OPERATION RESEARCH II
ASSIGNMENT – 1

Qn1) The simulation table for the Customer processing using Head and Tail to generate customer is given below. As per the question description we are using a FIRST IN FIRST OUT(FIFO) Queue and the Simulation begins with Simulation Clock at t = 0. A Home Customer is represented by a Heads and arrives with an inter arrival time of 6 min where as a Business Customer represented as Tails arrives with an inter arrival time of 2 mins. The simulation starts after time = 2 mins with an arrival of a Business Customer

SIMULATION TABLE FOR COURIER SERVICE

Customer No:	Heads or Tails	Inter Arrival Time (mins)	Arrival Time (clock)	Service Time (mins)	Time Service Began (clock)	Waiting Time in Queue (mins)	Time Service Ends (clock)	Time Customer Spends in System(mins)	Idle Server Time (mins)
1	T	2	2	4.5	2	0.0	6.5	4.5	2
2	H	6	8	1.5	8	0.0	9.5	1.5	1.5
3	T	2	10	4.5	10	0.0	14.5	4.5	0.5
4	T	2	12	4.5	14.5	2.5	19.0	7	0
5	T	2	14	4.5	19	5.0	23.5	9.5	0
6	H	6	20	1.5	23.5	3.5	25.0	5	0
7	T	2	22	4.5	25	3.0	29.5	7.5	0
8	H	6	28	1.5	29.5	1.5	31.0	3	0
9	H	6	34	1.5	34	0.0	35.5	1.5	3
10	T	2	36	4.5	36	0	40.5	4.5	0.5
11	H	6	42	1.5	42	0	43.5	1.5	1.5
12	H	6	48	1.5	48	0	49.5	1.5	4.5
13	H	6	54	1.5	54	0	55.5	1.5	4.5
14	T	2	56	4.5	56	0	60.5	4.5	0.5
15	H	6	62	1.5	62	0	63.5	1.5	1.5
16	T	2	64	4.5	64	0	68.5	4.5	0.5
17	T	2	66	4.5	68.5	2.5	73.0	7	0
18	T	2	68	4.5	73	5	77.5	9.5	0
19	H	6	74	1.5	77.5	3.5	79.0	5	0
20	T	2	76	4.5	79	3	83.5	7.5	0

Chronological Event Table for Courier Service

Event #	Event Type	Customer #	Simulation clock
1	ARRIVAL	1	2
2	DEPARTURE	1	6.5
3	ARRIVAL	2	8
4	DEPARTURE	2	9.5
5	ARRIVAL	3	10
6	ARRIVAL	4	12
7	ARRIVAL	5	14
8	DEPARTURE	3	14.5
9	DEPARTURE	4	19
10	ARRIVAL	6	20
11	ARRIVAL	7	22
12	DEPARTURE	5	23.5
13	DEPARTURE	6	25
14	ARRIVAL	8	28
15	DEPARTURE	7	29.5
16	DEPARTURE	8	31
17	ARRIVAL	9	34
18	DEPARTURE	9	35.5
19	ARRIVAL	10	36
20	DEPARTURE	10	40.5
21	ARRIVAL	11	42
22	DEPARTURE	11	43.5
23	ARRIVAL	12	48
24	DEPARTURE	12	49.5
25	ARRIVAL	13	54
26	DEPARTURE	13	55.5
27	ARRIVAL	14	56
28	DEPARTURE	14	60.5
29	ARRIVAL	15	62
30	DEPARTURE	15	63.5
31	ARRIVAL	16	64
32	ARRIVAL	17	66
33	ARRIVAL	18	68
34	DEPARTURE	16	68.5

35	DEPARTURE	17	73
36	ARRIVAL	19	74
37	ARRIVAL	20	76
38	DEPARTURE	18	77.5
39	DEPARTURE	19	79
40	DEPARTURE	20	83

2)

a) Average Service time: Total Service time / Number of Customers
=63/20 = 3.15

b) Average Inter arrival time: Sum of all times between arrivals/ number of arrivals – 1
= 76/19= 4

c) Server Utilization factor = (Total simulation time – idle time/ total simulation time)
SERVICE TIME/ TOTAL TIME = 63/83.5
= 0.7544

d) Theoretical Server Utilization = Theoretical Service Time / Theoretical Arrival time

Theoretical Service Time: P (Home Customer) * Service Time of Home Customer + P (Business Customer) * Service Time of Business Customer
: 0.5 *1.5 + 05 * 4.5 = 0.75+2.25 = 3

Theoretical Arrival time: P (Home Customer) * Inter-arrival Time of Home Customer + P (Business Customer) * Inter-arrival Time of Business Customer)
: 0.5*6 + 0.5 *2 = 3 + 1 = 4

Theoretical Server Utilization = ¾ = 0.75

There is an expected discrepancy because number of simulations done is only one. As we perform more simulations the values become closer. Here though the values are closer though.

e) Average time customer spends in the system:
Total time spend by all customers/ total number of customers= 92.5/20
= 4.625

f) Package Received with unequal probability.
(i) Service time = P (Home Customer) * Service Time of Home Customer + P (Business Customer) * Service Time of Business Customer
= P * 1.5 + 1-P (4.5) = 1.5P + 4.5 – 4.5P = 4.5 – 3.0P

Arrival Time: P (Home Customer) * Inter-arrival Time of Home Customer + P (Business Customer) * Inter -arrival Time of Business Customer)

: $P * 6 + (1-P) * 2 = 6P + 2 - 2P = 4P + 2$

Utilization rate = Service time/ Arrival time = $(4.5 – 3.0P)/ 4P + 2 <= 1$

$$4.5 – 3.0P <= 4P + 2$$

$$2.5 <= 7P$$

$$0.35 <= P$$

The bounds of P are: $0.35 <= P < 1$, P should lie between 0.35 and 1.

3) a) Excel Sheet attached as OR1_Assignment_Mod_Able_baker. The policy for choosing the server was changed to random and various performance measures were analyzed.

b) <u>probability of idle server for both Able and Baker</u>

= (Total simulation time – Total service time of Able/Baker) /Total Simulation time

Probability of Idle Server(Able)	0.172566372
Probability of Idle Server(Baker)	0.14159292

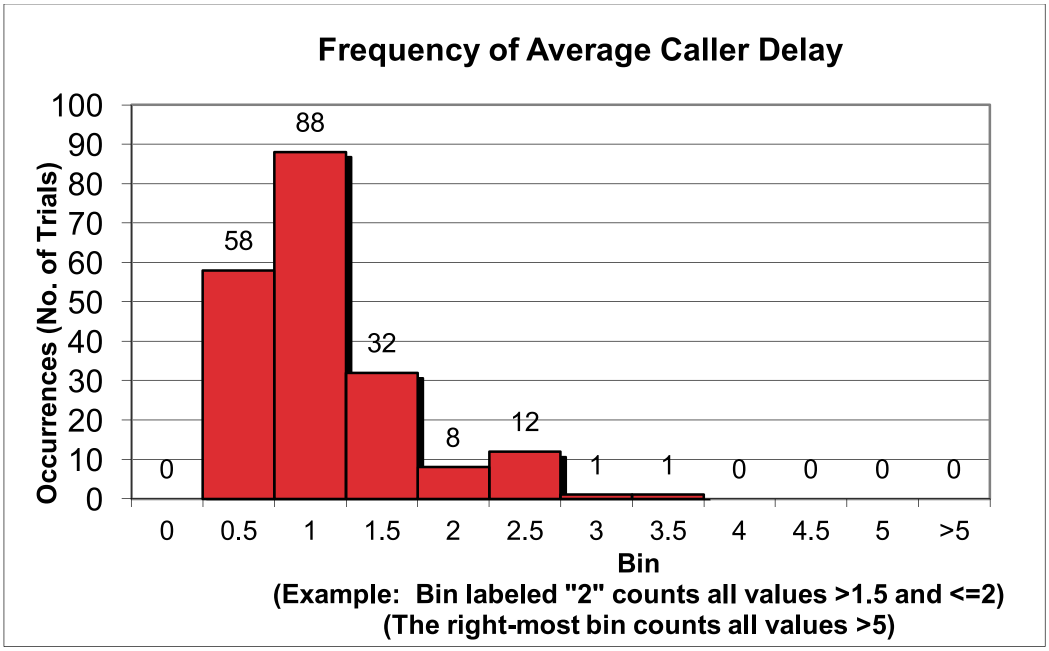
c) A single trial was run with the 100 Customers and below are the performance measures of the system.

Performances Analysis	
Total Simulation Time	226
Probability of Idle Server(Able)	0.172566372
Probability of Idle Server(Baker)	0.14159292
Average waiting time/Delay	0.71
Probability of Wait	0.42
Average Service Time(Able)	3.528301887
Average Service Time(Baker)	4.127659574
Average Time Between arrivals	2.222222222
Average Time Customer Spends in system	4.52
Average Waiting time for those who waited	2.975674

d) Experiment with original Trials VS Modified Policy (Able Preferred over Baker)

Number of Trials:	200	
Link to Measure of Performance:		
Name of Measure:		Link
Average Caller Delay		0.68

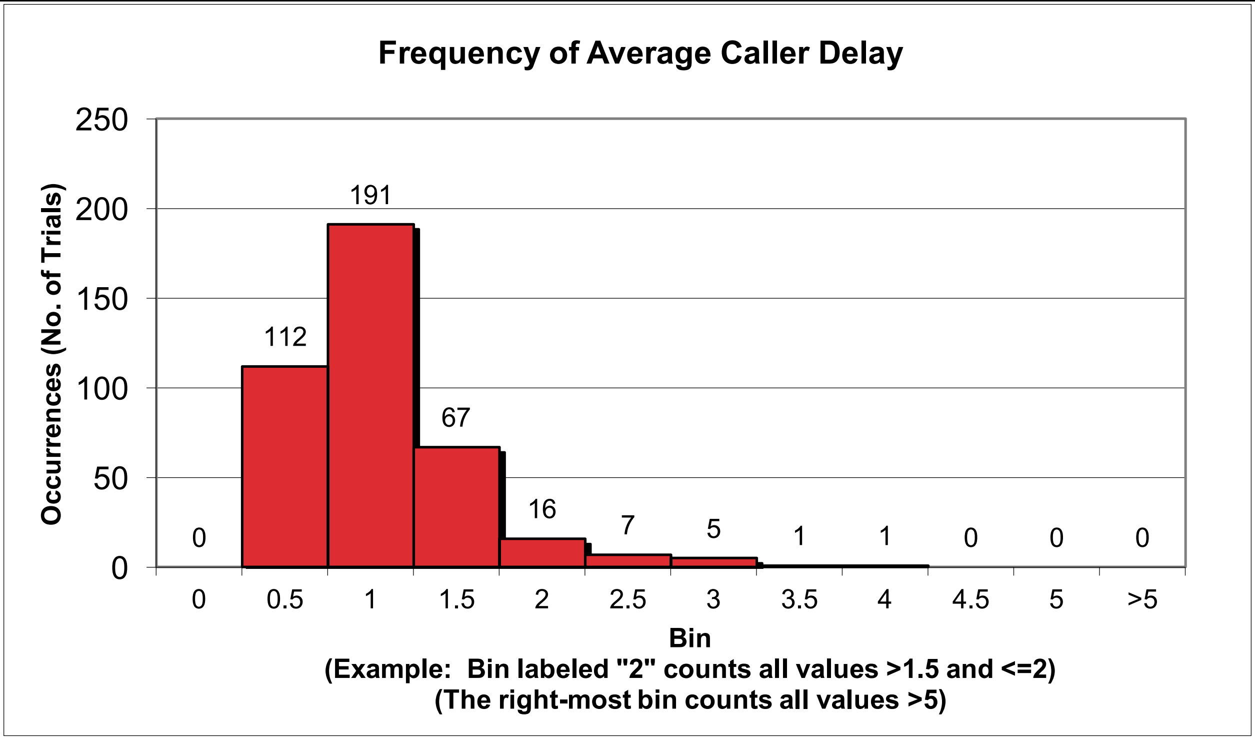
AVERAGE IS FOR ALL EXPERIMENT: 0.79



Experiment with modified random policy

Number of Trials:	200	
Link to Measure of Performance:		
Name of Measure:		Link
Average Caller Delay		0.85

AVERAGED FOR ALL EXPERIMENT : 0.89



As we can infer from the Above two trials using original policy and new modified random policy, the average caller delay has increased. **This proves that original policy was better. This could be accounted to the fact that Able had better service time than baker and could handle calls faster and many more customers as compared to baker.**

4) a) The type of Distribution for Inter Arrival Time: **Exponential Distribution**

This is because the arrival of Customers is independent from one another.

The theoretical mean for an exponential distribution is given as

Mean(u) = lambda-^{1,} where lambda is the rate parameter.

Theoretical Mean Inter Arrival Time = 4.5

Calculated Mean Arrival Time: 4.504275061

b) The type of Distribution for Service time is a Normal Distribution.

The service time per different category of customers are usually fixed and form a normal distribution

Theoretical Mean Service Time = 3.2

Calculated Mean: 3.189101516

c) Theoretical Server Utilization time is given by:

Theoretical Average Service time / Theoretical Average Inter Arrival time =

= 3.2 / 4.5 = 0.7111

d) Simulating for 10000 Customers with two different seeds:

Seed	Number of Customers	Mean Inter Arrival Time	Mean Service Time	Server Utilization	Mean Response Time(mins)
23651	10000	4.504275061	3.189101516	0.712309563	7.305487285
56376	10000	4.450231841	3.174083564	0.718430752	7.132174

e) Simulating for 50000 customers with two different seeds:

Seed	Number of Customers	Mean Inter Arrival Time	Mean Service Time	Server Utilization	Mean Response Time
23651	50000	4.494703953	3.178283	0.71204469	7.254525619
56376	50000	4.475703965	3.178988349	0.715351359	7.215730195

f). We can infer from the above two observations that as we increase the number of Simulations, we get better Simulation results. Seeds are varied to get different results. Increasing the number of customers and varying the seeds helps us Simulate the real world scenarios and helps us get better simulation results. When the number of customers are more, even though the seeds are changed, most simulation parameters are nearly the same. We get close to real simulation results.

g) Exponential Service time- 10000 Customers

Seed	Number of Customers	Mean Inter Arrival Time	Mean Service Time	Server Utilization	Mean Response Time
23651	10000	4.5453783	2.77309038	0.69942845	9.90499325
56376	10000	4.43328818	2.8443954	0.7277644	10.61205146

h) **<u>SIMULATION WITH EXPONENTIAL SERVICE DISTRIBUTION FOR FIVE SEEDS- 50000 CUSTOMERS</u>**

Seed	Number of Customers	Mean Inter Arrival Time	Mean Service Time	Server Utilization	Mean Response Time
56745	50000	4.50795718	2.816743	0.7106246	10.88866725
14325	50000	4.509048778	2.82549	0.71136217	11.307135
98234	50000	4.48472612	2.82075935	0.713290132	11.1521004
54367	50000	4.489640954	2.82218843	0.713524908	11.06885736
68342	50000	4.525375303	2.815094683	0.706665182	10.87647642
Average		4.503349667	2.820055093	0.711093398	11.05864728
Variance		0.000268401	0.0000140	0.0000076597	0.033165828

We have seen that as we changed the service time to exponential, the mean service time has decreased. However, we have an increase in the mean response time. We could also see that with Simulating with 50000 customers and using an exponential distribution, we have seen that variance is less which means the results across various simulations are near to same and Simulations are close to real life scenarios.

i. **Using the warm up period: (Code attached as Warm_time.zip)**

a) **Warm up period = 100 Customer; Service Time exponentially Distributed**

Seed	Number of Customers	Warm up Customers	Mean Inter Arrival Time	Mean Service Time	Server Utilisation	Mean Response Time
56745	5000	100	4.440401272	2.841224968	0.726813133	9.7320448
14325	5000	100	4.544610885	2.733370773	0.687997309	10.3006073
98234	5000	100	4.40030384	2.8340099	0.7243828	11.7911212
54367	5000	100	4.486876004	2.731150007	0.696993445	10.7702361
68342	5000	100	4.491916449	2.835004363	0.714428443	11.55288588

b) Warm up period = 1000 Customer; Service Time exponentially Distributed

Seed	Number of Customers	Warm up Customers	Mean Inter Arrival Time	Mean Service Time	Server Utilization	Mean Response Time
56745	5000	1000	4.413931345	2.834168674	0.728263366	9.569809965
14325	5000	1000	4.511178859	2.740089868	0.689013524	10.56655121
98234	5000	1000	4.405393512	2.850032984	0.726184362	12.0146857
54367	5000	1000	4.478519941	2.728479224	0.696537763	11.06639581
68342	5000	1000	4.513955559	2.822323814	0.708107225	11.7446146

The warm up period makes the calculated parameters as close as possible to actual parameters. With the trials of Warm up period we could accurately determine when a system will attain stability to do simulations. However, accurate results could have been obtained if number of Customers was as high as 50000 in (h).

5) For a Uniform Distribution, the probability of each random variable between the interval of the Distribution is the same, say p.

Modified Policy

For the example 2.5, The probability of each service time will be the same, ie 1/6

a) **Estimated Service time = 1/6(1+2+3+4+5+6) = 21/6 = 3.5**
b) **Estimated Inter arrival Time = (1+8)/2 = 4.5**
   Server Utilization Rate Theoretical: 3.5/4.5 = 0.7778

Modified policy:

Trial 1:

Performances Analysis	
Number Of Customers	100
Total Simulation Time	457
Average Service Time	3.42
Average Time Between arrivals	4.535353535
Server utilization rate	0.757111597

Trial 2

Performances Analysis	
Number Of Customers	100

Total Simulation Time	471
Average Service Time	3.75
Average Time Between arrivals	4.676767677
Server utilization rate	0.804670913

Experiment with Modified Service Time as Uniform Distribution

Seed for Random Numbers	12345

Number of Trials:	200
Link to Measure of Performance (Sample Values):	
Name of Measure:	Link
Avg. Cust. Waiting Time	2.77

Seed for Random Numbers	45643

Number of Trials:	200
Link to Measure of Performance (Sample Values):	
Name of Measure:	Link
Avg. Cust. Waiting Time	2.48

Original Policy:

Trial 1

Performances Analysis	
Number Of Customers	100
Total Simulation Time	468
Average Service Time	2.94
Average Time Between arrivals	4.686868687
Server utilization rate	0.636752137

Trial 2

Performances Analysis	
Number Of Customers	100
Total Simulation Time	435
Average Service Time	3.16
Average Time Between arrivals	4.353535354
Server utilization rate	0.735632184

Experiment with Original Service Time.

Seed for Random Numbers	12345
Number of Trials:	200
Link to Measure of Performance (Sample Values):	
Name of Measure:	Link
Avg. Cust. Waiting Time	1.35

Seed for Random Numbers	45643
Number of Trials:	200
Link to Measure of Performance (Sample Values):	
Name of Measure:	Link
Avg. Cust. Waiting Time	0.69

When we compare the Original policy with Service time being normal Distribution to the new policy with Uniform Distribution, we can infer the following.

a) **Avg Customer waiting has increased for new policy as compared to the old one.**
b) **There was also an increase in the Average Service time as per the new policy. This might have caused the increase in the Average Customer Waiting time.**

When the service time was Normally distributed we calculated the theoretical Service time as : 0.1 * 1 + 2 * 0.2 + 3*.30 + 4*.25 + 5*.10 + 6*0.05 = 2.3 and when we changed it to Uniform it became 3.5

c)

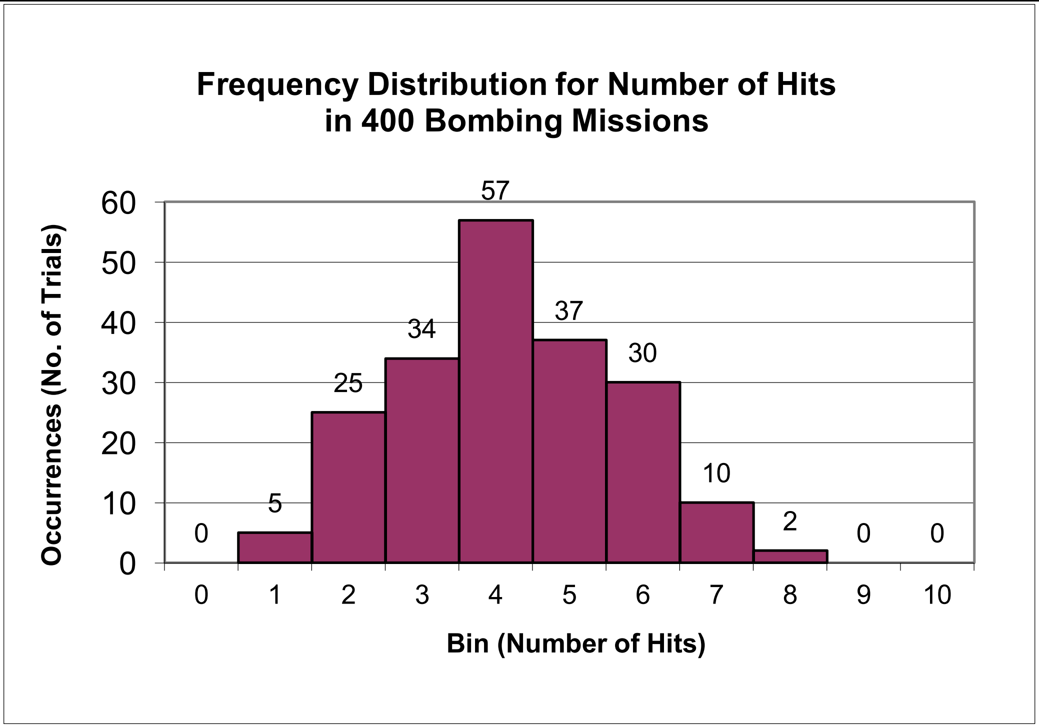
Therefore, the performance of System with Service time as Normal Distribution was better than System with Service time as Uniform Distribution. In short old/ Original Policy was better than the new policy.

Qn6

a)

Standard Deviation in X Direction =	650
Standard Deviation in Y Direction =	300

Number of Trials:	200

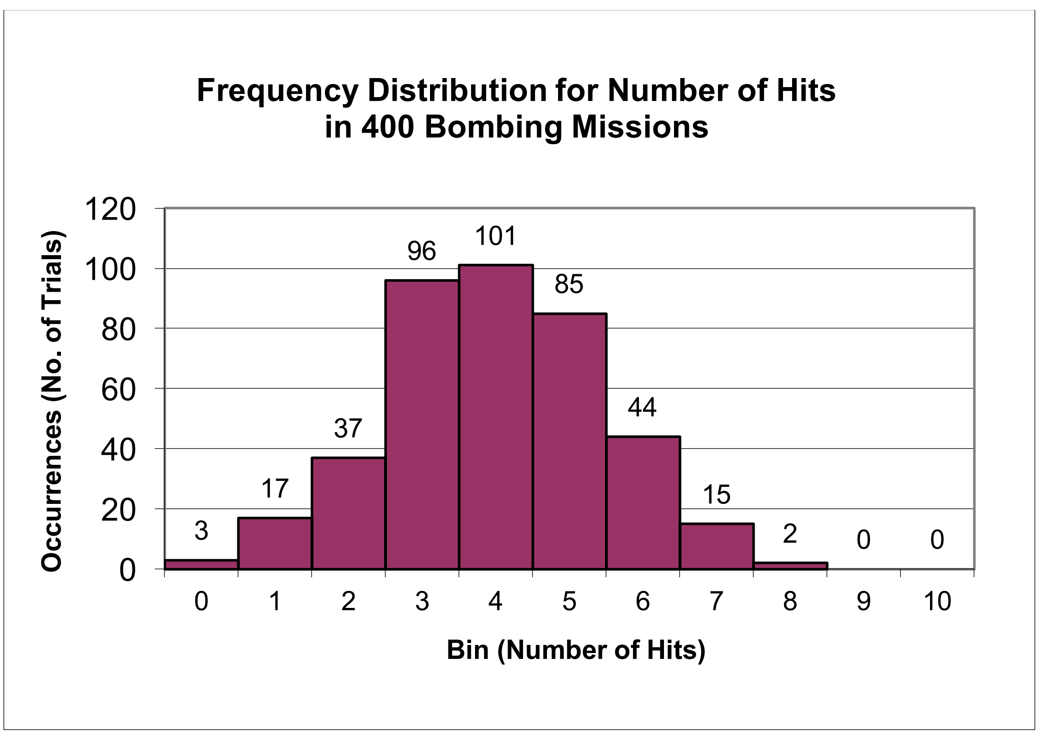


Average Number of Hits:

Average	4.18

b) Repeating Above with 400 Trials

Number of Trials:	**400**



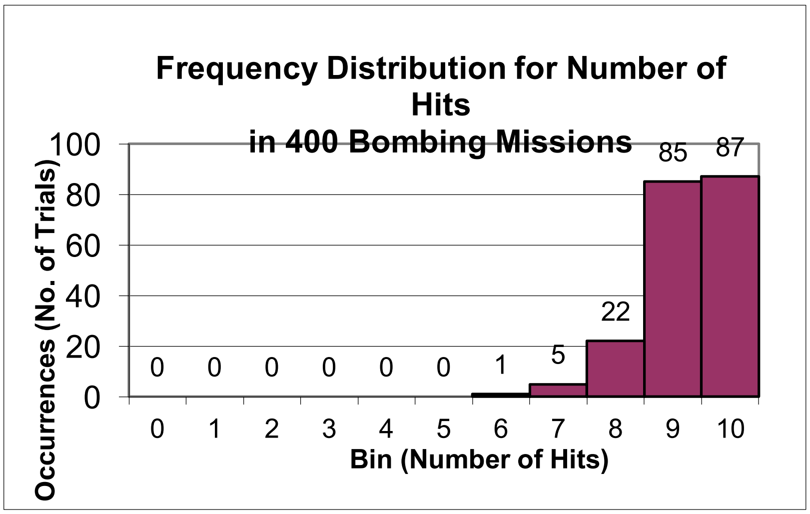
Average Number of Hits:

Average	3.98

c)

Standard Deviation in X Direction =	50
Standard Deviation in Y Direction =	250

Number of Trials:	**200**

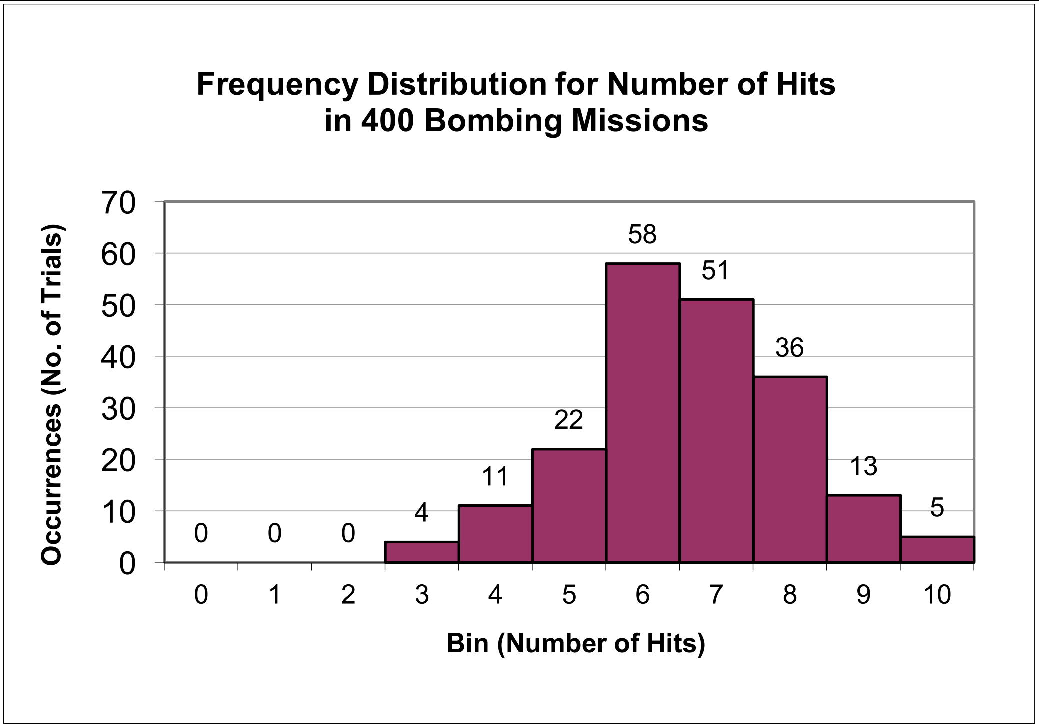


Average Number of Hits

Average	9.26

d)

Standard Deviation in X Direction =	50
Standard Deviation in Y Direction =	500



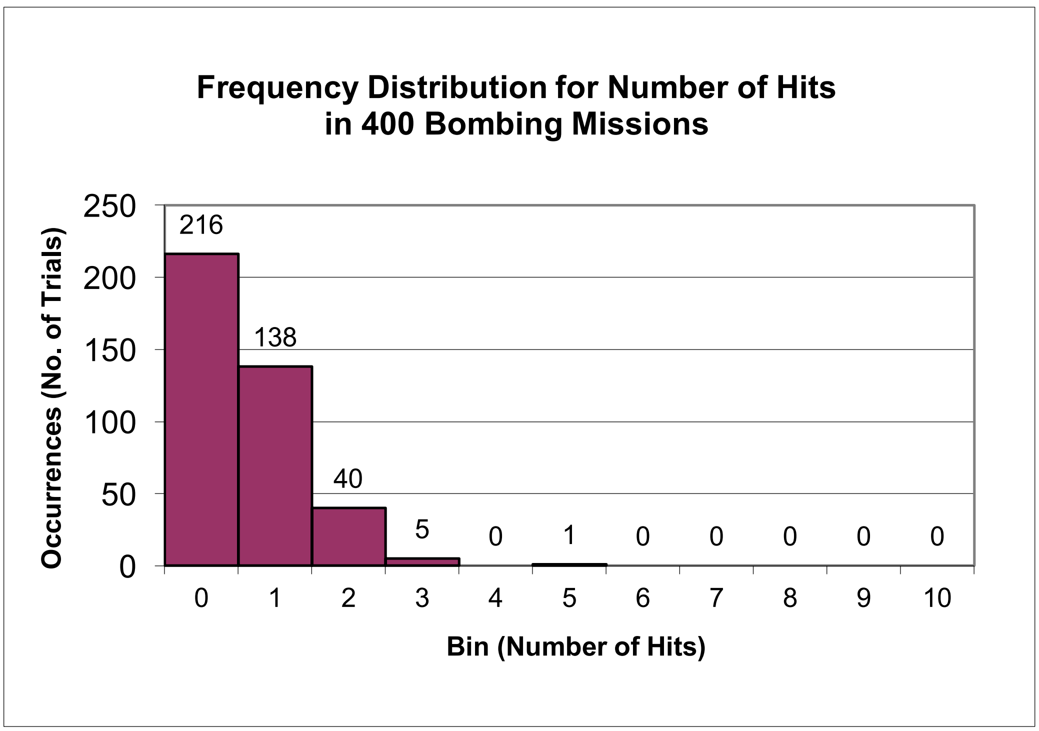
Average Number of Hits for this experiment

| Average | 6.63 |

e) Various Trials Shown:

Standard Deviation in X Direction =	900	Average	2.26
Standard Deviation in Y Direction =	450		
Standard Deviation in X Direction =	1300	Average	1.18
Standard Deviation in Y Direction =	650		
Standard Deviation in X Direction =	1600	Average	0.80
Standard Deviation in Y Direction =	800		
Standard Deviation in X Direction =	2000	Average	0.55
Standard Deviation in Y Direction =	1000		
Standard Deviation in X Direction =	1800	Average	0.64
Standard Deviation in Y Direction =	900		
Standard Deviation in X Direction =	1900		
Standard Deviation in Y Direction =	950		

Bins	Frequency
0	216
1	138
2	40
3	5
4	0
5	1
6	0
7	0
8	0
9	0
10	0
Average	0.60
Median	0
Mode	0
Minimum	0
Maximum	5



The answer is therefore:

Standard Deviation in X Direction =	1900
Standard Deviation in Y Direction =	950

f) We can infer from the above experiments that the Accuracy or average hits remains maximum if we have a smaller standard deviation.

Standard Deviation in X Direction =	50
Standard Deviation in Y Direction =	50

With a standard deviation above we get accuracy close to 10 on all experiments, thus we can infer that the Standard deviation plays the most important role in determining the number of hits in this simulation. Lower the Standard deviation, the higher will be accuracy for the bombing mission.

If we look at the bombing area, we can see that it's a function of area with mean centered at origin. If we have higher standard deviation, we will be moving away from the bombing area and likely to encounter more miss.

7)

Code :

```
import random

Probablity_head= 0.3
Probablity_tail = 1 - Probablity_head
total_head_count  = 0
total_tail_count  = 0
Total_simulation_count = 10000
for count in range(Total_simulation_count):
    toss = random.random()
    if (toss >= 0 and toss <= Probablity_head):
        total_head_count += 1
    elif (toss >= Probablity_head and toss <= 1):
        total_tail_count += 1
    else:
            continue


Parameter_head_estimated = (total_head_count)/float(Total_simulation_count)
Normalized_Estimated_Error = abs(Probablity_head - Parameter_head_estimated)/
Probablity_head
print "Probability of Head                                  :" + str(Probablity_head)
print "Probability of Tail                                  :" + str(Probablity_tail)
print "Count of simulations                                 :" + str(Total_simulation_count)
print "Simulated Frequency - Head               :" + str(total_head_count)
print "Simulated Frequency - Tail:              "  + str(total_tail_count)
print "Estimated Parameter 'p'          :" + str(Parameter_head_estimated)
print "Normalized estimation error     :" + str(Normalized_Estimated_Error)
```

a) **P(head) = 0. 3 and number of Simulation : 10000**

```
Probability of Head                           :0.3
Probability of Tail                           :0.7
Count of simulations                          :10000
Simulated Frequency - Head                     :2964
Simulated Frequency - Tail                    :7036
Error values                                   :0
Estimated Parameter 'p'                       :0.2964
Normalized estimation error                    :0.012
```

b) **P(head) = 0.1 and number of simulation = 10000**

```
Probability of Head                           :0.1
Probability of Tail                           :0.9
Count of simulations                          :10000
Simulated Frequency - Head                    :1046
Simulated Frequency - Tail                    :8954
Error values                                   :0
Estimated Parameter 'p'                       :0.1046
Normalized estimation error                   :0.046
```

c) **P(head) = 0.001 and Number of Simulation = 10000**

```
Probability of Head                           :0.001
Probability of Tail                           :0.999
Count of simulations                          :10000
Simulated Frequency - Head                    :14
Simulated Frequency - Tail                    :9986
Error values                                   :0
Estimated Parameter 'p'                       :0.0014
Normalized estimation error                   :0.4
```

d) **P(head) = 0.0001 and Number of Simulation = 10000**

```
Probability of Head                           :0.0001
Probability of Tail                           :0.9999
Count of simulations                          :10000
Simulated Frequency - Head                    :2
Simulated Frequency - Tail                    :9998
Error values                                  :0
Estimated Parameter 'p'                       :0.0002
Normalized estimation error                   :1.0
```

e) **We can conclude from the experiment that as the probability value of Head decreases, the Normalized estimation error increases. In order to increase the accuracy of the random generator, we need to increase the number of Simulations. For example, for the last simulation, the p(head) input was very low and it resulted in very high error.**

We need to increase the number of simulations to get high accuracies for such low values for P(head).

Example below for P(head) = 0.0001 and Number of Simulations at 1 million. We get lower estimated error

```
Probability of Head                                   :0.0001
Probability of Tail                                   :0.9999
Count of simulations                                  :1000000
Simulated Frequency - Head                            :105
Simulated Frequency - Tail                            :999895
Error values                                          :0
Estimated Parameter 'p'                               :0.000105
Normalized estimation error                           :0.05
```

8)

ORIGINAL FIFO	MODIFIED LIFO
Seed 12345	**Seed 12345**
NUMBER OF CUSTOMERS SERVED 50000	NUMBER OF CUSTOMERS SERVED 50000
SERVER UTILIZATION 0.7073670206785333	SERVER UTILIZATION 0.7073670206785333
MAXIMUM LINE LENGTH 25.0	MAXIMUM LINE LENGTH 25.0
AVERAGE RESPONSE TIME 10.659983459340033 MINUTES	AVERAGE RESPONSE TIME 10.659983459339854 MINUTES
PROPORTION WHO SPEND FOUR MINUTES OR MORE IN SYSTEM 0.69328	PROPORTION WHO SPEND FOUR MINUTES OR MORE IN SYSTEM 0.42614
SIMULATION RUNLENGTH 225436.83125152334 MINUTES	SIMULATION RUNLENGTH 225436.83125152334 MINUTES
NUMBER OF DEPARTURES 50000	NUMBER OF DEPARTURES 50000
NEW AVERAGE INTER-ARRIVAL TIME 4.508730569369282	NEW AVERAGE INTER-ARRIVAL TIME 4.508730569369282
NEW AVERAGE SERVICE TIME 2.807796414776796	ANEW AVERAGE SERVICE TIME 2.807796414776796

Seed: 34321 NUMBER OF CUSTOMERS SERVED 50000 SERVER UTILIZATION 0.7124774000286774 MAXIMUM LINE LENGTH 28.0 AVERAGE RESPONSE TIME 11.268788101248076 MINUTES PROPORTION WHO SPEND FOUR MINUTES OR MORE IN SYSTEM 0.69594 SIMULATION RUNLENGTH 224751.49175994593 MINUTES NUMBER OF DEPARTURES 50000 NEW AVERAGE INTER-ARRIVAL TIME 4.495099679982928 NEW AVERAGE SERVICE TIME 2.823631797995591	**Seed:** 34321 NUMBER OF CUSTOMERS SERVED 50000 SERVER UTILIZATION 0.7124774000286774 MAXIMUM LINE LENGTH 28.0 AVERAGE RESPONSE TIME 11.26860434626455 MINUTES PROPORTION WHO SPEND FOUR MINUTES OR MORE IN SYSTEM 0.42804 SIMULATION RUNLENGTH 224751.49175994593 MINUTES NUMBER OF DEPARTURES 50000 NEW AVERAGE INTER-ARRIVAL TIME 4.495099679982928 NEW AVERAGE SERVICE TIME 2.823631797995591

Seed: 89765 NUMBER OF CUSTOMERS SERVED 50000 SERVER UTILIZATION 0.7086477237325903 MAXIMUM LINE LENGTH 27.0 AVERAGE RESPONSE TIME 10.755953139121653 MINUTES PROPORTION WHO SPEND FOUR MINUTES OR MORE IN SYSTEM 0.69402 SIMULATION RUNLENGTH 224646.43573149716 MINUTES NUMBER OF DEPARTURES 50000 NEW AVERAGE INTER-ARRIVAL TIME 4.4928975744323685 NEW AVERAGE SERVICE TIME 2.7972794128858793	**Seed:** 89765 NUMBER OF CUSTOMERS SERVED 50000 SERVER UTILIZATION 0.7086477237325903 MAXIMUM LINE LENGTH 27.0 AVERAGE RESPONSE TIME 10.755469914320726 MINUTES PROPORTION WHO SPEND FOUR MINUTES OR MORE IN SYSTEM 0.42718 SIMULATION RUNLENGTH 224646.43573149716 MINUTES NUMBER OF DEPARTURES 50000 NEW AVERAGE INTER-ARRIVAL TIME 4.4928975744323685 NEW AVERAGE SERVICE TIME 2.7972794128858793

Seed: 13267 NUMBER OF CUSTOMERS SERVED 50000 SERVER UTILIZATION 0.7123011813494758 MAXIMUM LINE LENGTH 25.0 AVERAGE RESPONSE TIME 11.042370723336418 MINUTES PROPORTION WHO SPEND FOUR MINUTES OR MORE IN SYSTEM 0.69794 SIMULATION RUNLENGTH 224484.73267373623 MINUTES NUMBER OF DEPARTURES 50000 NEW AVERAGE INTER-ARRIVAL TIME 4.489631412539999 NEW AVERAGE SERVICE TIME 2.803462939404701	**Seed:** 13267 NUMBER OF CUSTOMERS SERVED 50000 SERVER UTILIZATION 0.7086477237325903 MAXIMUM LINE LENGTH 27.0 AVERAGE RESPONSE TIME 10.755469914320726 MINUTES PROPORTION WHO SPEND FOUR MINUTES OR MORE IN SYSTEM 0.42718 SIMULATION RUNLENGTH 224646.43573149716 MINUTES NUMBER OF DEPARTURES 50000 NEW AVERAGE INTER-ARRIVAL TIME 4.4928975744323685 NEW AVERAGE SERVICE TIME 2.7972794128858793

Inference, Most of System parameters of the Simulation remained the same for both FIFO and LIFO queue, but we can see that 'Proportion of Customers who spend more than four minutes have decreased due to LIFO queue model.