ENM 307-SIMULATION

2018-2019 SPRING TERM

FINAL REPORT

Group-4

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PROCESS

Our plant name is Ziraat Bank. This bank is one of biggest banks in Turkish Republic. T.C Ziraat Bank was found in the Ottoman Empire, Ziraat Bank was made an incorporated company under the budget law. Growing of Ziraat Bank was started with opening Hamburg agency and 3 branches in Cyprus in 1975.

The branch of that we observed is Ziyapaşa branch of Eskişehir. Branch address is Kurtuluş ST. Ziya Paşa AVE. No:49A 26100 Odunpazarı/Eskişehir.Labor time is 8.5 hours from 09.00 a.m. to 17.30 p.m. and there is no service at the weekend. we took our observations between 1 and 5 o'clock. There are 1 security employee, 4 servers,2 individual servers, 8 workers ,2 manager and 2 cleaning employees in this bank. And there are two types of customer that normal (teller's department customer) and individual customer. The customers enter the bank and take the queue number and wait their turn.

This project is about a bank simulation at Ziraat Bank and the objective of this study is to determine if current systems could be better or not. Our study aims to reduce number of waiting customer and total waiting time of each customer on the queue in the bank.

DATA AVAILABLE AND ANALYSIS

Firstly, we analysed inter-arrival times and service times at different periods for different types of customer. At the following table, there are observation dates and times for individual customers. In fact, working time of the bank is between 9:00 to 17:30. But we generally observed the Türkiye Ziraat Bank's data in afternoons (because of lessons at university). Their inter-arrival times and service times are observed and they are saved to excel page.

Observation Dates	Observation Times	Number of Individual Customers
26.02.2019	13:30-17:00	15
11.03.2019	11:30-12:30+13:30-17:30	23
22.03.2019	13:30-16:15	11
26.03.2019	11:50-12:30+13:30-17:30	19
28.03.2019	15:00-17:00	7
5.04.2019	14:00-16:10	8
10.04.2019	15:00-16:30	5
12.04.2019	13:30-16:50	14
Total		102

Secondly, at the following table there are observation dates for customer that came for teller's department. Observation times are almost the same with individual customers'. Also, observations are taken by different students. We analysed distribution of each type of customer's inter arrival times and service times via Arena Input Analyzer. These results are at the following pages.

Observation Dates	Number of Teller's Department Customer
26.02.2019	82
11.03.2019	120
22.03.2019	89
26.03.2019	101
28.03.2019	63
5.04.2019	77
10.04.2019	26
12.04.2019	84
Total	642

Missing Data and Assumptions About Missing Data

We could not get the average arriving people during the all day. We know that during the period 13.00-17.30 in the bank and we continued observations as we showed above excel table. Since, we can not count total people that came to bank all day, We took our observations afternoon. And we did not take any observation at morning.
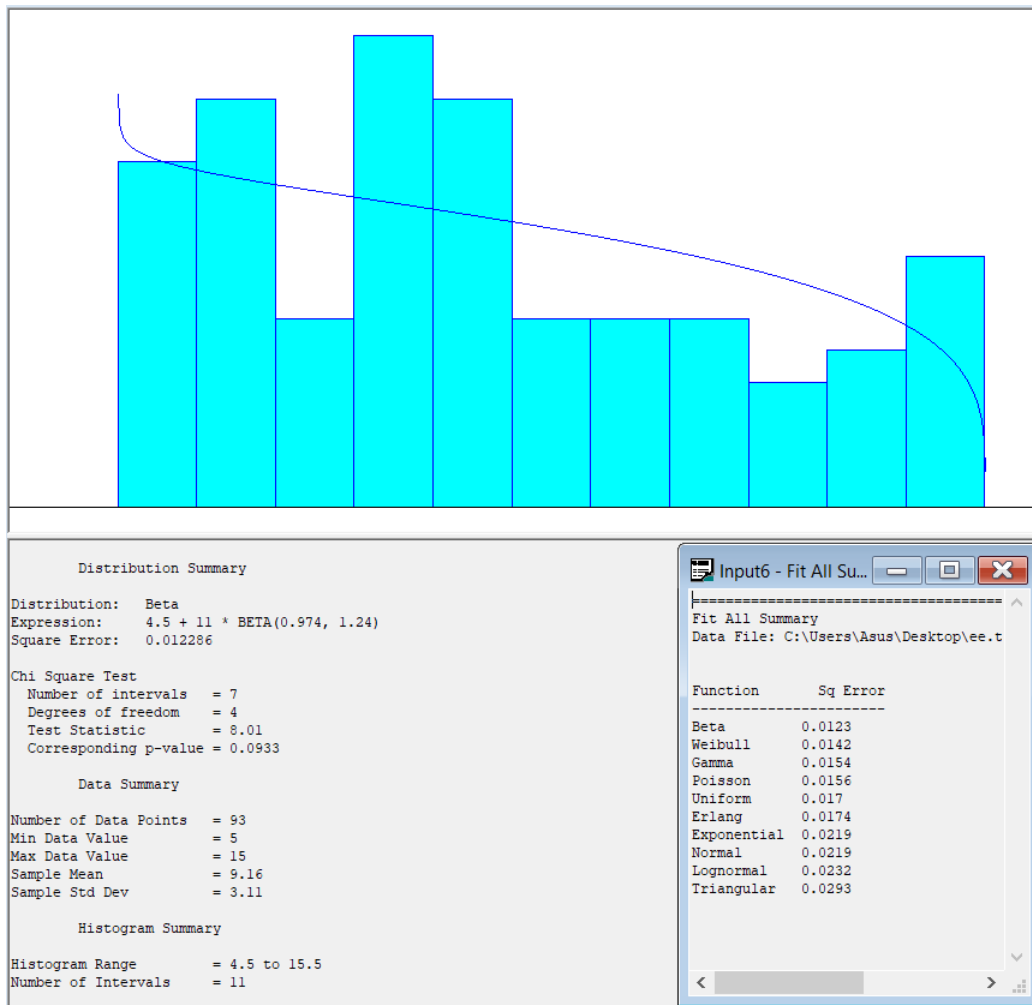
Results of Input Data Analysis

We analysed distribution of each type of customer's inter-arrival times and service times via Arena Input Analyzer. The distribution results are as it follows:

Inter-arrival times for individual customers distribution fit= =4.5+11*BETA (0.97, 1.24)

Service time distribution for Booth = 4.5+21*BETA (1.12,1.25)

FOR INDIVIDUAL CUSTOMERS

Inter-arrival Time


```
        Distribution Summary

Distribution:   Beta
Expression:     4.5 + 11 * BETA(0.974, 1.24)
Square Error:   0.012286

Chi Square Test
  Number of intervals   = 7
  Degrees of freedom    = 4
  Test Statistic        = 8.01
  Corresponding p-value = 0.0933

        Data Summary

Number of Data Points   = 93
Min Data Value          = 5
Max Data Value          = 15
Sample Mean             = 9.16
Sample Std Dev          = 3.11

        Histogram Summary

Histogram Range         = 4.5 to 15.5
Number of Intervals     = 11
```

```
Input6 - Fit All Su...

================================
Fit All Summary
Data File: C:\Users\Asus\Desktop\ee.t


Function      Sq Error
-----------------------
Beta          0.0123
Weibull       0.0142
Gamma         0.0154
Poisson       0.0156
Uniform       0.017
Erlang        0.0174
Exponential   0.0219
Normal        0.0219
Lognormal     0.0232
Triangular    0.0293
```

Hypotheses:

H_0: Sample data is fitted to Beta Distribution
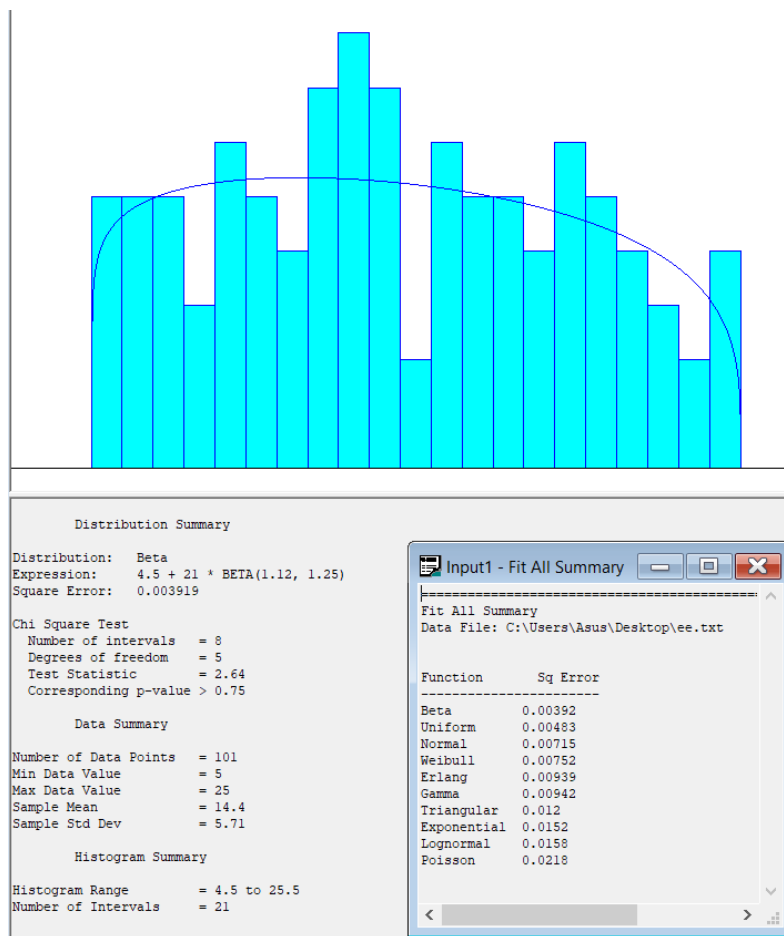
$H\alpha$: Sample data is not fitted to Beta Distribution

Test Statistics:

P-Value 0.0933> 0.05 it also satisfies this condition in %95 confidence interval.

H_0 cannot be rejected which means data is fitted to Beta Distribution.

Also, since we have lowest Square Error in Beta comparing with the other functions, we can conclude that this data is fitted.

Service Time


```
        Distribution Summary

Distribution:   Beta
Expression:     4.5 + 21 * BETA(1.12, 1.25)
Square Error:   0.003919

Chi Square Test
  Number of intervals   = 8
  Degrees of freedom    = 5
  Test Statistic        = 2.64
  Corresponding p-value > 0.75

         Data Summary

Number of Data Points   = 101
Min Data Value          = 5
Max Data Value          = 25
Sample Mean             = 14.4
Sample Std Dev          = 5.71

        Histogram Summary

Histogram Range         = 4.5 to 25.5
Number of Intervals     = 21
```

Input1 - Fit All Summary

```
==========================================
Fit All Summary
Data File: C:\Users\Asus\Desktop\ee.txt


Function      Sq Error
-----------------------
Beta          0.00392
Uniform       0.00483
Normal        0.00715
Weibull       0.00752
Erlang        0.00939
Gamma         0.00942
Triangular    0.012
Exponential   0.0152
Lognormal     0.0158
Poisson       0.0218
```

Hypotheses:

H_0: Sample data is fitted to Beta Distribution

$H\alpha$: Sample data is not fitted to Beta Distribution

Test Statistics:

P-Value 0.75> 0.05 it also satisfies this condition in %95 confidence interval.

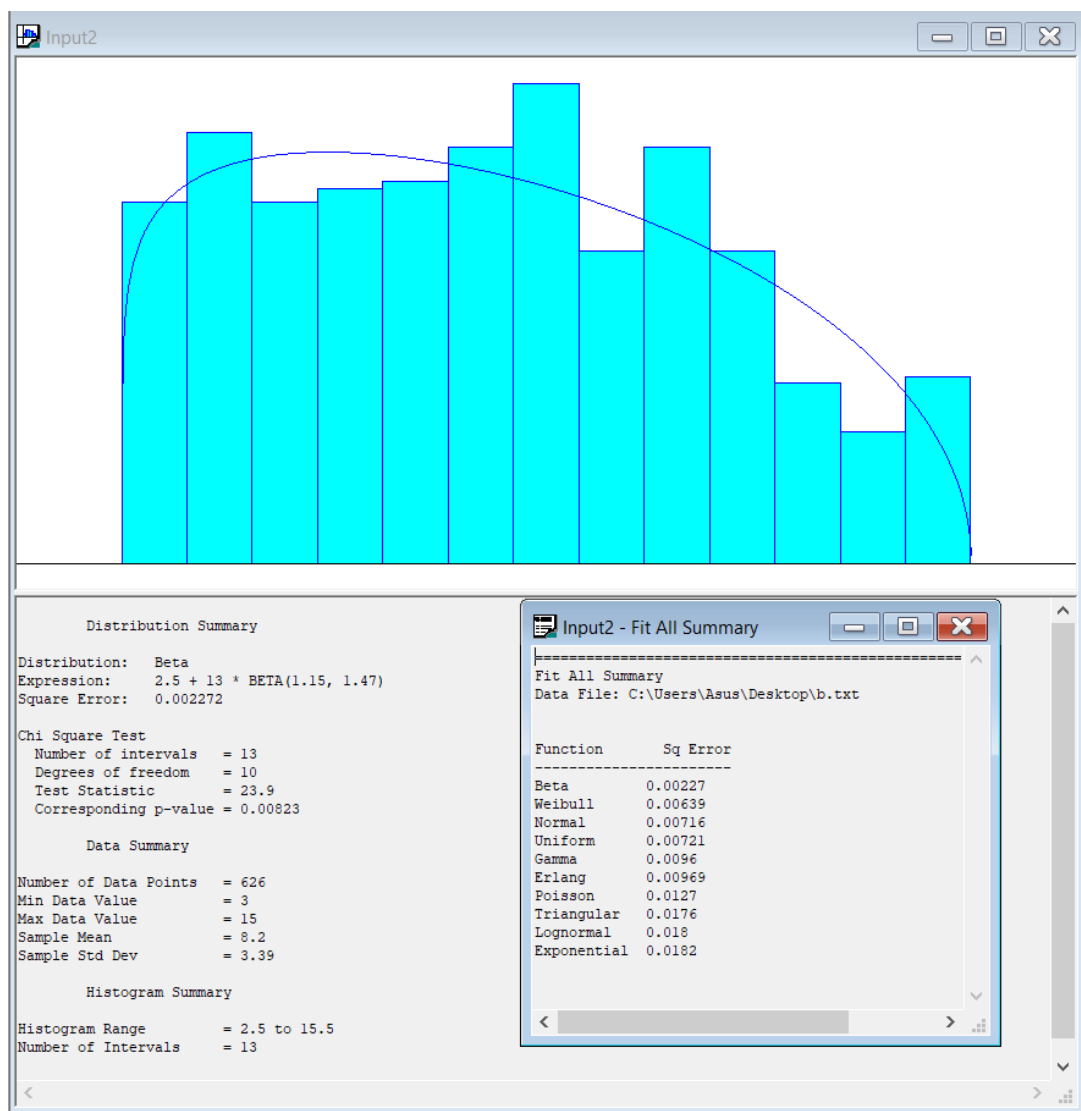H_0 cannot be rejected which means data is fitted to Beta Distribution.

Also, since we have lowest Square Error in Beta comparing with the other functions, we can conclude that this data is fitted.

Inter-arrival times for teller's department customers distribution fit= =2.5+13*BETA (1.15, 1.47)

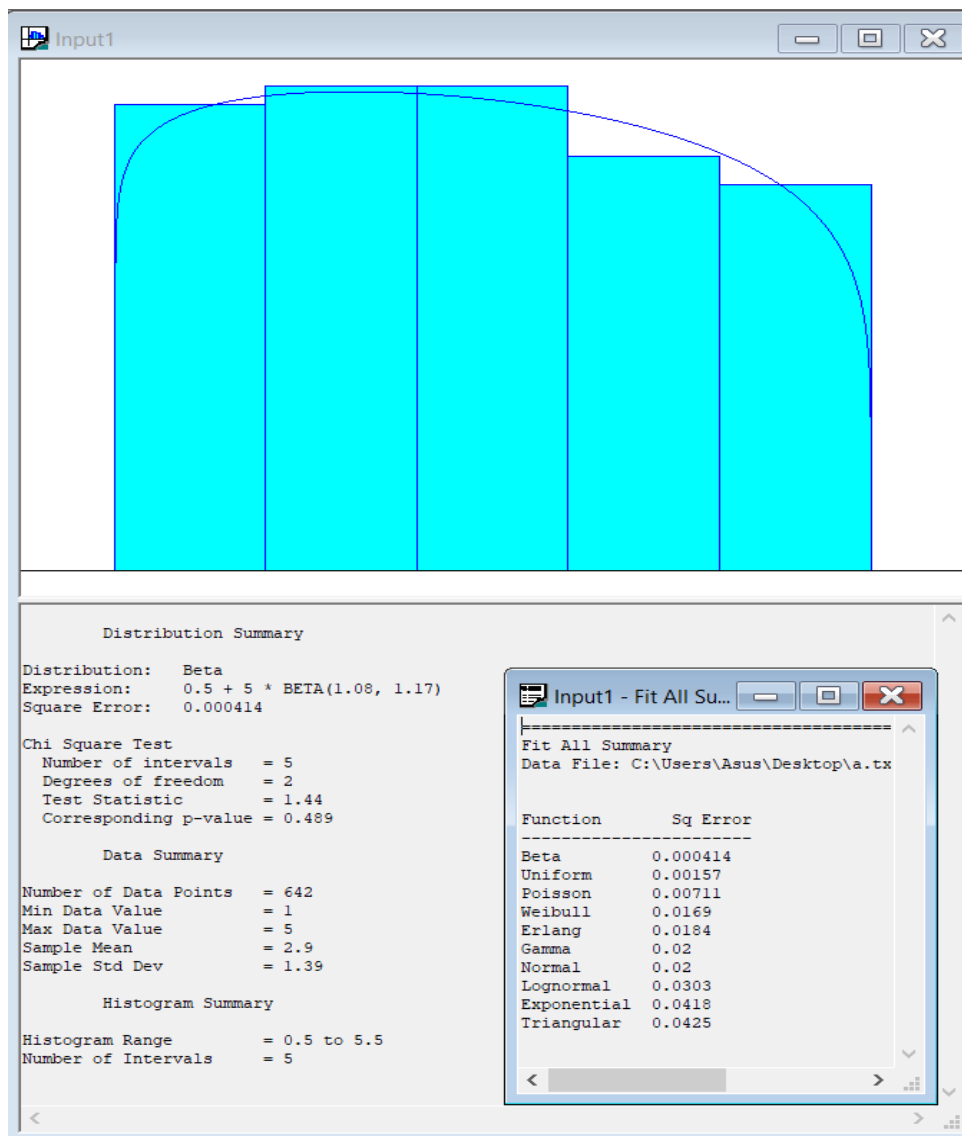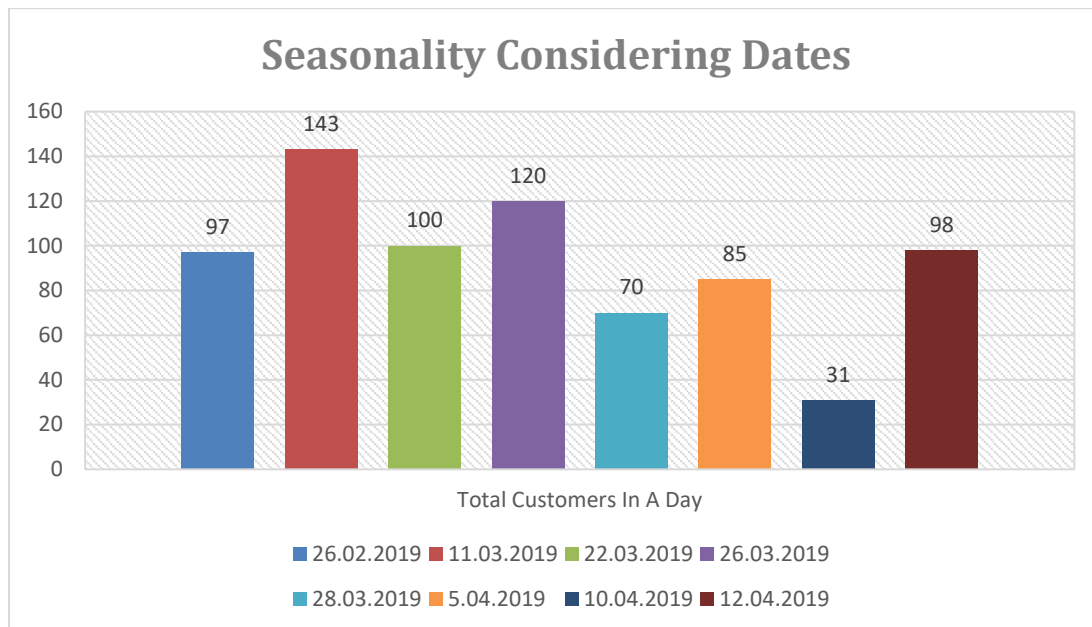Service time distribution for Booth = 0.5+5*BETA (1.08,1.17)

FOR TELLER'S DEPARTMENT CUSTOMERS

Inter-Arrival

We have lowest Square Error in Beta comparing with the other functions, we can conclude that this data is fitted to Beta distribution.

Service Time


```
        Distribution Summary

Distribution:    Beta
Expression:      0.5 + 5 * BETA(1.08, 1.17)
Square Error:    0.000414

Chi Square Test
  Number of intervals   = 5
  Degrees of freedom    = 2
  Test Statistic        = 1.44
  Corresponding p-value = 0.489

        Data Summary

Number of Data Points   = 642
Min Data Value          = 1
Max Data Value          = 5
Sample Mean             = 2.9
Sample Std Dev          = 1.39

        Histogram Summary

Histogram Range         = 0.5 to 5.5
Number of Intervals     = 5
```

```
Input1 - Fit All Su...
===================================
Fit All Summary
Data File: C:\Users\Asus\Desktop\a.tx


Function      Sq Error
-----------------------
Beta          0.000414
Uniform       0.00157
Poisson       0.00711
Weibull       0.0169
Erlang        0.0184
Gamma         0.02
Normal        0.02
Lognormal     0.0303
Exponential   0.0418
Triangular    0.0425
```

Hypotheses:

H$_0$: Sample data is fitted to Beta Distribution

Hα: Sample data is not fitted to Beta Distribution

Test Statistics:

P-Value 0.489> 0.05 it also satisfies this condition in %95 confidence interval.

H$_0$ cannot be rejected which means data is fitted to Beta Distribution.

Also, since we have lowest Square Error in Beta comparing with the other functions, we can conclude that this data is fitted.

Discussing Seasonality

With this graph it can be seen that our data has seasonality. The biggest number of customers are coming on Monday. It can be also concluded that the busiest day for the bank is Monday.
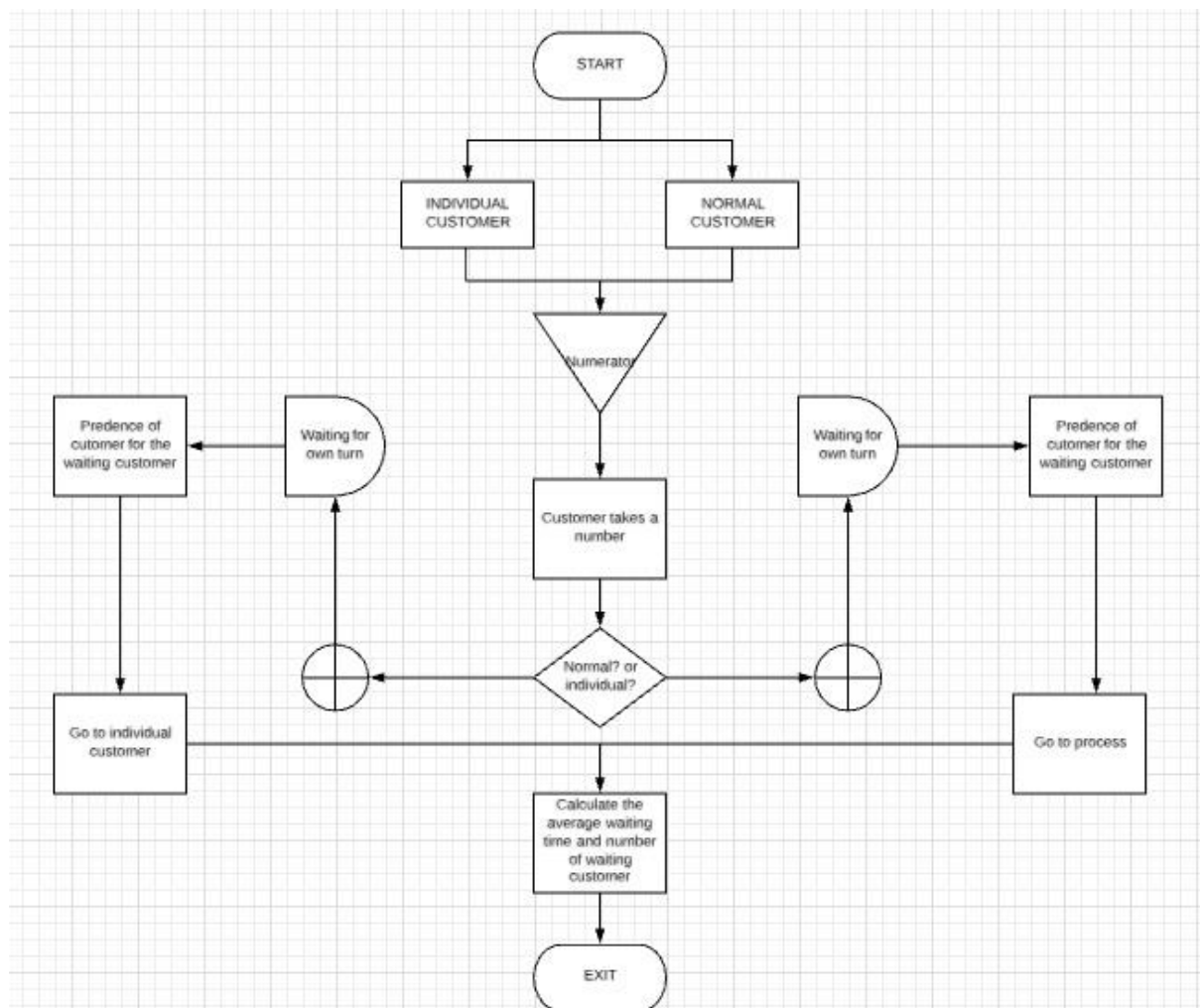

Seasonality Considering Dates

Total Customers In A Day

Legend: 26.02.2019, 11.03.2019, 22.03.2019, 26.03.2019, 28.03.2019, 5.04.2019, 10.04.2019, 12.04.2019

Seasonilty Considering Days

Tuesday, Monday, Friday, Tuesday, Thursday, Friday, Wednesday, Friday

Total Customers In A Day

Modelling Assumptions And The Model

In the current system, 4 teller employees and 2 individual customer services employees are available. However, when we go to the bank to get the observation, we see that there are 2 teller employees and 1 individual customer services employee in the bank because when the bank is too busy , other employees(the other 2 teller employees and 1 individual customer services employee) are involved in the system. For this reason, despite of 4 teller employees and 2 individual customer services employees are available in fact , we assume that there are 2 teller employees and 1 individual customer services employee in the bank for our observations. Another assumption is that when the customers come to the bank, they don't wait to get number from numerator. We assumed that getting number process takes time approximately 5 seconds.
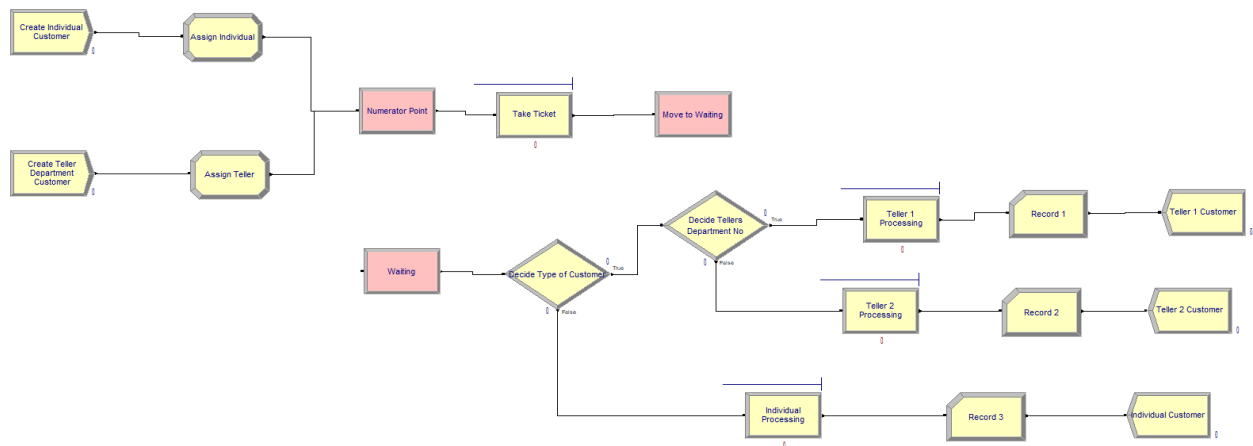
Description of Arena Model and Process

In this simulation model two types of customer is defined according to their services that they want to receive services for the queue. For each type of customer, create modules are generated and fitted distributions of each customer types' inter arrival time are assigned as their attributes and the services time that obtained from input analyser from ARENA are added to assign module to use in processes. Every single customer that enters to the system is directed from "Numerator Point "Station by "Move to Numerator "Route module. To determine the services that received by customers, decide module is added. Thus, we separated the type of customers as individual customer and teller department customer. And then, one more decide module is added to determine the customers that want to receive service in which teller's department to pass the shorter queue.

In addition to these, three different record modules are added to the model to record number of customers that received service from related process. The customers that complete their services exit the system via dispose module.

The Process of the simulation Model on Flow Chart

```
                              ┌─────────┐
                              │  START  │
                              └─────────┘
                                   │
                    ┌──────────────┴──────────────┐
                    ▼                              ▼
            ┌──────────────┐              ┌──────────────┐
            │  INDIVIDUAL  │              │    NORMAL     │
            │  CUSTOMER    │              │   CUSTOMER    │
            └──────────────┘              └──────────────┘
                    └──────────────┬──────────────┘
                                   ▼
                                 Numerator
                                   │
                                   ▼
                            ┌──────────────┐
                            │ Customer takes│
                            │   a number    │
                            └──────────────┘
                                   │
                                   ▼
                              Normal? or
                              individual?
```

Predence of cutomer for the waiting customer

Waiting for own turn

Waiting for own turn

Predence of cutomer for the waiting customer

Go to individual customer

Go to process

Calculate the average waiting time and number of waiting customer

EXIT

Arena Flow Chart

ARENA model steps:

1) 2 create modules are generated for each type of customer, and their fitted distributions are defined with related parameters.

2) 2 Assign Modules are generated for each create module. The services time that obtained from input analyser from ARENA are added to assign module to use in processes.

3) A route called "Move to Numerator" is generated. This module directs customers from the numerator point station. Also the time that customer spends while going to the numerator is defined as uniform distribution between 5-15 seconds.

4) A station called "Numerator Point" is generated.

5) Take ticket process is generated. This module provides people take their ticket number. Its' allocation is chosen as "Non-Value Added".

6) A route called "Move to Waiting" is generated. This module directs customers with ticket numbers from "Numerator Point" station to "Waiting".Also the time that customer spends while going to the waiting area is defined as uniform distribution between 5-15 seconds.

7) A station called "Waiting" is generated.

8) Decide module is called "Decide Type of Customer" is generated. Using the attributes defined before, (probability of each customer to select individual service is %14 and the teller's department service is %86) selection of service is proceed.

9) Another decide module is called "Decide Teller's Department No" is generated to determine the customers that want to receive service in which teller's department to pass the shorter queue.

10) Two processes module are called "Teller 1 Processing" and "Teller 2 Processing" are generated. Resources are defined as Server 1 and Server 2. Service time distribution is defined as expression in processes because we defined them in assign modules before.

11) The another option is individual processing according to decide module that defined at eight item. Service time distribution is defined as expression in processes because we defined them in assign modules before.
12) Three different record modules are added to the model to record number of customers that received service from related process.
13) The customers that complete their services exit the system via dispose module.

OUTPUT ANALYSIS OF REPORTS

Set Up

Entity

At the end of 40 hours of the simulation, 548 customers exited from the system.

Unnamed Project

Replications: 100   Time Units: Minutes

Key Performance Indicators

System
	Average
Number Out	548

Unnamed Project

Replications: 100   Time Units: Minutes

Entity

Time

VA Time
	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	1.9896	0,07	1.0318	2.9928	0.00	25.4976
Entity 2	2.5054	0,02	2.2782	2.7007	0.00	5.4998

NVA Time
	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.1665	0,00	0.1598	0.1728	0.08335008	0.2500
Entity 2	0.1663	0,00	0.1578	0.1743	0.08333857	0.2500

Wait Time
	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.6293	0,02	0.3640	0.9962	0.00	41.1553
Entity 2	0.3302	0,03	0.07418282	0.8017	0.00	48.1464

Transfer Time
	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.1667	0,00	0.1604	0.1734	0.08333665	0.2500
Entity 2	0.1666	0,00	0.1604	0.1741	0.08333775	0.2500

Other Time
	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0,00	0.00	0.00	0.00	0.00
Entity 2	0.00	0,00	0.00	0.00	0.00	0.00

Total Time
	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	2.9522	0,08	1.9814	4.2216	0.1688	55.8620
Entity 2	3.1686	0,03	2.9133	3.5520	0.1766	48.5402

This the report of entity. We have 2 entities. There are some time values for these entities. The average service time of 1 customer of entity 1 is 1.9896 minutes and the average service time of 1 customer of entity 2 is 2.5054 minutes. One customer of entity 1 waits 0.6293 minutes in the queue and one customer of entity 2 waits 0.3302 minutes in the queue. In addition to these, when we add the NVA time(0.1663 minutes) and transfer time(0.1667 minutes) to VA time and wait time, it is equal to total time(2.9522 minutes) for entity 1.In addition to these, when we add the NVA time(0.1665 minutes) and transfer time(0.1666 7minutes) to VA time and wait time, it is equal to total time(3.1686 minutes) for entity 2.

Other

Number In

	Average	Half Width	Minimum Average	Maximum Average
Entity 1	256.08	1,03	246.00	269.00
Entity 2	292.60	1,34	277.00	306.00

Other

Number Out

	Average	Half Width	Minimum Average	Maximum Average
Entity 1	255.74	1,02	245.00	268.00
Entity 2	292.20	1,34	277.00	305.00

WIP

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.3156	0,01	0.2122	0.4468	0.00	4.0000
Entity 2	0.3862	0,00	0.3450	0.4428	0.00	4.0000

256 customers entire to the system and 255 customers exited from the system for entity one. 292 customers entire to the system and 292 customers exited from the system for entity 2.

QUEUE

Queue

Time

Waiting Time

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Individual Processing.Queue	1.6624	0,13	0.3157	3.5094	0.00	48.1464
Take Ticket.Queue	0.00198033	0,00	0.00052141	0.00391297	0.00	0.2471
Teller 1 Processing.Queue	0.2760	0,01	0.1964	0.3688	0.00	5.4207
Teller 2 Processing.Queue	0.00475765	0,01	0.00	0.4758	0.00	4.2819

Other

Number Waiting

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Individual Processing.Queue	0.05372438	0,00	0.00749807	0.1283	0.00	5.0000
Take Ticket.Queue	0.00045300	0,00	0.00011797	0.00088042	0.00	1.0000
Teller 1 Processing.Queue	0.05360105	0,00	0.03657737	0.07359706	0.00	1.0000
Teller 2 Processing.Queue	0.00001784	0,00	0.00	0.00178412	0.00	1.0000

The average waiting time of one customer of individual is 1.6624 minutes and minimum waiting time is 0 minutes, maximum waiting time is 48.1464 minutes.

The average waiting time of one customer that wait for ticket is 0.00198 minutes and minimum waiting time is 0 minutes, maximum waiting time is 0.2471 minutes.

 The average waiting time of one customer that received service in teller 1 is 0.2760 minutes and minimum waiting time is 0 minutes, maximum waiting time is 5.4207 minutes.

The average waiting time of one customer that received service in teller 2 is 0.00475 minutes and minimum waiting time is 0 minutes, maximum waiting time is 4.2819 minutes.

The average number waiting in individual queue is 0.05372438 customers.

The average number waiting in take ticket queue is 0.000425300customers.

The average number waiting in teller 1 queue is 0.05360105 customers.

The average number waiting in teller 2 queue is 0.00001784 customers.

Resource

Resource

Usage

Instantaneous Utilization

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Individual Server	0.2127	0,01	0.1105	0.3167	0.00	1.0000
Numerator	0.03803255	0,00	0.03628170	0.03960802	0.00	1.0000
Server 1	0.2992	0,00	0.2708	0.3258	0.00	1.0000
Server 2	0.00598174	0,00	0.00129495	0.01325678	0.00	1.0000

Number Busy

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Individual Server	0.2127	0,01	0.1105	0.3167	0.00	1.0000
Numerator	0.03803255	0,00	0.03628170	0.03960802	0.00	1.0000
Server 1	0.2992	0,00	0.2708	0.3258	0.00	1.0000
Server 2	0.00598174	0,00	0.00129495	0.01325678	0.00	1.0000

Number Scheduled

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Individual Server	1.0000	0,00	1.0000	1.0000	1.0000	1.0000
Numerator	1.0000	0,00	1.0000	1.0000	1.0000	1.0000
Server 1	1.0000	0,00	1.0000	1.0000	1.0000	1.0000
Server 2	1.0000	0,00	1.0000	1.0000	1.0000	1.0000

Scheduled Utilization

	Average	Half Width	Minimum Average	Maximum Average
Individual Server	0.2127	0,01	0.1105	0.3167
Numerator	0.03803255	0,00	0.03628170	0.03960802
Server 1	0.2992	0,00	0.2708	0.3258
Server 2	0.00598174	0,00	0.00129495	0.01325678

Resource

Usage

Total Number Seized	Average	Half Width	Minimum Average	Maximum Average
Individual Server	76.3000	1,76	57.0000	100.00
Numerator	548.68	1,46	534.00	565.00
Server 1	465.75	1,88	446.00	486.00
Server 2	6.4300	0,52	1.0000	13.0000

User Specified

Counter

Count	Average	Half Width	Minimum Average	Maximum Average
Counter 1	465.46	1,89	446.00	486.00
Counter 2	6.4100	0,52	1.0000	13.0000
Counter 3	76.0700	1,76	57.0000	100.00

This is the report of resources. We have 4 resources. These are individual server, numerator, teller 1(server 1) and teller 2(server 2). Utilization of individual server is %21.27, numerator is %3.8,teller 1 is %29.92 and teller 2 is %0.5.

```
                    Output Summary for 100 Replications

Project: Unnamed Project                      Run execution date : 5/ 5/2019
Analyst: user                                 Model revision date: 5/ 5/2019


                              OUTPUTS

Identifier                            Average   Half-width Minimum   Maximum # Replications
_____

Entity 1.NumberIn                     256.08    1.0255    246.00    269.00    100
Entity 1.NumberOut                    255.74    1.0235    245.00    268.00    100
Entity 2.NumberIn                     292.60    1.3406    277.00    306.00    100
Entity 2.NumberOut                    292.20    1.3427    277.00    305.00    100
Individual Server.NumberSeized        76.300    1.7598    57.000    100.00    100
Individual Server.ScheduledUtilization .21268   .00775    .11049    .31673    100
Server 1.NumberSeized                 465.75    1.8815    446.00    486.00    100
Server 1.ScheduledUtilization         .29922    .00244    .27084    .32582    100
Server 2.NumberSeized                 6.4300    .51839    1.0000    13.000    100
Server 2.ScheduledUtilization         .00598    5.7569E-04 .00129   .01326    100
Numerator.NumberSeized                548.68    1.4581    534.00    565.00    100
Numerator.ScheduledUtilization        .03803    1.5512E-04 .03628   .03961    100
System.NumberOut                      547.94    1.4235    534.00    564.00    100


Simulation run time: 1.63 minutes.
Simulation run complete.
```

The values of half width are close to 0 so we understand that our simulation model founds the results that close to real system.

VALIDATION AND VERIFICATION OF THE MODEL

Errors have specified using with simulations output and observations for food types. Values have shown in Table 5.

$$\text{Error in } \hat{\mu}_M = \left| \hat{\mu}_M - \mu_S \right|$$

$$= \left| \hat{\mu}_M - \mu_M + \mu_M - \mu_S \right|$$

$$\leq \underbrace{\left| \hat{\mu}_M - \mu_M \right|}_{\text{Output data analysis}} + \underbrace{\left| \mu_M - \mu_S \right|}_{\text{Validation}}$$

	Average Service Time		
	Theoretical	simulation	error
Individual	14,26	1,98	12,28
Teller	2,89	2,5	0,39

Average Service Time
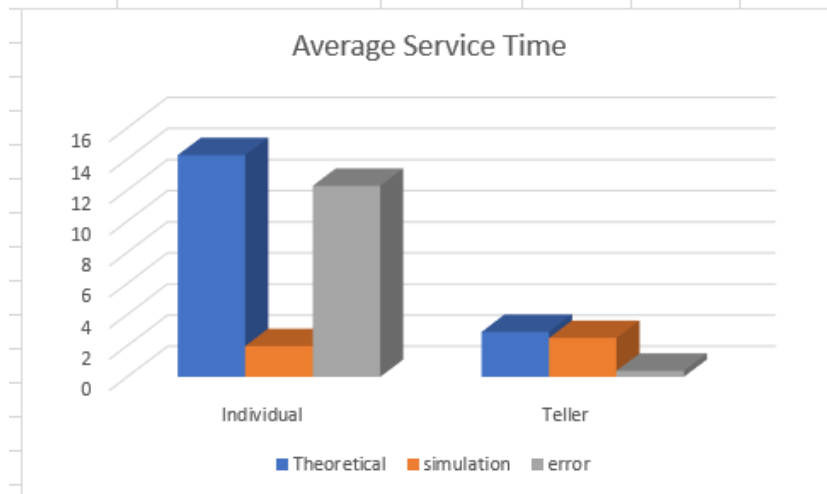
	Max Service Time		
	Theoretical	simulation	error
Individual	25	25,49	0,49
Teller	5	5,49	0,49
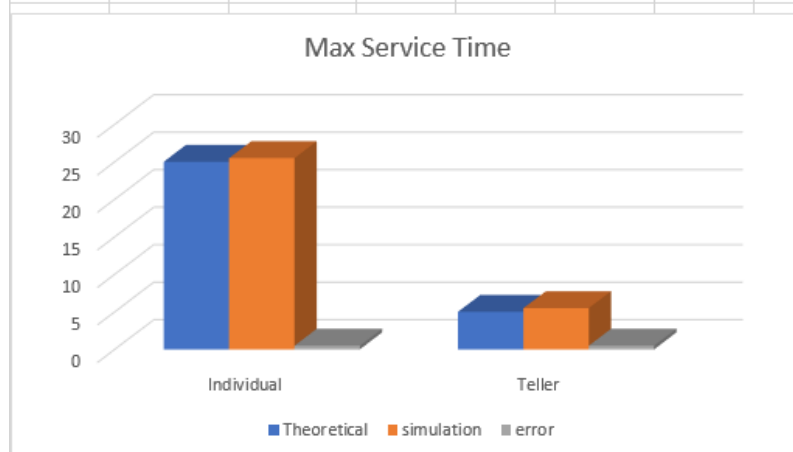
Max Service Time

The difference between the theoretical and the simulated outputs is caused by some limits defined at input analyzer.

Extreme situations at max values (like service time about three hours) is ignored while fitting a distribution.

OUTPUT ANALYSIS

Simulation model has indicated and designed as terminating simulation. Parameters to be estimated are defined relative to specific initial and stopping conditions that are part of the model for terminating simulations. (Kaya, 2016)
The terminating model has designed as 100 replication(8 days). Each experiment used the same starting condition of independence between the trial and are provided using different initial values. Performance measure has accepted as X.

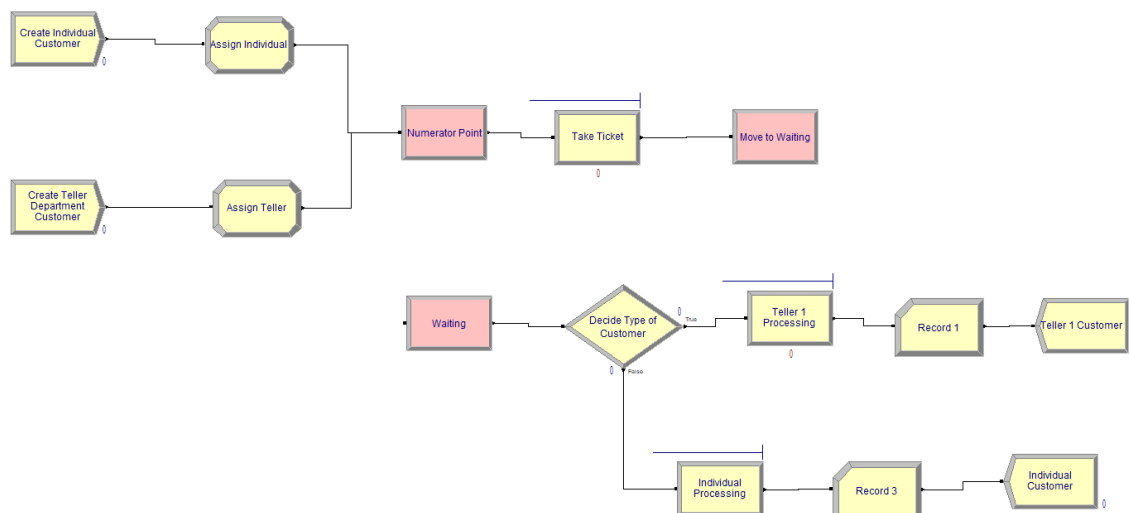X_j: Estimate of performance measure for jth replication.

$$\hat{\mu} = \overline{X}(n) = \frac{\sum_{j=1}^{n} X_j}{n} \qquad \text{(Unbiased estimator of } \mu\text{)}$$

$$S^2(n) = \frac{\sum(X_j - \overline{X}(n))^2}{n-1} \qquad \text{(Unbiased estimator of Var}(X_j))$$

$$\overline{X}(n) \pm t_{n-1,1-\alpha/2} \frac{S(n)}{\sqrt{n}} \qquad (100(1-\alpha)\% \text{ CI for } \mu)$$

ALTERNATIVES SCENARIOS AND THEIR COMPARISON

FIRST ALTERNATIVE

Key Performance Indicators

System

Average

Number Out   548

At the end of 40 hours of the simulation, 548 customers exited from the system. Customer numbers doesn't change.

Entity

Entity

Time

VA Time

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	2.1562	0,07	1.1970	3.1603	0.08335008	25.6881
Entity 2	2.6717	0,02	2.4491	2.8642	0.08336039	5.7394

NVA Time

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0,00	0.00	0.00	0.00	0.00
Entity 2	0.00	0,00	0.00	0.00	0.00	0.00

Wait Time

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.6573	0,02	0.3946	1.0048	0.00	41.1553
Entity 2	0.3490	0,03	0.07794773	0.8072	0.00	48.1464

Transfer Time

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.1667	0,00	0.1604	0.1734	0.08333665	0.2500
Entity 2	0.1666	0,00	0.1604	0.1741	0.08333775	0.2500

Other Time

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0,00	0.00	0.00	0.00	0.00
Entity 2	0.00	0,00	0.00	0.00	0.00	0.00

Total Time

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	2.9802	0,08	2.0332	4.2481	0.1688	55.8620
Entity 2	3.1873	0,03	2.9234	3.5574	0.1766	48.5402

Other

Number In

	Average	Half Width	Minimum Average	Maximum Average
Entity 1	256.08	1,03	246.00	269.00
Entity 2	292.60	1,34	277.00	306.00
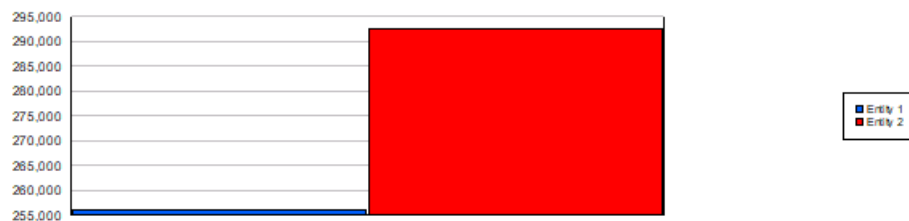
Entity

Other

Number Out	Average	Half Width	Minimum Average	Maximum Average		
Entity 1	255.73	1,02	245.00	268.00		
Entity 2	292.20	1,34	277.00	305.00		

WIP	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.3186	0,01	0.2177	0.4496	0.00	4.0000
Entity 2	0.3885	0,00	0.3453	0.4435	0.00	4.0000

This the report of entity. We have 2 entities. There are some time values for these entities. The average service time of 1 customer of entity 1 is 2.1562minutes and the average service time of 1 customer of entity 2 is 2.6717 minutes. One customer of entity 1 waits 0.6573minutes in the queue and one customer of entity 2 waits 0.3490 minutes in the queue. In addition to these, when we add the NVA time(0 minutes) and transfer time(0.1667 minutes) to VA time and wait time, it is equal to total time(2.9802 minutes) for entity 1.In addition to these, when we add the NVA time(0minutes) and transfer time(0.1666 minutes) to VA time and wait time, it is equal to total time(3.1873 minutes) for entity 2.

Queue

Queue

Time

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Individual Processing.Queue	1.6624	0,13	0.3157	3.5094	0.00	48.1464
Take Ticket.Queue	0.00198033	0,00	0.00052141	0.00391297	0.00	0.2471
Teller 1 Processing.Queue	0.2991	0,01	0.2222	0.3983	0.00	7.6406

Other

Number Waiting	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Individual Processing.Queue	0.05372438	0,00	0.00749807	0.1283	0.00	5.0000
Take Ticket.Queue	0.00045300	0,00	0.00011797	0.00088042	0.00	1.0000
Teller 1 Processing.Queue	0.05890350	0,00	0.04184057	0.08132835	0.00	3.0000

The average waiting time of one customer of individual is 1.6624 minutes and minimum waiting time is 0 minutes, maximum waiting time is 48.1464 minutes.

The average waiting time of one customer that wait for ticket is 0.00198 minutes and minimum waiting time is 0 minutes, maximum waiting time is 0.2471 minutes.

 The average waiting time of one customer that received service in teller 1 is 0. 2991 minutes and minimum waiting time is 0 minutes, maximum waiting time is 7.6406 minutes.

The average number waiting in individual queue is 0.05372438 customers.

The average number waiting in take ticket queue is 0.000425300 customers.

The average number waiting in teller 1 queue is 0.05890350 customers.

Resource

Usage

Instantaneous Utilization

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Individual Server	0.2127	0,01	0.1105	0.3167	0.00	1.0000
Numerator	0.03803255	0,00	0.03628170	0.03960802	0.00	1.0000
Server 1	0.3052	0,00	0.2768	0.3341	0.00	1.0000

Number Busy

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Individual Server	0.2127	0,01	0.1105	0.3167	0.00	1.0000
Numerator	0.03803255	0,00	0.03628170	0.03960802	0.00	1.0000
Server 1	0.3052	0,00	0.2768	0.3341	0.00	1.0000

Number Scheduled

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Individual Server	1.0000	0,00	1.0000	1.0000	1.0000	1.0000
Numerator	1.0000	0,00	1.0000	1.0000	1.0000	1.0000
Server 1	1.0000	0,00	1.0000	1.0000	1.0000	1.0000

Scheduled Utilization

	Average	Half Width	Minimum Average	Maximum Average
Individual Server	0.2127	0,01	0.1105	0.3167
Numerator	0.03803255	0,00	0.03628170	0.03960802
Server 1	0.3052	0,00	0.2768	0.3341

Resource

Usage

Total Number Seized	Average	Half Width	Minimum Average	Maximum Average
Individual Server	76.3000	1,76	57.0000	100.00
Numerator	548.68	1,46	534.00	565.00
Server 1	472.17	1,94	451.00	492.00

User Specified

Counter

Count	Average	Half Width	Minimum Average	Maximum Average
Counter 1	471.86	1,94	451.00	491.00
Counter 3	76.0700	1,76	57.0000	100.00
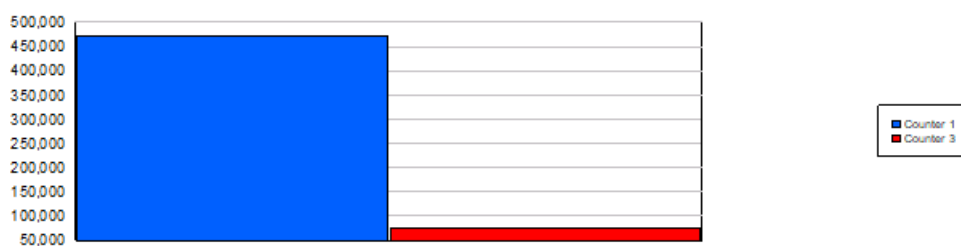
This is the report of resources. We have 3 resources. These are individual server, numerator and teller 1(server 1) Utilization of individual server is %21.27, numerator is %3.8,teller 1 is %30.52.

Second Alternative

At the end of 40 hours of the simulation, 548 customers exited from the system. Customer numbers doesn't change.
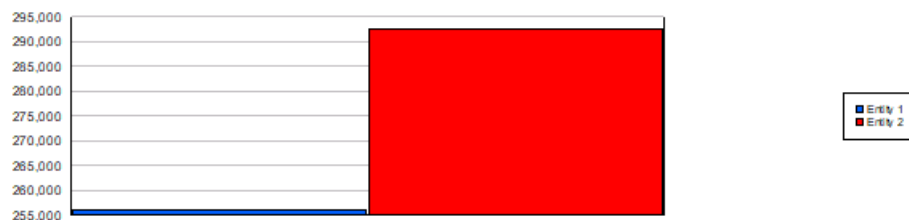
Key Performance Indicators

System

	Average
Number Out	548

Entity

Time

VA Time

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	2.1561	0,07	1.1970	3.1603	0.08335008	25.6881
Entity 2	2.6717	0,02	2.4491	2.8642	0.08336039	5.7394

NVA Time

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0,00	0.00	0.00	0.00	0.00
Entity 2	0.00	0,00	0.00	0.00	0.00	0.00

Wait Time

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.6293	0,02	0.3640	0.9962	0.00	41.1553
Entity 2	0.3302	0,03	0.07418282	0.8017	0.00	48.1464

Transfer Time

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.1667	0,00	0.1604	0.1734	0.08333665	0.2500
Entity 2	0.1666	0,00	0.1604	0.1741	0.08333775	0.2500

Other Time

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0,00	0.00	0.00	0.00	0.00
Entity 2	0.00	0,00	0.00	0.00	0.00	0.00

Total Time

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	2.9522	0,08	1.9814	4.2216	0.1688	55.8620
Entity 2	3.1686	0,03	2.9133	3.5520	0.1766	48.5402

Other

Number In

	Average	Half Width	Minimum Average	Maximum Average
Entity 1	256.08	1,03	246.00	269.00
Entity 2	292.60	1,34	277.00	306.00

Entity

Other

Number Out	Average	Half Width	Minimum Average	Maximum Average		
Entity 1	255.74	1,02	245.00	268.00		
Entity 2	292.20	1,34	277.00	305.00		

WIP	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.3156	0,01	0.2122	0.4468	0.00	4.0000
Entity 2	0.3862	0,00	0.3450	0.4428	0.00	4.0000

This the report of entity. We have 2 entities. There are some time values for these entities. The average service time of 1 customer of entity 1 is 2.1561 minutes and the average service time of 1 customer of entity 2 is 2.6717 minutes. One customer of entity 1 waits 0.6293minutes in the queue and one customer of entity 2 waits 0.3302 minutes in the queue. In addition to these, when we add the NVA time(0 minutes) and transfer time(0.1667 minutes) to VA time and wait time, it is equal to total time(2.9522 minutes) for entity 1.In addition to these, when we add the NVA time(0minutes) and transfer time(0.1666minutes) to VA time and wait time, it is equal to total time(3.1686 minutes) for entity 2.

Queue

Time

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Individual Processing.Queue	1.6624	0,13	0.3157	3.5094	0.00	48.1464
Take Ticket.Queue	0.00198033	0,00	0.00052141	0.00391297	0.00	0.2471
Teller 1 Processing.Queue	0.00475765	0,01	0.00	0.4758	0.00	4.2819
Teller 2 Processing.Queue	0.2760	0,01	0.1964	0.3688	0.00	5.4207

Other

Number Waiting	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Individual Processing.Queue	0.05372438	0,00	0.00749807	0.1283	0.00	5.0000
Take Ticket.Queue	0.00045300	0,00	0.00011797	0.00088042	0.00	1.0000
Teller 1 Processing.Queue	0.00001784	0,00	0.00	0.00178412	0.00	1.0000
Teller 2 Processing.Queue	0.05360105	0,00	0.03657737	0.07359706	0.00	1.0000
Teller 3 Processing.Queue	0.00	0,00	0.00	0.00	0.00	0.00

The average waiting time of one customer of individual is 1.6624 minutes and minimum waiting time is 0 minutes, maximum waiting time is 48.1464 minutes.

The average waiting time of one customer that wait for ticket is 0.00198 minutes and minimum waiting time is 0 minutes, maximum waiting time is 0.2471 minutes.

The average waiting time of one customer that received service in teller 1 is 0.00475765 minutes and minimum waiting time is 0 minutes, maximum waiting time is 4.2819 minutes.

The average waiting time of one customer that received service in teller 2 is 0.2760minutes and minimum waiting time is 0 minutes, maximum waiting time is 5.4207 minutes.

The average number waiting in individual queue is 0.05372438 customers.

The average number waiting in take ticket queue is 0.000425300customers.

The average number waiting in teller 1 queue is 0.00001784 customers.

The average number waiting in teller 2 queue is 0.05360105 customers.

The average number waiting in teller 3 queue is 0 customers(There is no body in queue so the report of waiting time is not include of teller 3).
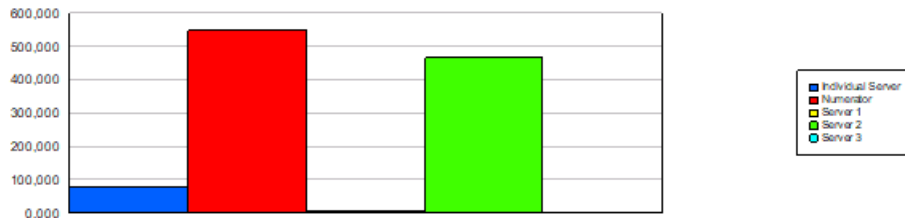
Resource

Usage

Instantaneous Utilization

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Individual Server	0.2127	0,01	0.1105	0.3167	0.00	1.0000
Numerator	0.03803255	0,00	0.03628170	0.03960802	0.00	1.0000
Server 1	0.00598174	0,00	0.00129495	0.01325678	0.00	1.0000
Server 2	0.2992	0,00	0.2708	0.3258	0.00	1.0000
Server 3	0.00	0,00	0.00	0.00	0.00	0.00

Number Busy

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Individual Server	0.2127	0,01	0.1105	0.3167	0.00	1.0000
Numerator	0.03803255	0,00	0.03628170	0.03960802	0.00	1.0000
Server 1	0.00598174	0,00	0.00129495	0.01325678	0.00	1.0000
Server 2	0.2992	0,00	0.2708	0.3258	0.00	1.0000
Server 3	0.00	0,00	0.00	0.00	0.00	0.00

Number Scheduled

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Individual Server	1.0000	0,00	1.0000	1.0000	1.0000	1.0000
Numerator	1.0000	0,00	1.0000	1.0000	1.0000	1.0000
Server 1	1.0000	0,00	1.0000	1.0000	1.0000	1.0000
Server 2	1.0000	0,00	1.0000	1.0000	1.0000	1.0000
Server 3	1.0000	0,00	1.0000	1.0000	1.0000	1.0000

Scheduled Utilization

	Average	Half Width	Minimum Average	Maximum Average
Individual Server	0.2127	0,01	0.1105	0.3167
Numerator	0.03803255	0,00	0.03628170	0.03960802
Server 1	0.00598174	0,00	0.00129495	0.01325678
Server 2	0.2992	0,00	0.2708	0.3258
Server 3	0.00	0,00	0.00	0.00
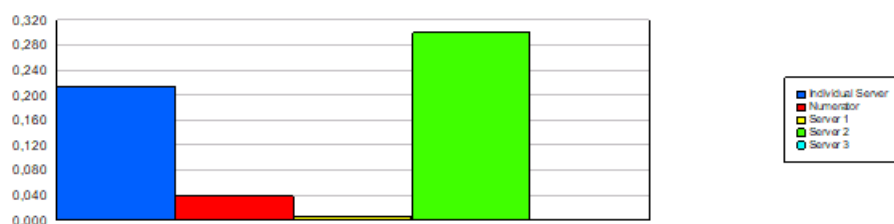
Resource

Usage

Total Number Seized	Average	Half Width	Minimum Average	Maximum Average
Individual Server	76.3000	1,76	57.0000	100.00
Numerator	548.68	1,46	534.00	565.00
Server 1	6.4300	0,52	1.0000	13.0000
Server 2	465.75	1,88	446.00	486.00
Server 3	0.00	0,00	0.00	0.00

User Specified

Counter

Count	Average	Half Width	Minimum Average	Maximum Average
Counter 1	6.4100	0,52	1.0000	13.0000
Counter 2	465.46	1,89	446.00	486.00
Counter 3	76.0700	1,76	57.0000	100.00
Counter 4	0.00	0,00	0.00	0.00
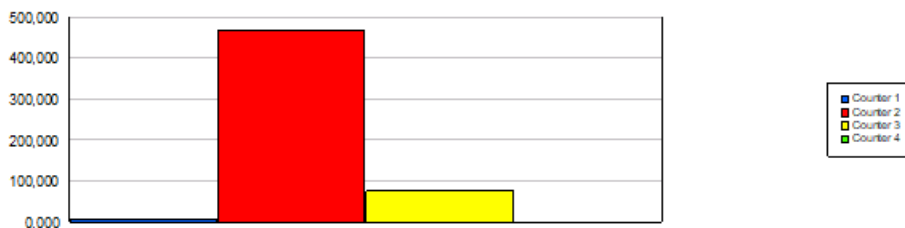
This is the report of resources. We have 5 resources. These are individual server, numerator, teller 1(server 1) teller 2(server 2) and teller 3(server 3). Utilization of individual server is %21.27, numerator is %3.8,teller 1 is %0.5 teller 2 is %29.92 and teller 3 is %0.

Process Design recommendations to the Company

In alternative 1, average waiting time in teller 1 queue is greater than current system and number of waiting customer is greater than the current system. According to these situations in alternative 1 , average waiting time and number of waiting customers do not different from the current system. Also, in alternative 1 one teller is fired from the system so expenses is decreased for employee. Utilization of server 1 is higher than current system. Considering all of these situations alternative 1 can be selected.

In alternative 2, average waiting time in teller 1 queue is less than alternative 1 and number of waiting customer is less than the alternative 1 but average waiting time in teller 2 queue is 0,2760 and number of waiting customer is 0,053.In alternative 2 new teller was added to the system but utilization of this teller is so low. For this reason, hiring a new teller is unnecessary. Besides hiring a new teller is extra expenses. Considering all of these situations alternative 1 is selected.

At the result of, selected of alternative 1 is more logical.

15.05.2019