# IE 306 Systems Simulation
# Assignment 3

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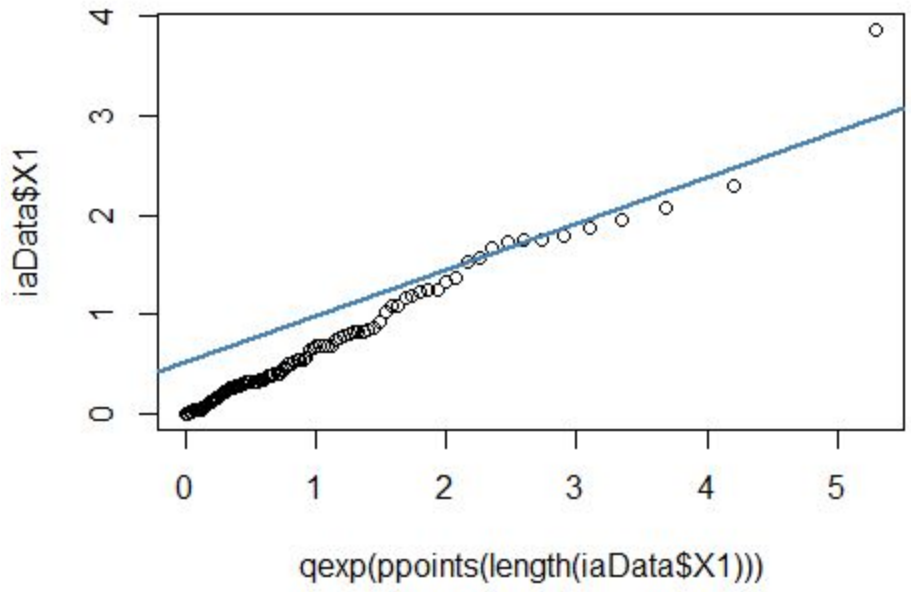
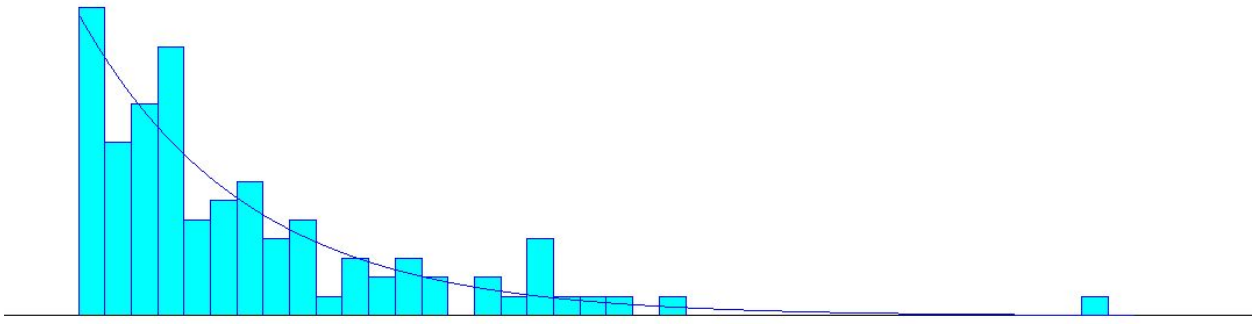
# 1. Fit a distribution to the given inter-arrival times.




As we see from the QQ-Plot above, given inter-arrival times nearly fits exponential distribution. Using the Arena Simulation Software's input analyzer, we confirm this hypothesis. Here is the output of the input analyzer:



Distribution Summary

Distribution: Exponential
Expression: EXPO(0.638)
Square Error: 0.007120

Chi Square Test

| | |
|---|---|
| Number of intervals | = 7 |
| Degrees of freedom | = 5 |
| Test Statistic | = 2.18 |
| Corresponding p-value | > 0.75 |

Kolmogorov-Smirnov Test

| | |
|---|---|
| Test Statistic | = 0.0506 |
| Corresponding p-value | > 0.15 |

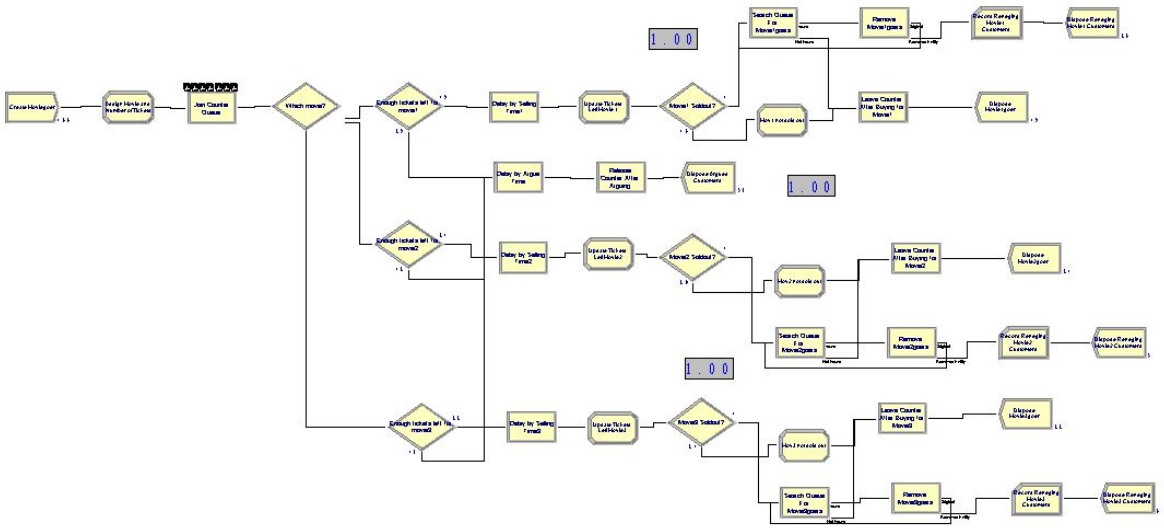
Data Summary

| | |
|---|---|
| Number of Data Points | = 100 |
| Min Data Value | = 0.002 |
| Max Data Value | = 3.87 |
| Sample Mean | = 0.638 |
| Sample Std Dev | = 0.643 |

Histogram Summary

| | |
|---|---|
| Histogram Range | = 0 to 4 |
| Number of Intervals | = 40 |

## 2. The sample model is built for a 2-movie case. Modify it for the 3-movie case as described above.






## 3. Simulate the base scenario for thirty independent replications and collect relevant statistics. Create confidence intervals for the collected statistics at a confidence level of 95%.

**Average time before the movie is sold out:**

**Time Persistent**

| Variable | Average | Half Width | Minimum Average | Maximum Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| LastTicket | 40.6627 | 1,98 | 30.2000 | 55.3595 | 0.00 | 103.62 |
| LastTicket2 | 44.1604 | 2,09 | 30.8750 | 53.9550 | 0.00 | 100.14 |
| LastTicket3 | 41.6867 | 2,36 | 25.9500 | 52.1890 | 0.00 | 82.4201 |

In our model, we updated lastTicket variable to current time everytime a ticket is sold. So, average time before the movie is sold out is the maximum average for each movie in the statistics above.

**95% confidence interval:**
Movie 1: 55.3595+-1.98
Movie 2: 53.9550+-2.09
Movie 3: 52.1890+-2.36

**Average number of people reneged when the movie is sold out:**

| Count | Average | Half Width | Minimum Average | Maximum Average |
|---|---|---|---|---|
| Record Reneging Movie1 Customers | 16.3667 | 4,87 | 0.00 | 41.0000 |
| Record Reneging Movie2 Customers | 13.4667 | 4,81 | 0.00 | 50.0000 |
| Record Reneging Movie3 Customers | 16.8000 | 5,03 | 0.00 | 47.0000 |

**95% confidence interval:**
Movie 1: 16.3667+-4.87
Movie 2: 13.4667+-4.81
Movie 3: 16.8000+-5.03

**Utilization of the personnel who is selling the tickets:**

| Instantaneous Utilization | Average | Half Width | Minimum Average | Maximum Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| counter | 0.9867 | 0,01 | 0.9282 | 1.0000 | 0.00 | 1.0000 |

**95% confidence interval:**
Counter: 0.9867+-0.01

## 4. Increase the counter capacity to three, and dedicate each counter to a movie. One personnel will be assigned to each counter, and a counter will sell tickets of a single movie. Arriving customers are assumed to know which queue to join. For all practical purposes the counter service is identical and takes one minute. Make thirty independent replications. Create confidence intervals for the collected statistics at a confidence level of 95%.

**average time before the movie is sold out:**

**Time Persistent**

| Variable | Average | Half Width | Minimum Average | Maximum Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| lastTicket | 29.9613 | 2.35 | 21.6847 | 52.0150 | 0.00 | 81.3682 |
| lastTicket2 | 31.5259 | 1.82 | 20.1381 | 42.6712 | 0.00 | 57.5224 |
| lastTicket3 | 30.4838 | 2.43 | 16.8381 | 47.6872 | 0.00 | 69.6547 |

In our model, we updated lastTicket variable to current time everytime a ticket is sold.So, average time before the movie is sold out is maximum average for each movie in statistics above.

**Confidence interval>>>**

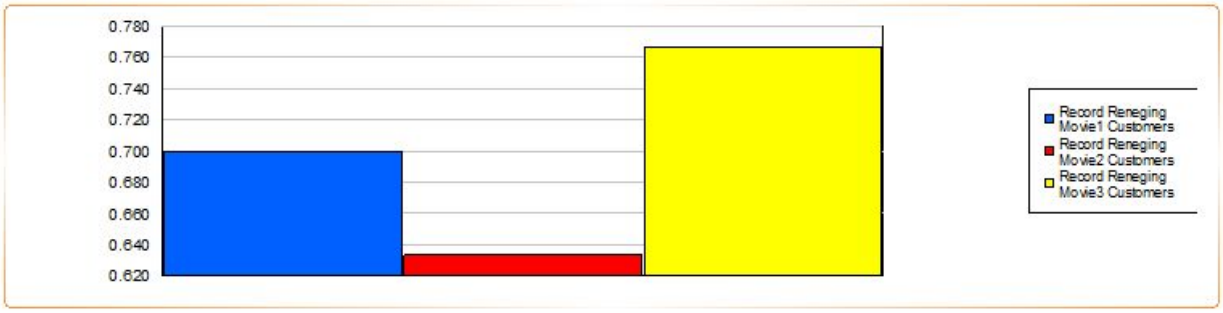
Movie1: 29.9613+-2.35

Movie2: 31.5259+-1.82

Movie3: 30.4838+-2.43

**average number of people reneged when the movie is sold out:**

| Count | Average | Half Width | Minimum Average | Maximum Average |
|---|---|---|---|---|
| Record Reneging Movie1 Customers | 0.7000 | 0.39 | 0.00 | 4.0000 |
| Record Reneging Movie2 Customers | 0.6333 | 0.29 | 0.00 | 2.0000 |
| Record Reneging Movie3 Customers | 0.7667 | 0.42 | 0.00 | 5.0000 |




**Confidence interval>>>**

Movie1: 0.7+-0.39

Movie2: 0.6333+-0.29

Movie3: 0.7667+-0.42

**utilization of the personnel who is selling the tickets:**

| Instantaneous Utilization | Average | Half Width | Minimum Average | Maximum Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| counter | 0.5370 | 0.03 | 0.3583 | 0.7433 | 0.00 | 1.0000 |
| counter2 | 0.5121 | 0.02 | 0.3583 | 0.6260 | 0.00 | 1.0000 |
| counter3 | 0.4972 | 0.03 | 0.3083 | 0.6167 | 0.00 | 1.0000 |

**Confidence interval>>>**
Counter1:0.5370+-0.03
Counter2:0.5121+-0.02
Counter3:0.4972+-0.03

# 5. Increase the inter-arrival rate you have found from part (1) by %50 and repeat the analysis of steps 2-4.

## 5.2- We modified it for the 3-movie case.

## 5.3-

**Average time before the movie is sold out:**

**Time Persistent**

| Variable | Average | Half Width | Minimum Average | Maximum Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| LastTicket | 40.6074 | 1,94 | 30.2000 | 50.4850 | 0.00 | 83.1013 |
| LastTicket2 | 42.6184 | 1,96 | 30.8750 | 52.6083 | 0.00 | 84.0000 |
| LastTicket3 | 41.3237 | 2,31 | 25.9500 | 50.9083 | 0.00 | 89.0000 |

In our model, we updated lastTicket variable to current time everytime a ticket is sold. So, average time before the movie is sold out is the maximum average for each movie in the statistics above.

**95% confidence interval:**
Movie 1: 50.4850+-1.94
Movie 2: 52.6083+-1.96
Movie 3: 50.9083+-2.31

**Average number of people reneged when the movie is sold out:**

| Count | Average | Half Width | Minimum Average | Maximum Average |
|---|---|---|---|---|
| Record Reneging Movie1 Customers | 39.4000 | 11,18 | 1.0000 | 91.0000 |
| Record Reneging Movie2 Customers | 25.0000 | 8,99 | 0.00 | 86.0000 |
| Record Reneging Movie3 Customers | 43.0000 | 10,75 | 0.00 | 96.0000 |

**95% confidence interval:**
Movie 1: 39.4+-11.18
Movie 2: 25.0+-8.99
Movie 3: 43.0+-10.75

**Utilization of the personnel who is selling the tickets:**

| Instantaneous Utilization | Average | Half Width | Minimum Average | Maximum Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| counter | 0.9974 | 0,00 | 0.9857 | 1.0000 | 0.00 | 1.0000 |

**95% confidence interval:**
Counter: 0.9974+-0.00

# 5.4-

**average time before the movie is sold out:**

**Time Persistent**

| Variable | Average | Half Width | Minimum Average | Maximum Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| lastTicket | 22.8153 | 1.71 | 17.5054 | 41.4170 | 0.00 | 54.5788 |
| lastTicket2 | 23.5677 | 1.36 | 15.9402 | 32.0230 | 0.00 | 38.6816 |
| lastTicket3 | 23.2522 | 1.81 | 14.9692 | 36.8857 | 0.00 | 46.7698 |

**Confidence interval>>>**
Movie1: 41.4170+-1.71
Movie2: 32.0230+-1.36
Movie3: 36.8857+-1.81

**average number of people reneged when the movie is sold out:**

| Count | Average | Half Width | Minimum Average | Maximum Average |
|---|---|---|---|---|
| Record Reneging Movie1 Customers | 1.5000 | 0.54 | 0.00 | 6.0000 |
| Record Reneging Movie2 Customers | 1.5667 | 0.59 | 0.00 | 6.0000 |
| Record Reneging Movie3 Customers | 1.9000 | 0.86 | 0.00 | 10.0000 |


**Confidence interval>>>**

Movie1: 1.5+-0.54

Movie2: 1.5667+-0.59

Movie3: 1.9+-0.86

**utilization of the personnel who is selling the tickets:**

| Instantaneous Utilization | Average | Half Width | Minimum Average | Maximum Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| counter | 0.7814 | 0.03 | 0.5755 | 0.9621 | 0.00 | 1.0000 |
| counter2 | 0.7552 | 0.03 | 0.5767 | 0.8968 | 0.00 | 1.0000 |
| counter3 | 0.7286 | 0.03 | 0.5640 | 0.9149 | 0.00 | 1.0000 |

**Confidence interval>>>**

Counter1:0.7814+-0.03

Counter2:0.7552+-0.03

Counter3:0.7286+-0.03

## 6. Under the conditions of step 5, can you have the counters open for only 60 minutes instead of 120 minutes?

**Time Persistent**

| Variable | Average | Half Width | Minimum Average | Maximum Average | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|
| lastTicket | 22.8153 | 1.71 | 17.5054 | 41.4170 | 0.00 | 54.5788 |
| lastTicket2 | 23.5677 | 1.36 | 15.9402 | 32.0230 | 0.00 | 38.6816 |
| lastTicket3 | 23.2522 | 1.81 | 14.9692 | 36.8857 | 0.00 | 46.7698 |

Since maximum value never exceed 60 minutes, we can have the counters open for only 60 minutes instead of 120 minutes.