IE 306.02 Simulation Assignment 3 Report

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Contents

1 Introduction **2**
1.1 Description . . . 2
1.2 Asuumptions . . . 2

2 Simulation Logic **2**

3 Analysis **3**
3.1 Question 1 . . . 3
3.1.1 Description . . . 3
3.1.2 Results . . . 3
3.2 Question 2-3 . . . 4
3.2.1 Description . . . 4
3.2.2 Results . . . 4
3.3 Interpretations . . . 4
3.4 Question 4 . . . 5
3.4.1 Description . . . 5
3.4.2 Results . . . 5
3.5 Interpretations . . . 5
3.6 Question 5 . . . 6
3.6.1 Description . . . 6
3.6.2 Results from steps 2 and 3 . . . 6
3.6.3 Interpretations for steps 2 and 3 . . . 6
3.6.4 Results from step 4 . . . 6
3.6.5 Interpretations for step 4 . . . 7
3.7 Question 6 . . . 7
3.7.1 Description . . . 7
3.7.2 Results . . . 7

1 Introduction

In this simulation, we are assigned to simulate moviegoers in a local cinema using ARENA tool.

1.1 Description

The cinema has three theaters showing science fiction movies "Captain Marvel", "Captive State" and "Avengers: Endgame". Each theater can hold 50 people. People arrive at the cinema at random times. The inter-arrival times (in minutes) are given us in a data sheet and we will use this data to fit a distribution to the common arrival process. There is a single counter that sells tickets for all three films. People line up in a single queue in front of the counter. If they arrive at the counter they try to buy a random number of tickets distributed as uniform integer between [1–4] for a randomly chosen movie with equal probability. If not enough tickets are left, they argue with the teller for a fixed amount of time and leave. If at most one ticket is left after the moviegoer bought her tickets, the "sold out" event for this movie is triggered. When a movie is sold out, all people waiting to buy a ticket for that movie renege (leave the queue). The counter stays open for 120 minutes before the films start showing and it is observed that the counter service time shows no variability and can be taken to be a constant of one minute per customer. The statistics to collect are: for each movie, average time before the movie is sold out, average number of people reneged when the movie is sold out, and utilization of the personnel who is selling the tickets.

1.2 Asuumptions

- Counter service time has been used as in description and set to 1 minute
- In the descripton, it says "if at most one ticket left, raise **sold out**". Therefore, it 3 tickets left and customer demands 3 tickets, she/he can get tickets and the theatre will raise sold out. However, if only 1 ticket left, she/he cannot get ticket, even if she/he demands only one ticket, since theater tickets are already sold out.
- If not enough tickets are left, moviegoer will argue with the teller for a 0.5 minute

2 Simulation Logic

After we found distribution from step-1, **EXPO(0.638)**, we have used it from other steps for inter-arrival times. In the template, there were 2 branches after module "which movie", so we have added another branch to it. We have set variables for each tickets as 50. At beginning we use more randoms, one for which movie with 1/3 chance for each movie and the other one for number of

tickets customer demands in [1,4] as integer. We then set run time as 120 min from run settings. We then put a counter for all movies to raise **Sold Out** and renege people in the queue. After the purchase of last person before "Sold Out", system searches queue for this movie and reneges them. We put one minute delay for each ticket purchase. If not enough ticket left, customer will argue with the teller for 0.5 min. We will add another attribute for getting last minute before "Sold Out", it will be updated only when customer buys ticket so that last person will be the last to update it for current time and we will obtain this data.

Question 3 $->$ We will set repetition to 30 in the run settings.

Question 4 $->$ Queue will be shifted to after the "Which Movie" model, and one three for each branch will be added.

Question 5 $->$ Our distribution **EXPO(0.638)** has parameter 0.638 as mean so we will decrease it to obtain 50% increase in the inter-arrival rate. We will multiply 0.638 by 2/3 and result will be 0.425333. We will repeat steps in the Question 3 and Question 4 but this time we will use **EXPO(0.425333)** for inter-arrival time distribution.

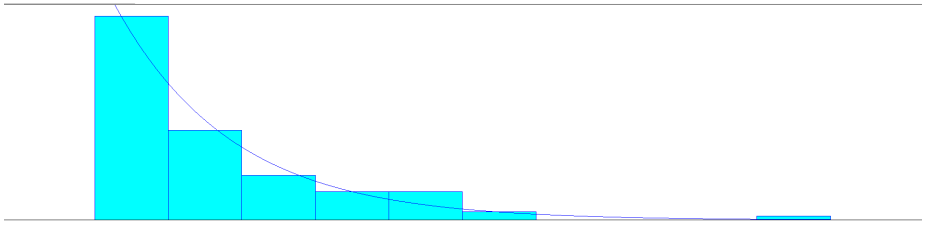
3 Analysis

3.1 Question 1

3.1.1 Description

We are asked to fit a distribution to the given inter-arrival times in data sheet.

3.1.2 Results



Distribution Summary

Distribution: Exponential
Expression: EXPO(0.638)
Square Error: 0.003780

Chi Square Test
Number of Intervals = 4
Degrees of Freedom = 2
Test Statistic = 2.12
Corresponding p-value = 0.365

Kolmogorov-Smirnov Test
Test Statistic = 0.0596
Corresponding p-value > 0.15

Data Summary

Number of Data Points = 100
Min Data Value = 0.002
Max Data Value = 3.57
Sample Mean = 0.638
Sample Std Dev = 0.643

Histogram Summary

Histogram Range = 0 to 4
Number of Intervals = 10

After using fit, we have found best fit is BETA distribution. However, as we can see in question 5, changing rate in BETA distribution is not easy so that we have switched to exponential distribution and it is given as **EXPO(0.638)**

3.2 Question 2-3

Code file $->$ "Q3 Code.doe"

3.2.1 Description

First, we are asked to change sample model for a 2-movie case and modify it for the 3-movie case as described in Introduction(Q1). Then simulate it for thirty independent replications and collect relevant statistics. Create confidence intervals for the collected statistics at a confidence level of 95%.

Relevant statistics to collect for each movie:

1. Average time before the movie is sold out
2. Average number of people reneged when the movie is sold out
3. Utilization of the personnel who is selling the tickets

3.2.2 Results

Utilization of the personnel(All Movies)
Average $->$ 88.70%
Half-width $->$ 2%
Confidence interval(95%) $->$ $86.70\% < x < 90.70\%$

Movie	Time before the movie is sold out			Number of people reneged when the movie is sold out		
	Average	Half-width	Confidence Interval(95%)	Average	Half-width	Confidence Interval(95%)
Movie 1	58.7049	3.67	55.0349 <x <62.3749	11.7667	5.10	6.6667 <x <16.8667
Movie 2	61.0060	3.94	57.066 <x <64.946	9.6667	3.62	6.0467 <x <13.2867
Movie 3	57.1458	4.11	53.0358 <x <61.2558	12.8667	4.60	8.2667 <x <17.4667

Table 1: Single counter case with initial inter-arrival rate

3.3 Interpretations

Utilization of personnel looks high, that means personnel almost never stops working for customers that may result in long queues. For "sold out" case, we can see that almost all movie ticket sales ends before 60, after 60 almost all of the customers cannot buy ticket and they waste their time with arguing personnel.

3.4 Question 4

Code file $->$ "Q4 Code.doe"

3.4.1 Description

We are asked to 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%.

3.4.2 Results

Utilization of the personnel(Movie-1)
Average $->$ 35.09%
Half-width $->$ 1%
Confidence interval(95%) $->$ $34.09\% < x < 36.09\%$

Utilization of the personnel(Movie-2)
Average $->$ 33.96%
Half-width $->$ 1%
Confidence interval(95%) $->$ $32.96\% < x < 34.96\%$

Utilization of the personnel(Movie-3)
Average $->$ 33.30%
Half-width $->$ 1%
Confidence interval(95%) $->$ $33.20\% < x < 35.30\%$

Movie	Time before the movie is sold out			Number of people reneged when the movie is sold out		
	Average	Half-width	Confidence Interval(95%)	Average	Half-width	Confidence Interval(95%)
Movie 1	39.2858	4.08	35.2058 <x <43.3658	0.7667	0.38	0.3867 <x <1.1467
Movie 2	41.0442	2.99	38.0542 <x <44.0342	0.7	0.28	0.42 <x <0.98
Movie 3	39.8939	4.10	35.7939 <x <43.9939	0.7333	0.44	0.2933 <x <1.1733

Table 2: Three counter case with initial inter-arrival rate

3.5 Interpretations

Utilization of all personnel looks lower than one queue case so shorter queues will be for each movie. For "sold out" case, we can see that almost all movie ticket sales ends earlier than previous case. And less people will be reneged in three capacity queue case because 3 times faster more customer can be handled in this case.

3.6 Question 5

Code file for steps 2-3− > "Q5-1 Code.doe" Code file for step 4− > "Q5-2 Code.doe"

3.6.1 Description

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

3.6.2 Results from steps 2 and 3

Utilization of the personnel(All Movies)
Average − > 98.83%
Half-width − > 0%
Confidence interval(95%) − > $98.83\% \leq x \leq 98.83\%$

Movie	Time before the movie is sold out			Number of people reneged when the movie is sold out		
	Average	Half-width	Confidence Interval(95%)	Average	Half-width	Confidence Interval(95%)
Movie 1	57.0071	3.19	53.8171 <x <60.1971	30.9	10.89	20.01 <x <41.79
Movie 2	58.9912	3.28	55.7112 <x <62.2712	21.3	9.93	11.37 <x <31.23
Movie 3	56.3489	3.86	52.4889 <x <60.2089	30.2667	9.93	19.2567 <x <41.2767

Table 3: Single counter case with increased inter-arrival rate

3.6.3 Interpretations for steps 2 and 3

Utilization of the personnel looks almost perfect, that will result in longer queues and more people to be reneged after sold out. For "sold out" case, we can see that almost all movie ticket sales ends a bit earlier than previous case. Therefore, there is not need for increasing customer arrival rate since it has already reached its boundary. Again, all cinemas sold out before 60.

3.6.4 Results from step 4

Utilization of the personnel(Movie-1)
Average − > 47.64%
Half-width − > 2%
Confidence interval(95%) − > $45.64\% < x < 49.64\%$

Utilization of the personnel(Movie-2)
Average − > 46.57%
Half-width − > 2%
Confidence interval(95%) − > $44.57\% < x < 48.57\%$

Utilization of the personnel(Movie-3)
Average $->$ 45.31%
Half-width $->$ 2%
Confidence interval(95%) $->$ $43.31\% < x < 47.31\%$

Movie	Time before the movie is sold out			Number of people reneged when the movie is sold out		
	Average	Half-width	Confidence Interval(95%)	Average	Half-width	Confidence Interval(95%)
Movie 1	27.6217	2.55	25.0717 <x <30.1717	1.7333	0.66	1.0733 <x <2.3933
Movie 2	28.5943	1.86	26.7343 <x <30.4543	1.5	0.53	0.97 <x <2.03
Movie 3	28.03	2.56	25.47 <x <30.59	1.8	0.83	0.97 <x <2.63

Table 4: Three counter case with increased inter-arrival rate

3.6.5 Interpretations for step 4

Utilization of all personnel looks higher than previous three capacity case, so longer queues will happen but still not too many people will get reneged. For "sold out" case, we can see that almost all movie ticket sales ends earlier than previous cases even before 30 min.

3.7 Question 6

3.7.1 Description

Under the conditions of step 5, can we have the counters open for only 60 minutes instead of 120 minutes?

3.7.2 Results

As we can see from previous interpretations, almost in all cases all cinema theatres raise "Sold Out" before 60. Under the conditions of step 5, case is more clear.

For single counter case, in general we should keep counters open for only 60 minutes because after that time people will generally arrive and argue with the personnel nothing more. We see from the report that sold-out time for each movie is less than 60 on the average. Therefore, it means that if a single counter works for only 60 minutes, on the average, each movie is sold-out. However, from the report, we see that maximum value of sold-out times are 80.2842 for movie 1, 74.8672 for movie 2 and 76.5 for movie 3. This means in some cases, there will be movie theaters that aren't sold-out, if we keep counter open for 60 minutes.

For 3-counter case, we better keep counters open for only 60 minutes because after that time people will arrive and argue with the personnel nothing more. As we see from report, the maximum values of sold-out times for each movie and 30 different repetitions are less than 60. Therefore, we can conclude that each movie will be sold-out before 60th minute, and the probability that sold-out

time of a movie is greater than 60 minute is really small. Therefore, we must keep counters open for only 60 minutes.

In general, even with single and multiple counter case, we think that we should keep counter(s) open for only 60 minutes, so that Personnel will be paid for only 60 min instead of 120 min.