulation

Language = Python

```
For 1000 Experiments:
        Probability of X = 1 is 0.01
        Probability of X = 2 is 0.03
        Probability of X = 3 is 0.1
        Probability of X = 4 is 0.16
        Probability of X = 5 is 0.29
        Probability of X = 6 is 0.41
```

Largest of 3 Numbers X	1	2	3	4	5	6
Estimated Probability	0.01	0.03	0.1	0.16	0.29	0.41

Question 3 : Monte- Carlo Simulation

Language : Python

Testing the 2 algorithms for Center = (1,1) and Radius = 2

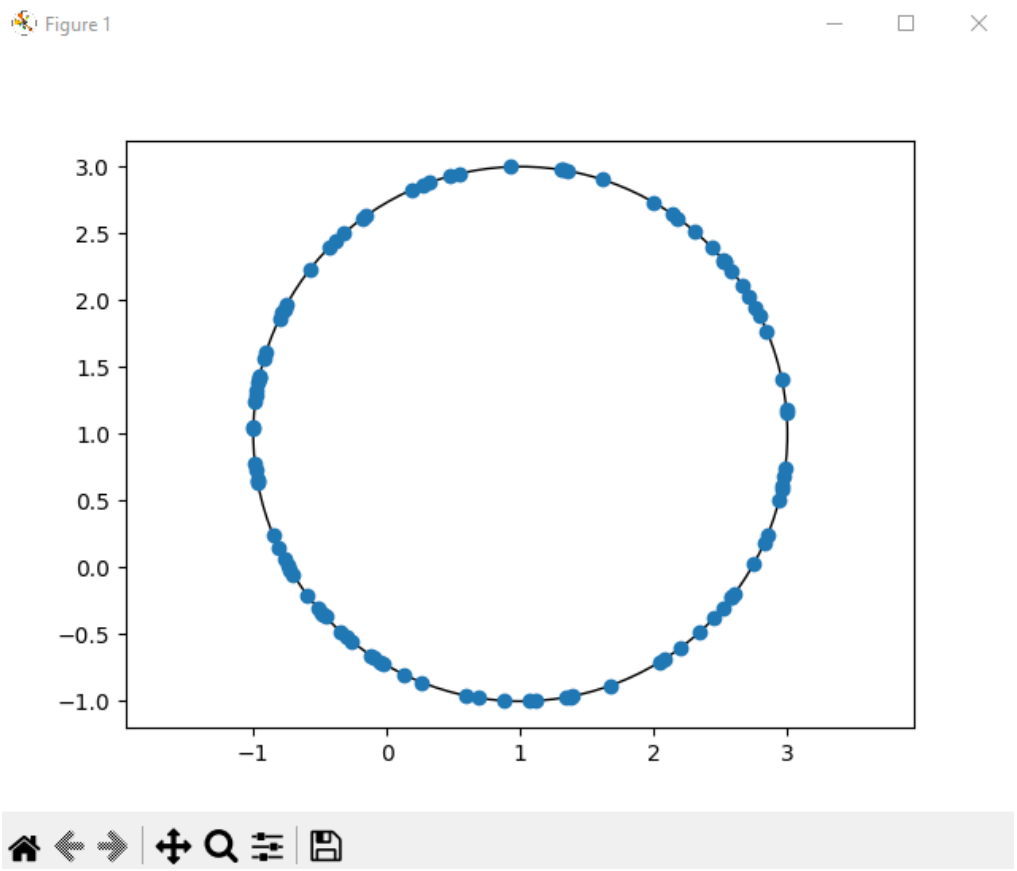
```
Please Enter the x-coordinate of the center: 1
Please Enter the y-coordinate of the center: 1
Please Enter the radius of the circle: 2
```

Algorithm 1 :

Algorithm 1:

$$\theta = \text{Uniform}(-\pi, \pi);\ \ r = \text{Uniform}(0, \rho);$$
$$x = \alpha + r^{*}\cos(\theta);\ \ \ y = \beta + r\ ^{*}\sin(\theta);$$

This is correct for Part a. This gives us all the points ON the circle. I sed matplotlib.pyplot to print the results as a visualization. Please see below.



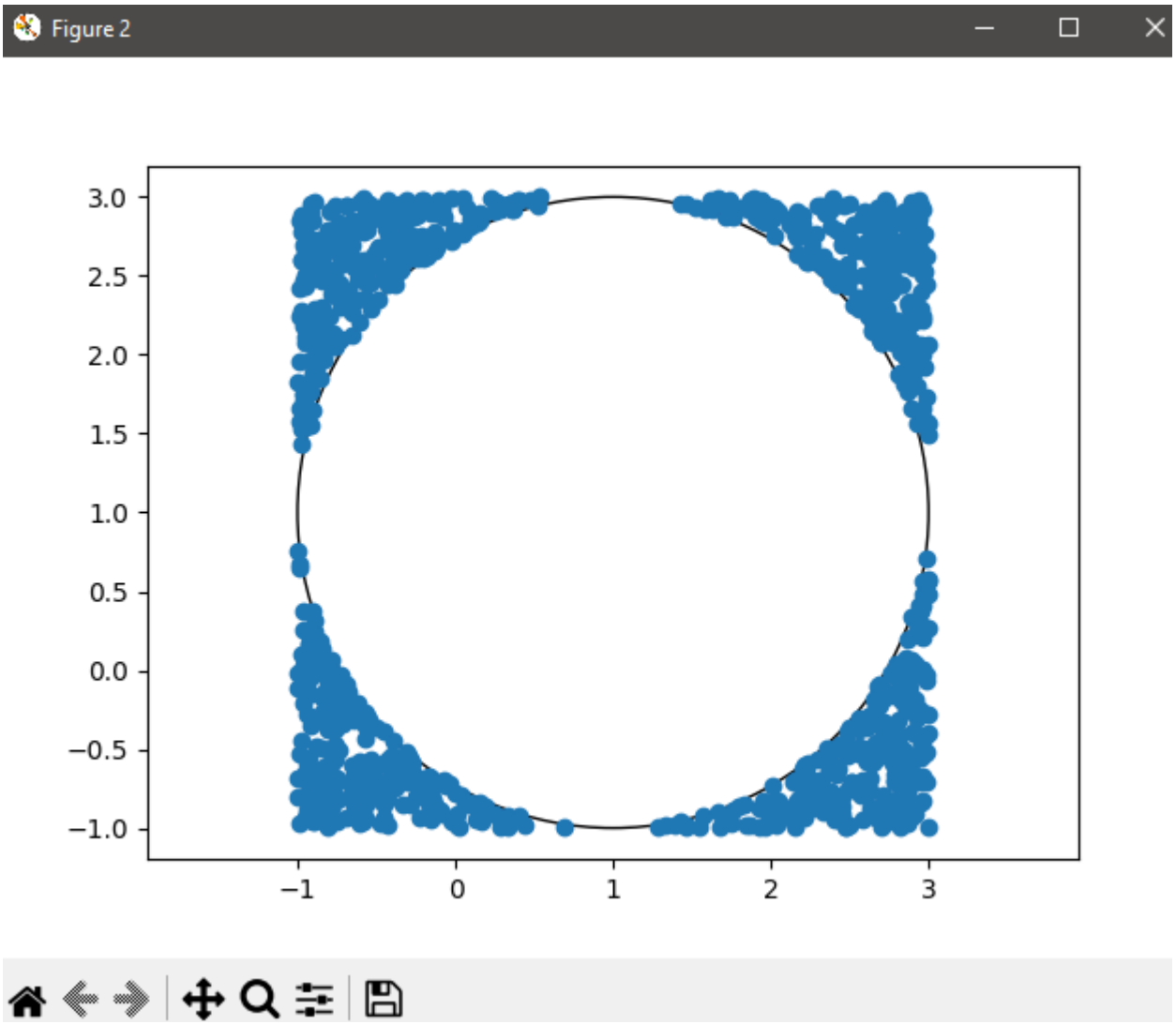
Algorithm 2:

Algorithm 2:

```
do {
        x = Uniform(-ρ, ρ);
        y = Uniform(-ρ, ρ);
    } while (x * x + y * y >= ρ * ρ);
        x = α + x;
        y = β + y;
        return (x, y);
```

This algorithm is not correct because it generates all points that liw OUTSIDE of circle. To correct this, e change the while condition from “>=” to “<=” since we want it to lie within the circle.

Here is the output before correction:



After correction :

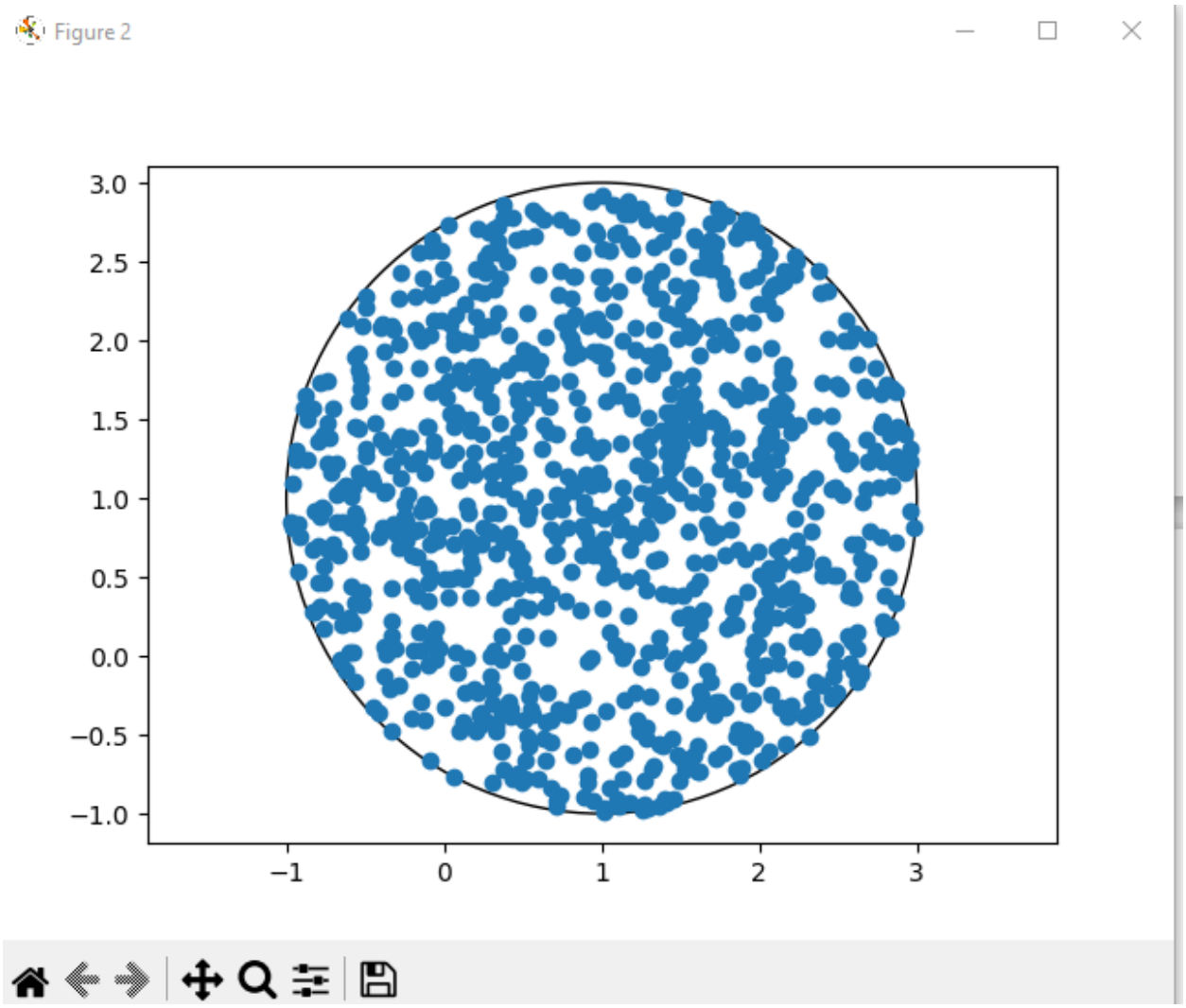


Figure 2
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1
0
1
2
3

Question 4 – GPSS Program 1

GPSS Program calculates the Average Delay time for Patient from when they arrive till when they get service.

a) Interarrival Time = 15 +- 10.5 minutes
Service Time = 14 +- 5 minutes

Mean Waiting Time	Mean Number of Patients in the waiting Room	Maximum Number of Patients in the Waiting Room	Doctor's Idle Time (1 – AVG Total Time)
0.00	0.00	1	0.075

C: > Users > punya > Documents > Priyam > 2023 Winter > COIS 4470H > Assignments > A2 > A2Q4a.gps

```
1   *12345678901234567890123456789O
2           SIMULATE
3           GENERATE    15,10.5     PATIENT INTERARRIVAL TIME
4           QUEUE       WAIT        WAITING FOR DOCTOR
5           SEIZE       DOCTOR      GET DOCTOR
6           DEPART      WAIT        DONE WAITING LINE
7           ADVANCE     14,5        DOCTOR SERVICE TIME
8           RELEASE     DOCTOR
9           TABULATE    RES
10          TERMINATE   1           REMOVE 1 PATIENT FORM TERMINATION COUNTER
11  RES     TABLE       M1,5,5,10
12
13          START       100         FOR 100 CUSTOEMRS
14          END
```

b) Interarrival Time = 5 +- 3.5 minutes
Service Time = 14 +- 5 minutes

Mean Waiting Time	Mean Number of Patients in the waiting Room	Maximum Number of Patients in the Waiting Room	Doctor's Idle Time
188.026	37.286	75	0.008

C: > dosbox > A2Q4b.gps

```
1  *123456789012345678901234567890
2          SIMULATE
3          GENERATE    5,3.5      PATIENT INTERARRIVAL TIME
4          QUEUE       WAIT         WAITING FOR DOCTOR
5          SEIZE       DOCTOR       GET DOCTOR
6          DEPART      WAIT         DONE WAITING LINE
7          ADVANCE     14,5         DOCTOR SERVICE TIME
8          RELEASE     DOCTOR
9          TABULATE    RES
10         TERMINATE   1            REMOVE 1 PATIENT FORM TERMINATION COUNTER
11 RES     TABLE       M1,5,5,10
12
13         START       100          FOR 100 CUSTOEMRS
14         END
```

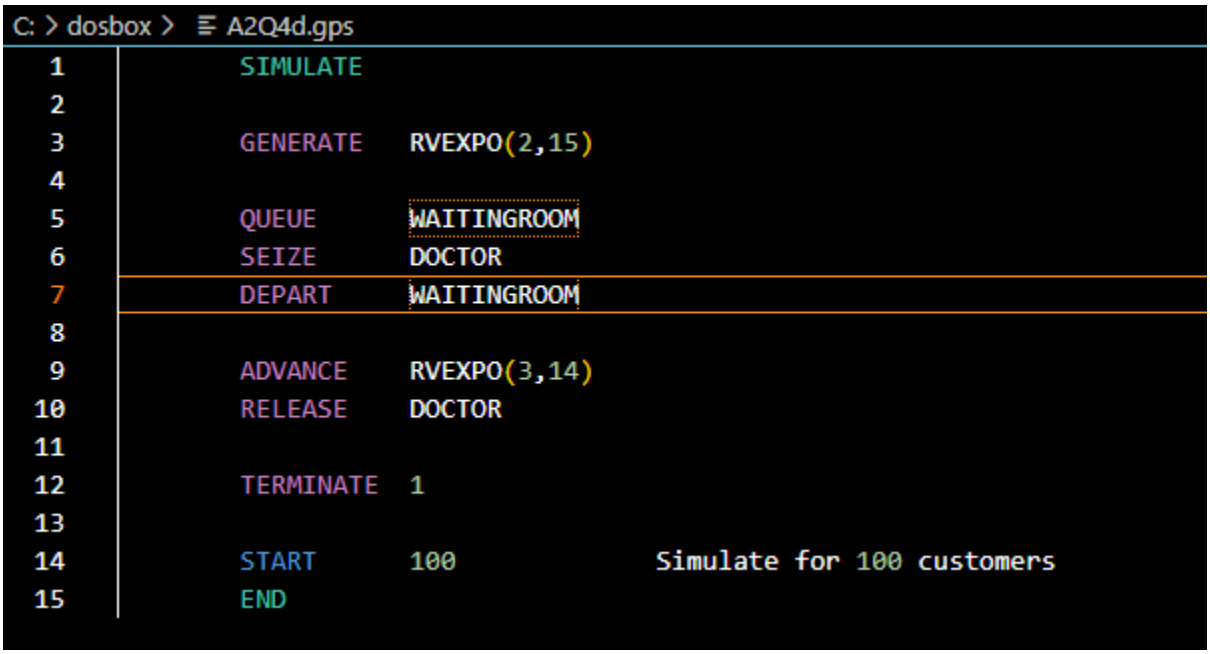
c) Interarrival Time = 20 +- 3.5 minutes
Service Time = 14 +- 5 minutes

Mean Waiting Time	Mean Number of Patients in the waiting Room	Maximum Number of Patients in the Waiting Room	Doctor's Idle Time
0.00	0.00	1	0.305

```
1  *123456789012345678901234567890
2          SIMULATE
3          GENERATE    20,3.5     PATIENT INTERARRIVAL TIME
4          QUEUE       WAIT         WAITING FOR DOCTOR
5          SEIZE       DOCTOR       GET DOCTOR
6          DEPART      WAIT         DONE WAITING LINE
7          ADVANCE     14,5         DOCTOR SERVICE TIME
8          RELEASE     DOCTOR
9          TABULATE    RES
10         TERMINATE   1            REMOVE 1 PATIENT FORM TERMINATION COUNTER
11 RES     TABLE       M1,5,5,10
12
13         START       100          FOR 100 CUSTOEMRS
14         END
```

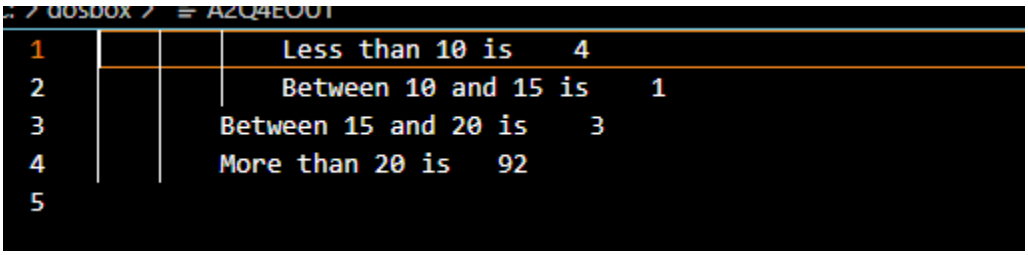
d) Interarrival Time = RVEXP(1, 15) minutes
Service Time = RVEXP(1, 14) minutes

Mean Waiting Time	Mean Number of Patients in the waiting Room	Maximum Number of Patients in the Waiting Room	Doctor's Idle Time
89.549	5.850	20	0.107



e) Interarrival Time = RVEXPO(2, 15) minutes
Service Time = RVEXPO(3, 14) minutes

Less than 10 minutes	Between 10 and 15 minutes	Between 15 and 20 minutes	More than 20
4	1	3	92



Question 5 – GPSS Program 2

3 hoists – 3 servers – 3 mechanics

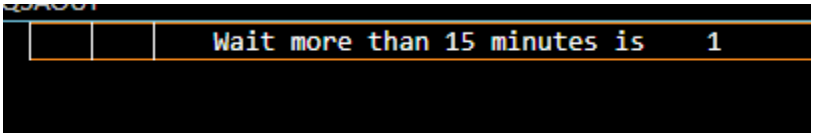
Interarrival time = avg 15 cars per hour = 4 minutes for each car

Service time = avg 10 minutes

a. **Interarrival times = 4 +-1**
service time = 10 +- 2
Customers = 2000

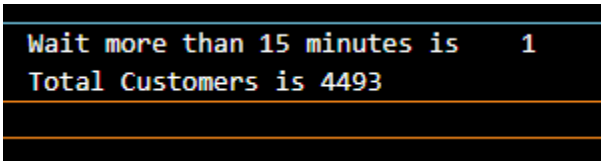
i. First Model – 2000 customers

Avg time car spends at garage	Utilization of mechanic	Percentage of time customer waits > 15 minutes
2.518	Total Time = 0.833 Avg time = 10.10 Avg Contents = 2.499	1



ii. Second Model, based on time period
Total Time = 10 hours a day * 5 days a week * 6 weeks * 60 minutes = 18000

Number of customers that went through the system = 4493



b. **Interarrival times = RVEXPO(2, 4)**
service time = RVEXPO(3, 10)
Customers = 2000

i. First Model – RVEXPO

Avg time car spends at garage	Utilization of mechanic	Percentage of time customer waits > 15 minutes
17.800	Total Time = 0.779 Avg time = 9.732 Avg Contents = 2.338 Contents Waited = 21 Avg Wait Time = 8.083	953

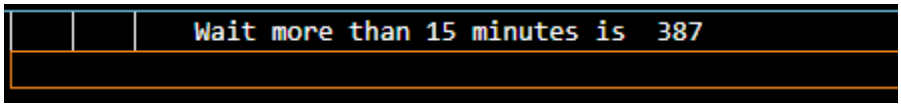
ii. 20% of 2000 customers = 400
Less than 400 customers spend more than 15 minutes in the system

Average Service Time = 7.5 minutes

For Service time exponentially distributed with mean 7.5 minutes, the number of customers that spend more than 15 minutes = 387 < 400

For Service time exponentially distributed with mean 7 minutes, the number of customers that spend more than 15 minutes = 316 < 400

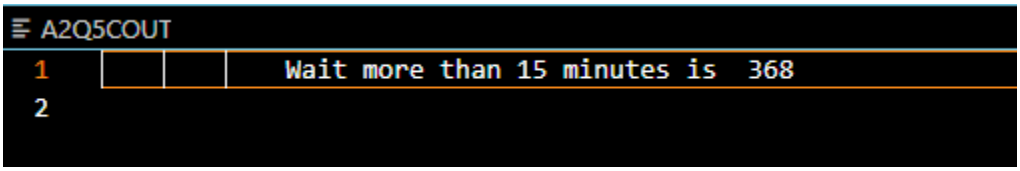
For Service time exponentially distributed with mean 8 minutes, the number of customers that spend more than 15 minutes = 455 > 400



c. **Interarrival times = RVEXPO(2, 4)**
Hoist up Time = RVEXPO(1,1)
Service time = RVEXPO(3, 7)
Hoist Down Time = RVEXPO(2,2)
Customers = 2000

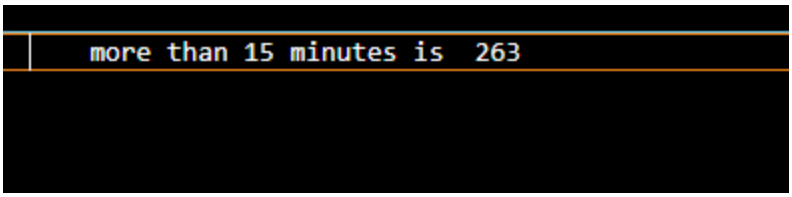
i. First Model ~~2000~~ 400 customers

Avg time car spends at garage	Utilization of Hoists (3)	Utilization of Driver (1)	Utilization of mechanic (2)	Percentage of time customer waits > 15 minutes
90.446	Total Time = 0.965 Avg Time = 13.240 Avg Content = 2.984	Total Time = 0.672 Avg Time = 1.541 Avg Content = 0.672	Total Time = 0.757 Avg Time = 6.925 Avg Content = 1.514	368



ii. Mechanics = 3; Hoists = 5; Driver = 1

Avg time car spends at garage	Utilization of Driver (1)	Utilization of Hoists (3)	Utilization of mechanic (2)	Percentage of time customer waits > 15 minutes
20.057	Total Time = 0.748 Avg Time = 1.541 Avg Content = 0.748	Total Time = 0.749 Avg Time = 15.310 Avg Content = 3.743	Total Time = 0.562 Avg Time = 6.931 Avg Content = 1.686	263



Observations:

- The average time a car spends at the garage decreases drastically. The number of customers spending more than 15 minutes also decreases.