TEAM 18

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1. BANK SYSTEM

1.1. SYSTEM EXPLANATION

We have a bank system with different kinds of customers and three kind of services. All the incoming customers will have to sign in with SignIn employee and then they can be redirected to 3 possible bank servers for help. In our system, bank servers are SignIn, ATM machine, Tellers and Managers. Our customers can be classified into 3 categories such as customer with basic needs, customer with moderate needs and customer with advanced needs. For a basic need customer, it's most likely that they will be directed to an ATM but in some cases, they can be redirected to teller by the sign in employee. Similarly, it's most likely that a moderate need customer will be redirected to teller but in some cases, they can be redirected to ATM or managers as well. Finally, the customer with advanced need will most likely be redirected to manager but is some cases they may get redirected to tellers by the sign in employee as well. Sign in employee helps customer to navigate in the bank and redirects customer to ATM, teller or manager based on customer type.

As we mentioned earlier, in our banking system we have SignIn, ATM machines, Tellers and Bankers as our servers. Currently we have 3 ATMs in the ATM service area. In our project we will consider ATM as one type of bank service with 3 ATMs as 3 servers. A single queue feeds ATM service area and ATM execution time is independent of customer type. Originally, we have 4 tellers and again we will consider Teller as bank service with 4 servers (tellers). Teller execution time is independent of customer type and a single queue feeds to the tellers. Finally, we have 2 managers as 2 servers and thus as manager as a bank service. A single queue feeds to the managers and manager execution time is independent of the customer type. There is one sign-in server that is the first server that caters to any customer approaching the bank and the only server that serves all types of customer. There is a single queue that caters to sign-in server. The Sign in execution time depends on the customer type it caters to. All the queuing discipline for these above-mentioned queues are based on first-come-first-serve principle.

Below is a diagram showing the flow in the bank.

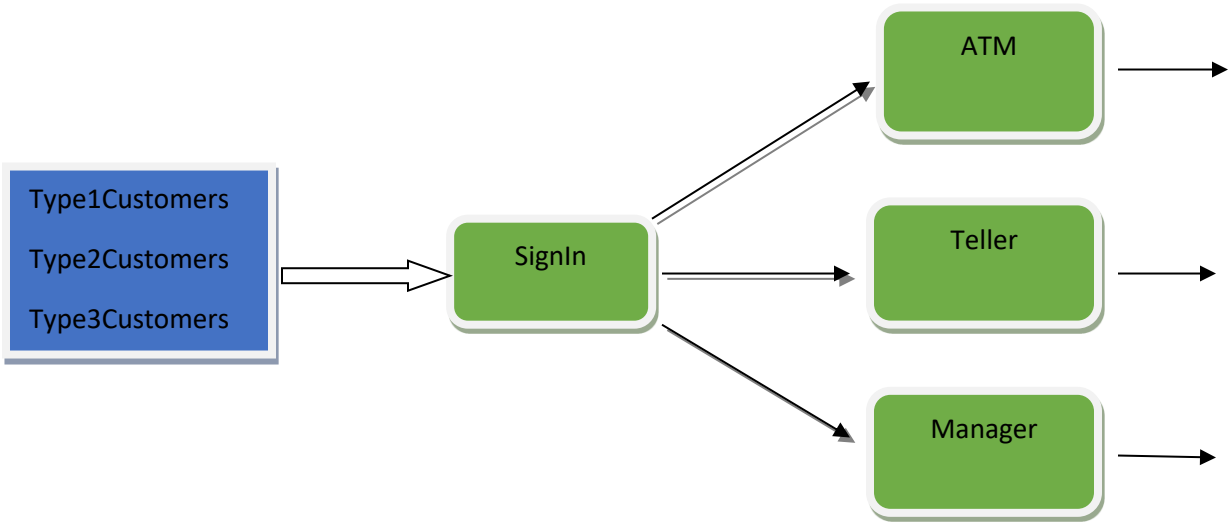

Figure 1.1

1.2. DATA ANALYSIS

We have recorded data for 500 customers. Each record has information about customer inter arrival time, customer type, sign in time (in seconds) for each customer, information about where the customer was directed to (ATM, Teller or Manager) and service time (in seconds) for that customer. In our data, the customers are coded as '1' for customer with basic needs, '2' for customer with moderate needs and '3' customer with advanced needs. Finally, 'Directed To' column is coded as '1' if customer is directed to ATM, '2' if the customer is directed to tellers and '3' if customer is directed to managers and the service time for each customer (either at ATM, teller or manager) is given in a different column.

For simulation, we calculated the percentage of different types of customers out of a total of 500 customers. Now, to summarize the distribution of customers; it turned out that we had 36.6% customer with basic needs, 38% of customers had moderate needs and 25.4% of total customers had advanced needs. We also evaluated the percentage distribution of customers who availed a specific service in the bank. The results were as follows; percentage of customers directed to ATM was 36.6%, customers directed to teller was 33.8% and customers directed to manager was 29.6%.

Now, in order to evaluate the spread or distribution of the data we have, we utilized Stat::Fit for best fitting the given data over a curve. First things first, we computed interarrival time distribution for all the customers, which followed an exponential distribution with 54.4 seconds as its mean value. The observed curve is showcased below on figure 1.2.

Upon that, we estimated the best distributions for SignIn time for each customer type. For this, we filtered the data based the type of customers in the given spreadsheet, selected the data points for SignIn times and generated a distribution in Stat::Fit. We observed that, all three customer types were triangularly distributed for the given SignIn time data. The shape parameters of the triangular distribution were as follows; for Type 1 customer the maximum value was 40.7 and the mode was found at 37.5, for type 2 customer the maximum value was 80.4 and the mode was 35.4. Similarly, we calculated the maximum and mode for Type 3 customers and it came out to be 104 and 78 respectively. All the above calculated values were in the unit – seconds. An illustrated curve for type 1 customers is shown in figure 1.3.

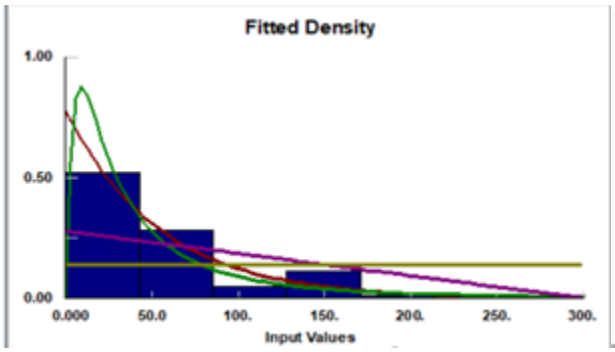

Figure 1.2

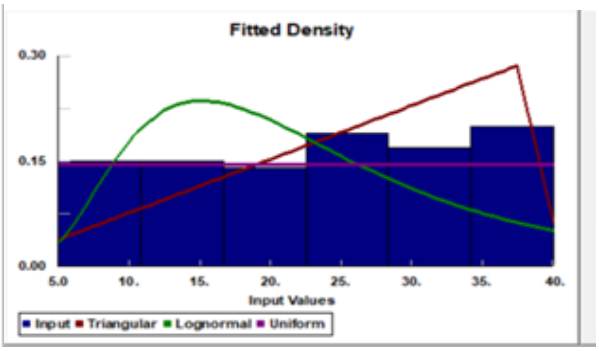

Figure 1.3

Now, we compute 9 probabilities, 3 for each customer type, which would essentially help us in evaluating the percentage of each customer type being directed to every service option in the bank. Below, we have put together the probabilities for each customer against every service station. The result we received for Type 1 customer is as follows - 74.3% (or 74%) was directed to ATM and 25.7% (or 26%) was directed to teller and 0% was directed towards manager. The result we received for Type 2 customer is as follows - 24.7% (25%) was directed to ATM and 50.5% (50%) was directed to teller and 24.7% (25%) was directed towards the manager. The result we received for Type 3 customer is as follows: 0% was directed to ATM and 20.5% (or 20%) was directed to teller and 79.5% (or 80%) was directed towards manager.

Using the data file, we have determined the best distributions for service time at each service option and in a nutshell, the results were something like give below-

Next up, for the ATM, we found the service times to be lognormally distributed too with the shape parameters obtained as 0, 3.69 and 1.02. Now finally for our remaining two servers, that is for the teller and manager, the service time distributions had a Lognormal distribution and the observed shape parameters

were 0, 3.69, 1.02 and 0, 4.89 and 1.31 respectively. Below figure demonstrate the curve obtained for an station ATM.

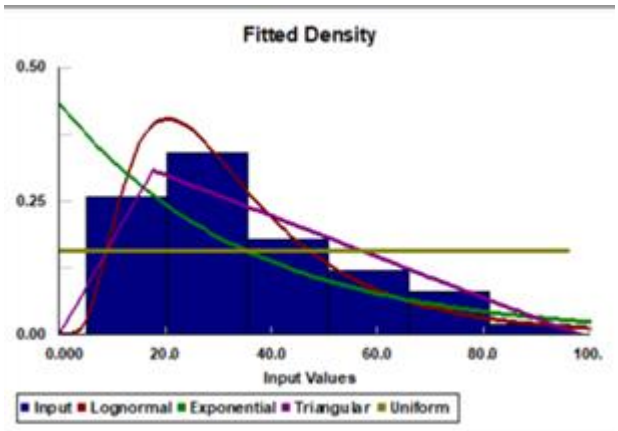

Figure 1.4

1.3 SIMIO MODEL AND VERIFICATION

The figure below shows the schematic of the main Simio model in facility view. We have 4 server objects out of which 1 is a SignIn object, and three other server objects are ATM, Teller and Manager. We create three different entities for each type of customer. The entities were subsequently referenced in the data table we created. According to the system information we have, the initial capacity of 3. Similarly, the number of servers for the teller server is 4 for the base model and number of servers for manager object is 2. We have created reference properties for every initial capacity while defining them in the model. Execution times for all three objects are independent of customer type. All queues are first-come-first serve. In this model we included our 3 types of customers. The data distributions we had computed in Stat::Fit, were utilized as inputs for the required interarrival and service time distributions. Our source object would fetch data from a data table to generate input values to the models. We construct a data table based on the percentage distribution calculation we did about type of customers (Tyep1, Type2 and Type3) and their service providers (ATM, teller, manager). Based on this information we have created the Simio model and below is the facility view of the model.

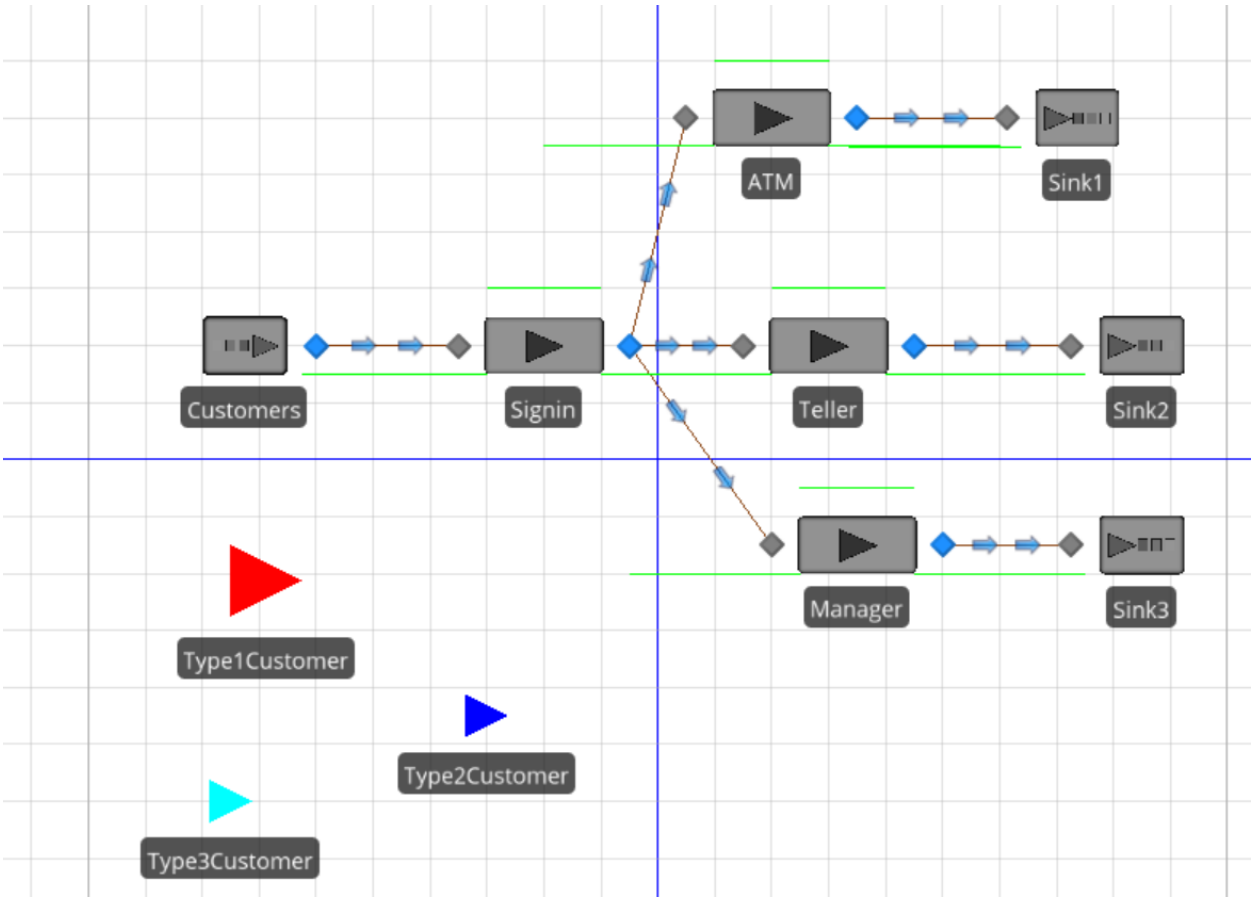

Figure 1.5

In order verify this model, we created and obtained theoretical network results from the Jackson Network.

In order to do so, we first constructed a verification model in Simio itself, very similar to the original model but we selected only one type of customer as an input entity. Type2 customers had visited all three stations, that is ATM, Teller and Manager. This essentially was lacking in the other two customer types, in which the data distribution was not sufficiently uniform. This is the reason why we select Type2 customer as input entity. We consider all the distributions to be exponential and by evaluating mean values of a specific distribution in Stat::Fit. We consider the probability of Type2 Customers while defining its interarrival time distribution exponentially. Finally, we run an experiment and compare our results with the theoretical results of queuing template. Below figure showcases the schematic of the Jackson Network we evaluated over.

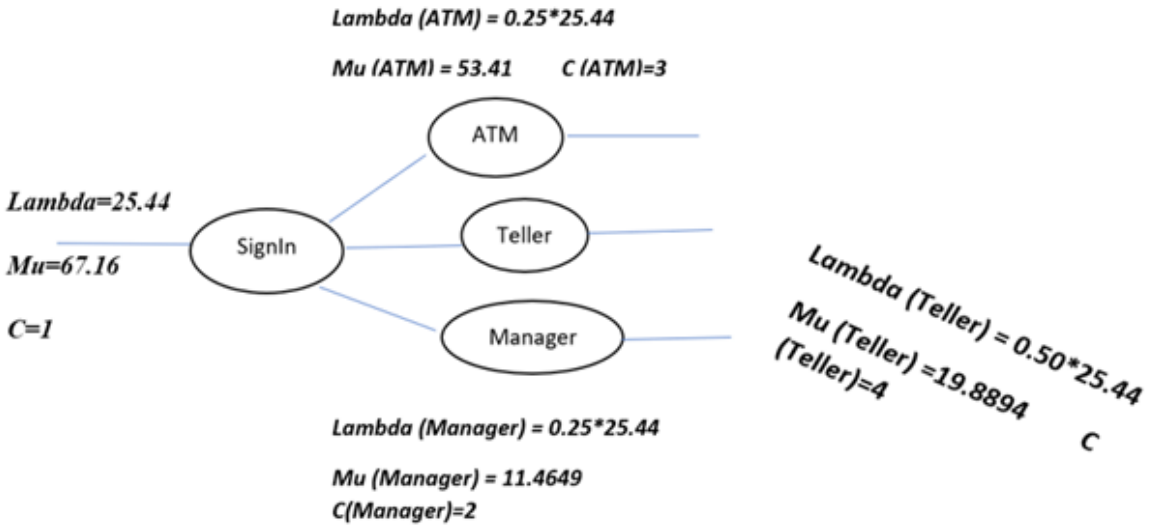

Figure 1.6

Comparison Parameters	Theoretical Results	Model Results
L (Number in Bank)	1.97021	1.8846 ± 0.1090
W (Time in Bank)	0.077445	0.766 ± 0.0032

Table 1.1

1.4 SYSTEM ISSUES AND ALTERNATIVE ACTIONS

Based on initial run of the current system, we observe that the system is inefficient in a couple of grounds that we discuss here. The average time in queue to be served by the manager in this original model is not acceptable. The value of average time in queue is 698.452 Minutes approximately 11.64 hours which is not acceptable and not realistic. Eleven hours is the average of all the customer in the system meaning there can be customers who will have to wait for more than 11 hours, which is more than one working day for a bank. So, our System cannot be implemented in real world. The more time a customer spends in the queue, it will correspondingly cause an increase in the Number of customers in the system that will result in more

Another concern we have here in the system is the Average Time the customer spends in the bank is very large, almost 15 min. Imagine a customer who has come to avail just the ATM Service. The average time of 15 min in the bank is very unrealistic in today's scenario for customer for these types of basic need.

Again 15 min is just an average of these values and a customer may have to wait more than that time for be a small ATM withdrawal. The average time will also determine how many customers are in the system. So, we must reduce the service time and the time in the queue to reduce the average time of a customer in the system.

To overcome these, two new employees will be hired. Adding two new employees will increase the service rate of the stations. However, it must be strategically decided as in where this addition in the network will benefit us in decreasing the average Number of customers in the bank and the average time a customer spends in the bank. So, to decide the optimal allocation of the employees to the servers in order to reduce the average number of customers in the system and the average time a customer spends in the bank, we consider three scenarios. We have potential three server stations in this model where an addition to the number of servers can be done. They are to the Sign-in server station, Teller server station and the Manager server stations. Following are the three scenarios that we will consider.

Scenario 1 is to hire two managers and it is expected to help reducing the wait time to be served by a manager. The average time a customer waits in the queue to be served by the manager is an unrealistic value. Thus, adding Managers will increase the service rate and reduce the wait time as a single queue feeds into these manager servers. Currently we have 2 managers in the System. Scenario 1 aims at making the System a little more realistic. So, the total number of managers in this scenario will be 4

Scenario 2 is to consider increasing a server for sign-in station and a server for manager station. Currently there is one server for the sign-in station. All the customers flowing into this bank network is catered by this single server sign-in station who redirects the traffic according to their need. Increasing the service rate of this station will ensure that customer moves forward quicker in the system and since all the customers visit this station, this scenario may considerably reduce our number of customers in the bank. So, the total number of servers for sign-in station will be two and for the manager station will be three.

In Scenario 3 we will be adding 1 teller and 1 manager. The main idea behind this scenario is that other than ATM service area these are the two service areas where we can improve the efficiency and speed up the process by adding employees. Since employees leaving that either after visiting the teller or manager, we can assume that adding an extra person at one of each service station will speed up the process and reduce the waiting time for the customer to be served by these server stations. So, the total number of servers for teller station is 5 and for manager station is 3.

To select one of these options, we conduct a simulation experiment using the main Simio model presented above. The scenarios will be compared based on how much time a customer spends in the bank (from entrance until leaving) on average, how many customers are present inside the bank on average and on an

average how much time customers spent on ATM, Teller or, Manager queue. Next section explains the details of the simulation experiment and results.

2 SIMULATION STUDY

2.1 EXPERIMENT SETUP

We created 4 scenarios by manipulating initial capacity of the servers. Every scenario would have different combinations of number of servers used in each station. Based on the scenario assigned, the first scenario was the original scenario with given capacity distribution for all the servers. In the next here scenarios, we appended 2 managers, 1 SignIn and 1 Manger, 1 Teller and 1 Manager to the original count respectively. Based on these defined scenarios, we plotted 5 responses against each of them. First response being the time a customer spends in the bank, second was total number of customers in the bank and the third, fourth and fifth were average waiting times in the queues for ATM, Teller and the Manager respectively. We defined these responses by giving appropriate expressions as an input. The scenarios ran over 100 replications and each replication has 27200 seconds warmup period and 272000 seconds run length. We use the warm-up period to deal with the Initial transient Period. Initial transient Period is the amount of time a simulation starts to run and reaches its steady state. To ignore the initial transient period of a model during simulation we use warm up period. This will initialize the model close to the steady state and the model is run long enough to dilute the initial bias caused by including data from the transient period thereby fetching us results of a steady state system. Running the model for more replications may yield us better results. Below table showcases the expressions utilized for all the parameters computed during the experiment

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Parameter	Expression
TimeSpentInBank	0.37 * Type1Customer.Population.TimeInSystem.Average + 0.38 * Type2Customer.Population.TimeInSystem.Average + 0.25 * Type3Customer.Population.TimeInSystem.Average
CustomersinBank	Type1Customer.Population.NumberInSystem.Average + Type2Customer.Population.NumberInSystem.Average + Type3Customer.Population.NumberInSystem.Average
TimeinQueueATM	ATM.AllocationQueue.AverageTimeWaiting
TimeInQueueTeller	Teller.AllocationQueue.AverageTimeWaiting
TimeinQueueManager	Manager.AllocationQueue.AverageNumberWaiting

Table 2.1

2.2 SIMULATION OUTPUT AND DISCUSSION

We have the following results from the experiment we conducted on the Simio. The first row is for the original set up we have with the original number of servers for each station. The reason why we run the original set up in the experimentation set up is to help us to make an unbiased decision about the scenarios by comparing it to the existing system. As we see in the Table 2.2, the time spent in the bank and the average waiting time are not optimal value that can be used to design a real-world model. Scenario 1, 2 and 3(rows 2,3 and 4) are the results we get for the experiments of adding two additional employees at sign-in or manager stations.

	Average Time Spent in the Bank	Average Number of Customers in the bank	Average Time Spent in queue to be served by ATM	Average Time Spent in queue to be served by Teller	Average Time Spent in queue to be served by Manager
Original Set Up	15.1832	16.9168	0.0037	0.0364	698.452
Scenario 1(2 additional Mangers)	4.8730	5.3654	0.0039	0.0415	8.2272

Scenario2(One additional Sign in and a Manger)	4.6191	5.1183	0.0054	0.0447	60.9868
Scenario3 (One additional in Teller a Manger)	5.4425	6.0006	0.004576	0.0045	47.40

Table 2.2: Simio Results (in minutes)

Compared to the Original Set up Scenario 1 was successful in achieving two important positive changes. Scenario 1 reduced the Time spent in the bank by considerably reducing the time spent in the queue while waiting to be served by the manager. Now this is an expected result. This is because putting two additional servers as managers increases the service rate at the manager station. The Original Scenario had the waiting time to be served by the manager as approx. 11 hours which would have been more than one working day of the bank. However, Scenario 1 has reduced this value to 8.22 Min due to the increase service rate which is a very good improvement from the original scenario. This decrease in the waiting time has reduced the overall average time a customer spends in the bank. The lesser time customers spent in the bank the faster they get out of the system thereby reducing the number of customers in the bank. These can be very clearly seen in the SMORE Plots. In the SMORE Plots Scenario 1 will be Scenario 2 as Scenario 1 in the Smore plot is the original set up. In the SMORE Plots we see that there is a considerable improvement in the average time a customer spends in the bank, Number of customers in the Bank and the average waiting time for customers to be served by the manager than the original Scenario

Scenario 2 added an employee at the sign-in employee and a manager. Scenario 2 has reduced the average time the customer spends in the System and the average Number of customers in the system. This is expected. The addition of a sever in the sign-in station caters to the bottleneck that is created at the sign-in station. However, compared to Scenario 1 it has increased the average waiting time in queue to be served by the ATM and the teller. However, what we observe here is that the customers who gets processed at the sign-in may get served faster because of this addition. But it is not reducing their average time in the system but increased the wait time for these to be served by ATM or Teller. Having said that the even though there is an increase in the wait time there is considerable reduce in the average time and Number in system. This is attributed to the bottleneck issue this scenario takes care of.

Scenario 3 we see that the waiting time for the teller has reduced considerably and this was expected as we add one teller to the existing 4 tellers in the system. This increases the service rate of the teller station thereby reducing the queue feeding up to it. Also, we see that the addition of a manger server to the manager station has brought down the waiting time for the manager.

When Scenario 1 and Scenario 2 are compared, we observed that Scenario 2 has lesser average number of customers in the bank and lesser average number time customers spent in the bank. This was expected, as the average number of customers redirected to the manager station is much less than the other stations, adding two servers at the manger station may considerably reduce the average time to be served by the manager but adding a sign-in server and manager server seems to have bought down the average time and Number in system. However, this difference is not much.

When Scenario 1 and Scenario 3 are compared, we see that the average time in system and number in system for scenario 1 is better. This was expected as Manager was a station with the highest and unrealistic wait time. Adding two managers reduces this wait time considerably. The Teller had acceptable amount of wait time which got reduced even more on addition of teller server in Scenario 3 but did not create much impact on the average time in system and number in system.

When Scenario 2 and Scenario 3 are compared, we see that the average time in system and number in system for scenario 2 is better. We see that the Scenario 3 reduces the wait time for ATM, Teller and the Manager than Scenario2, we see that adding a sign-in in Scenario server increases the average number of customers processed at each station thereby reducing the average time in system and number in system. Refer to all the SMORE plots in the appendix section.

2. CONCLUSIONS

We have a banking system that needs to decide the new two employees should be allotted to which of the server stations. The possible server stations where these employees can be allotted are the Sign-in station, Teller Station and Manager Station.

We have three types of customers. The customers arrive exponentially with mean interarrival time of 54.4 seconds to the system whose distribution is defined in the Simio as Random. Exponential(54.4) Thirty-seven percentage of customers visiting the bank are type 1 customers. Also known as customers with base needs. Seventy four percent of these customers tend to be redirected from the sign-in station to the ATM station and twenty six percent of these customers are redirected to the teller station. 38% of customers who visits the bank are type 2 customers. That is, they have moderate needs. 25% percent of these customers

tend to be redirected from the sign-in station to the ATM station and fifty percent of these customers are redirected to the teller station 25% percent of these customers are redirected from the sign-in station to the manager station. 25% of customers visiting the bank are type 3 customers. Also known as customers with advanced needs. 20% of these customers tend to be redirected from the sign-in station to the Teller station and 80% percent of these customers are redirected to the manager station. The service rate of the sign-in station is dependent on the type of customer. We observed that, all three customer types were triangularly distributed for the given SignIn time data. The shape parameters of the triangular distribution were as follows; for Type 1 customer the maximum value was 40.7 and the mode was found at 37.5, for type 2 customer the maximum value was 80.4 and the mode was 35.4. Similarly, we calculated the maximum and mode for Type 3 customers and it came out to be 104 and 78 respectively. ATM, we found the service times to be lognormally distributed too with the shape parameters obtained as 0, 3.69 and 1.02. Now finally for our remaining two servers, that is for the teller and manager, the service time distributions had a Lognormal distribution and the observed shape parameters were 0, 3.69, 1.02 and 0, 4.89 and 1.31 respectively.

We created 4 scenarios by manipulating initial capacity of the servers. Scenario 1 is to hire two managers. Scenario 2 added an employee at the sign-in employee and a manager. Scenario 3 we added a teller employee and a manager employee. The scenarios ran over 100 replications and each replication has 27200 seconds warmup period and 272000 seconds run length.

If we must determine which of these scenarios is the most desirable, the answer is evident. It is scenario two with a sign-in and the manager server as it has the lease average number of customers in the system and least average. However, the optimal scenario is dependent on what is more important to the bank. All these scenarios address the issue we had in the system of very high waiting time for managers that was causing a greater number of customers in the bank and high average of time a customer spends in the bank. So, these scenarios make our system more plausible and realistic as these two aspects have been considerably bought down by our scenarios. However, determining which scenario depends on what's more appealing for the bank. If the average waiting time for manager is the aspect that concerns the bank the most and do not really care about the number in system or time in system, then Scenario one of adding two servers to manager station is optimal.

If the goal of the bank is to reduce the waiting time for the manager station and also maintain an optimal number of customers in the bank and optimal time a customer spends in the bank, then scenario 2 of adding a sign-in server and a manager server seems more plausible.

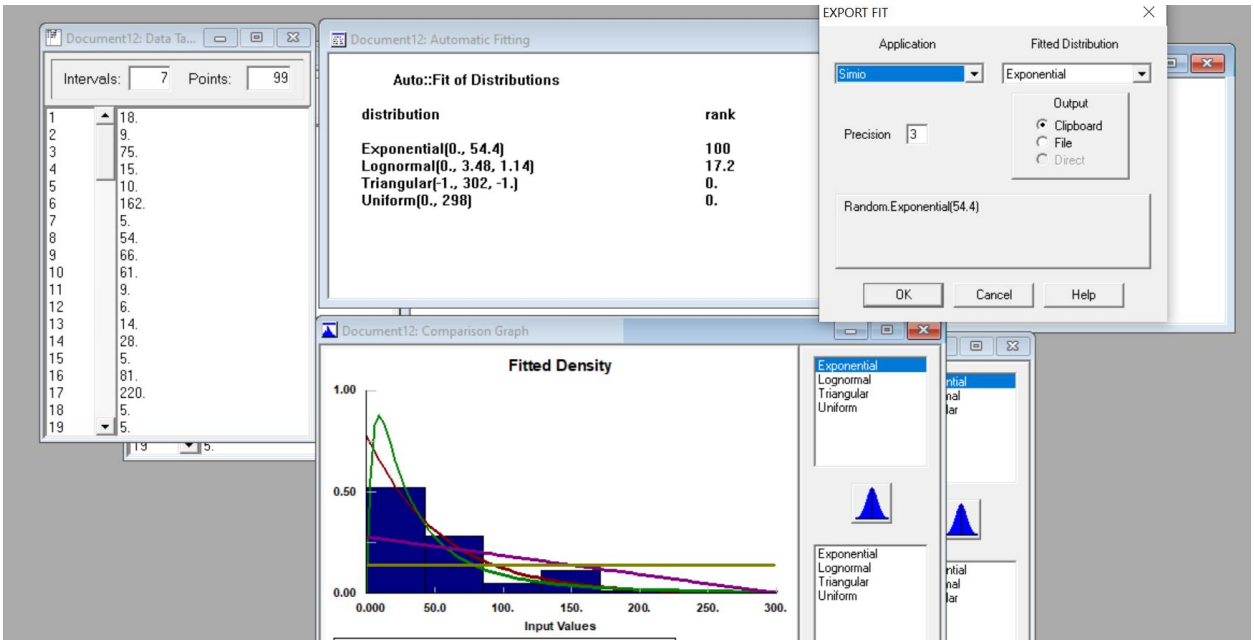
However, if the goal of the bank is to reduce the teller waiting time as that is the station that the majority of the customers visit but at the same time bring down the waiting time for the manager as much as possible the scenario 3 will be the ideal situation.

In the second scenario the average number in system and the time in system is the least and may seem the most plausible situation. However, the ideal scenario is a strategic decision that will depend on the what aspect of the model the bank wants to improve

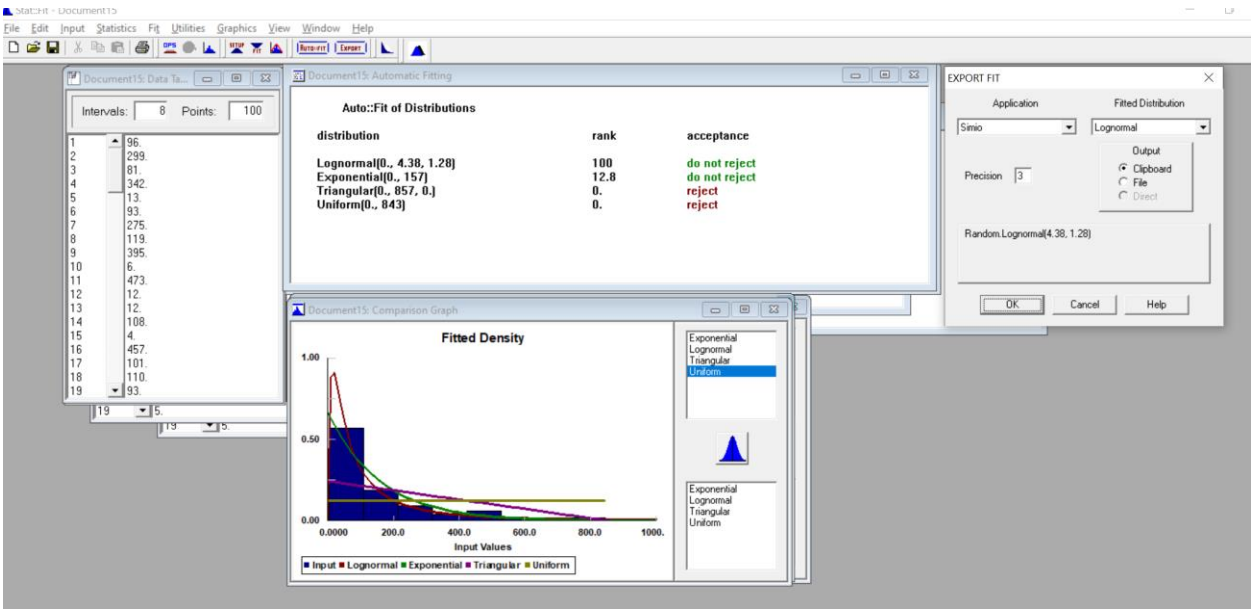
4. APPENDIX

4.1 Interarrival time distributions:

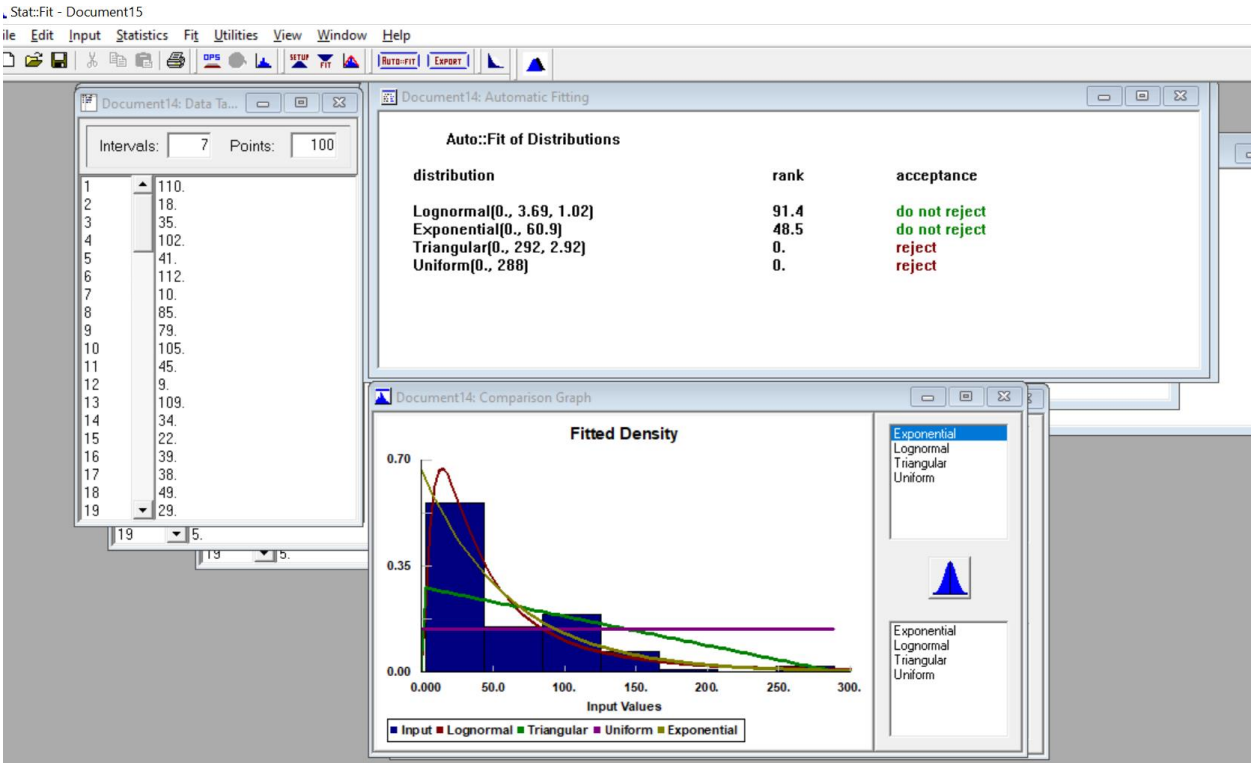
NEXT PAGE



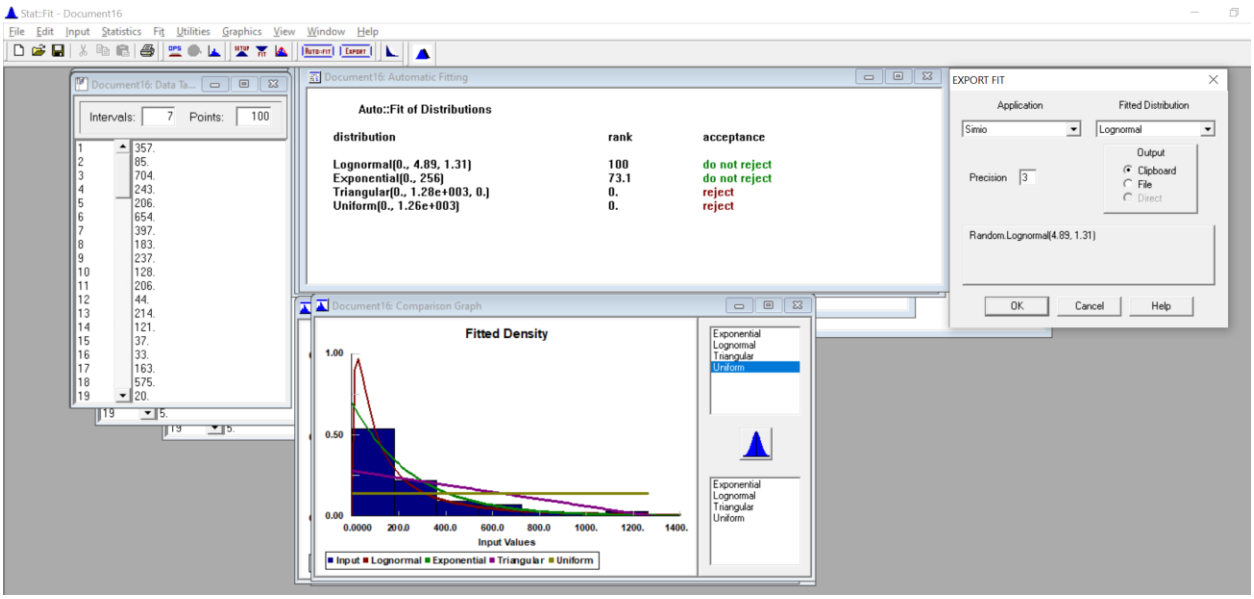
4.2 Teller Service time distributions:



4.3 ATM Service time distributions:

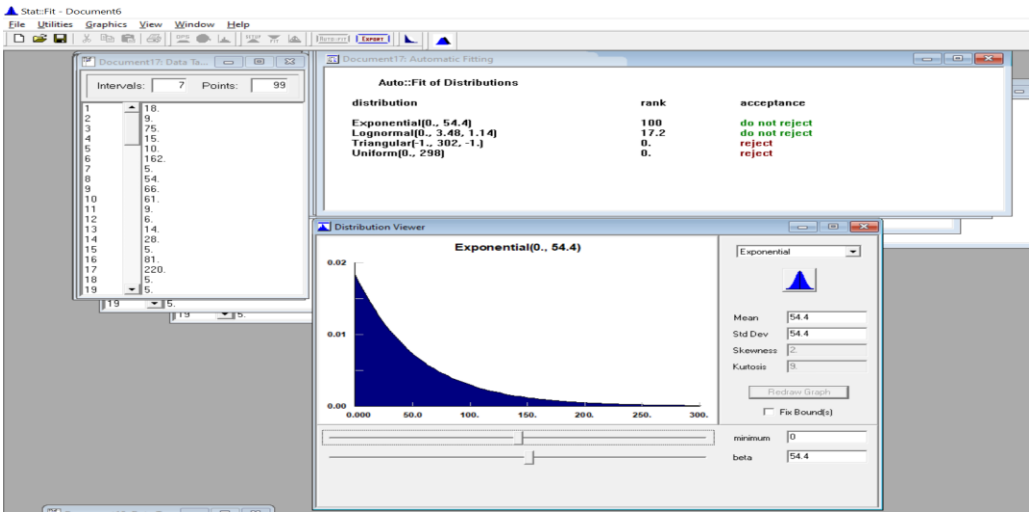


4.4 Manager service time distribution:

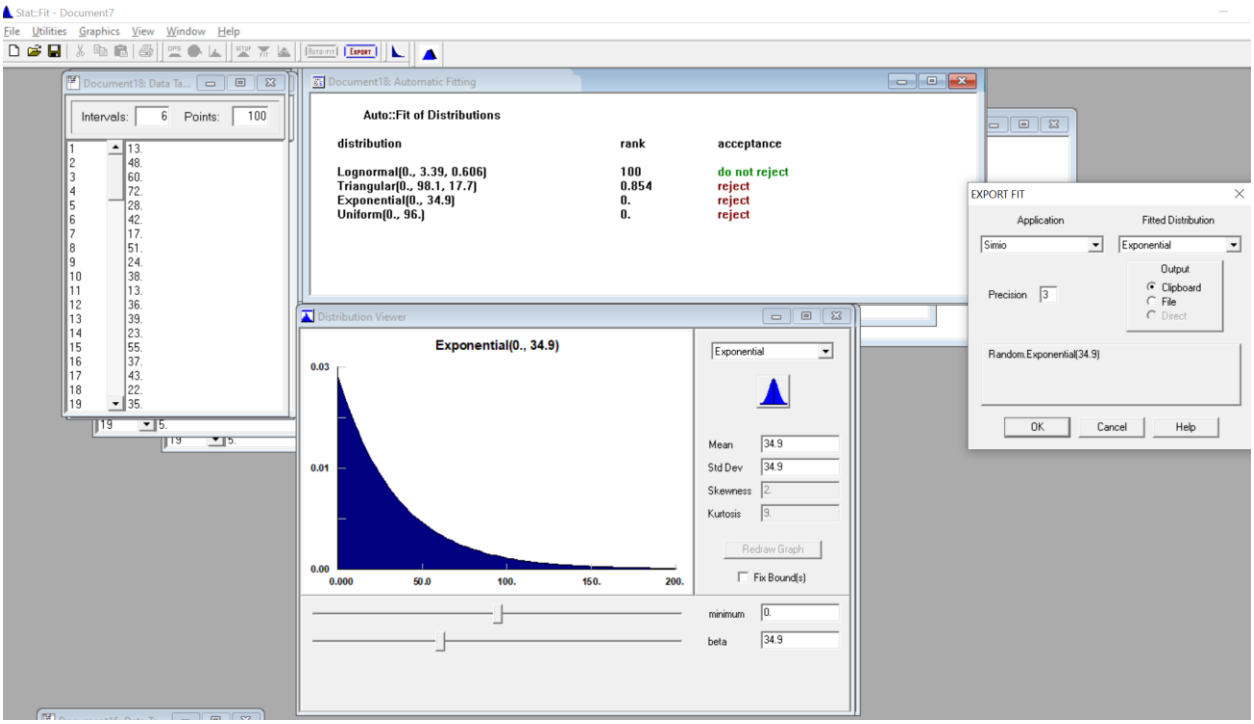


Shape parameters for the verification model:

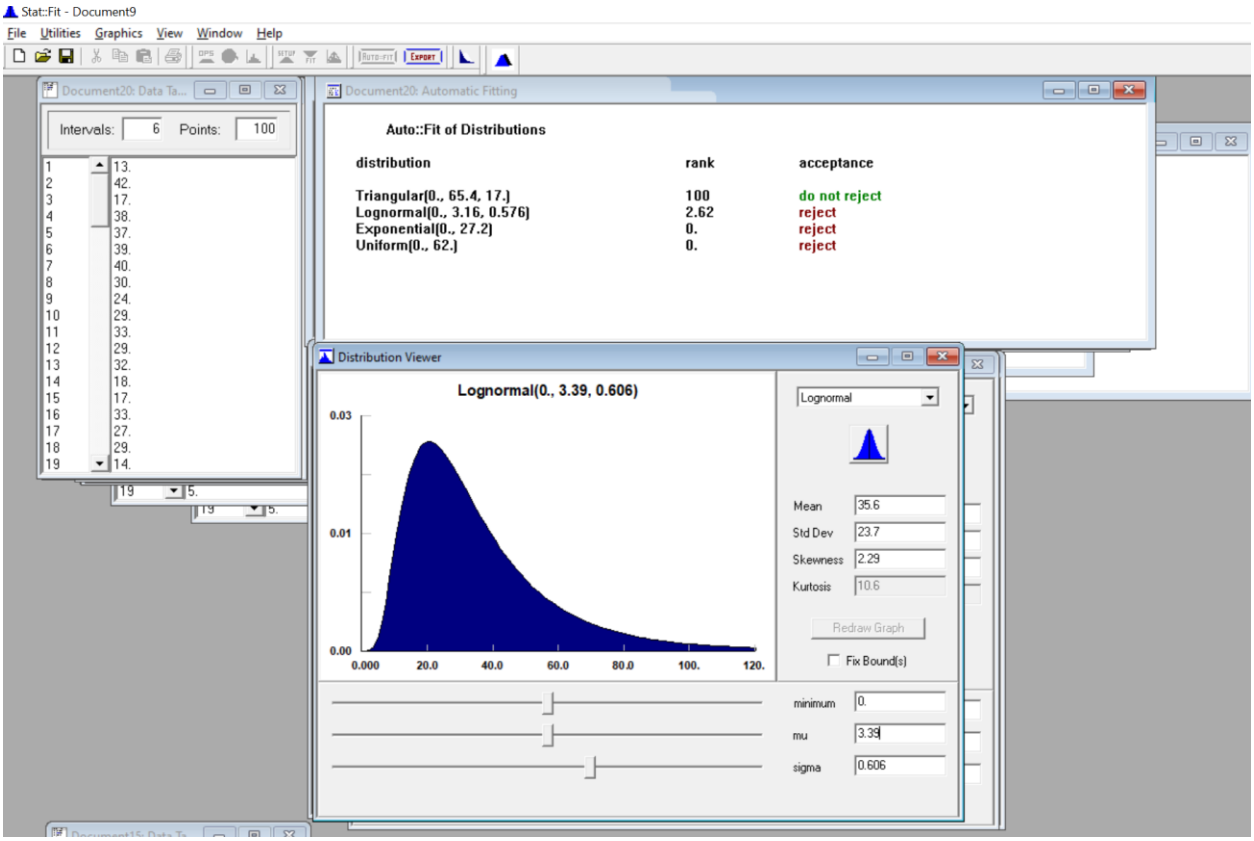
4.5 Interarrival time:



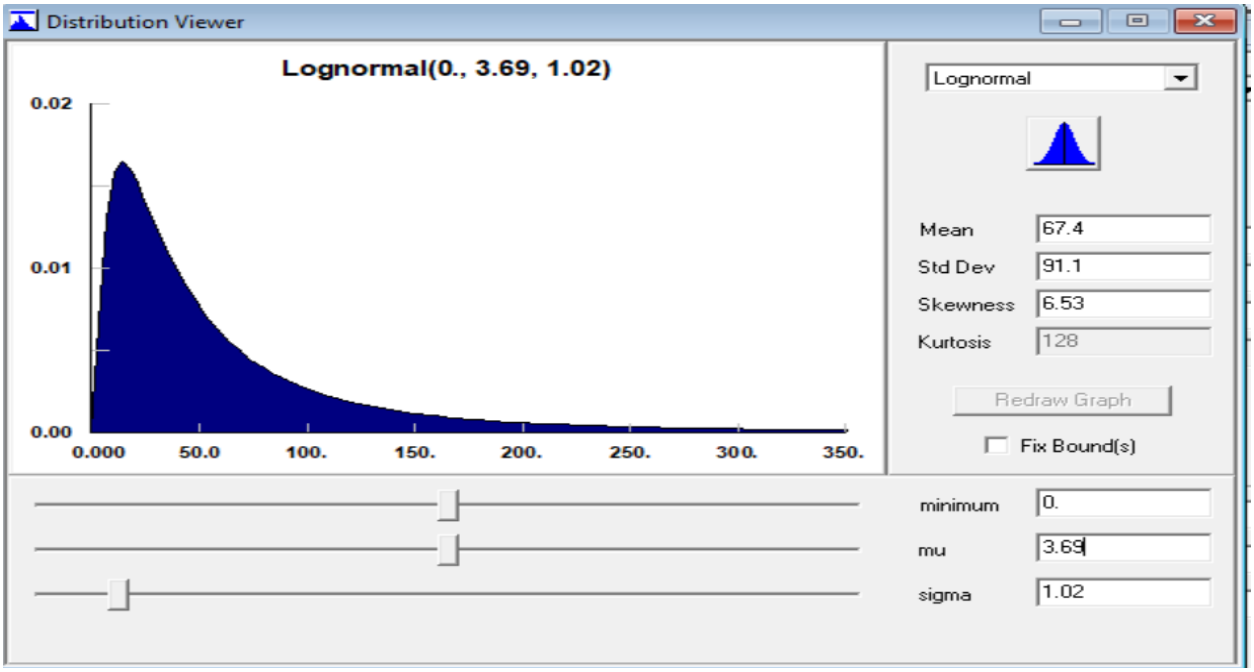
4.6 SignIn Time:



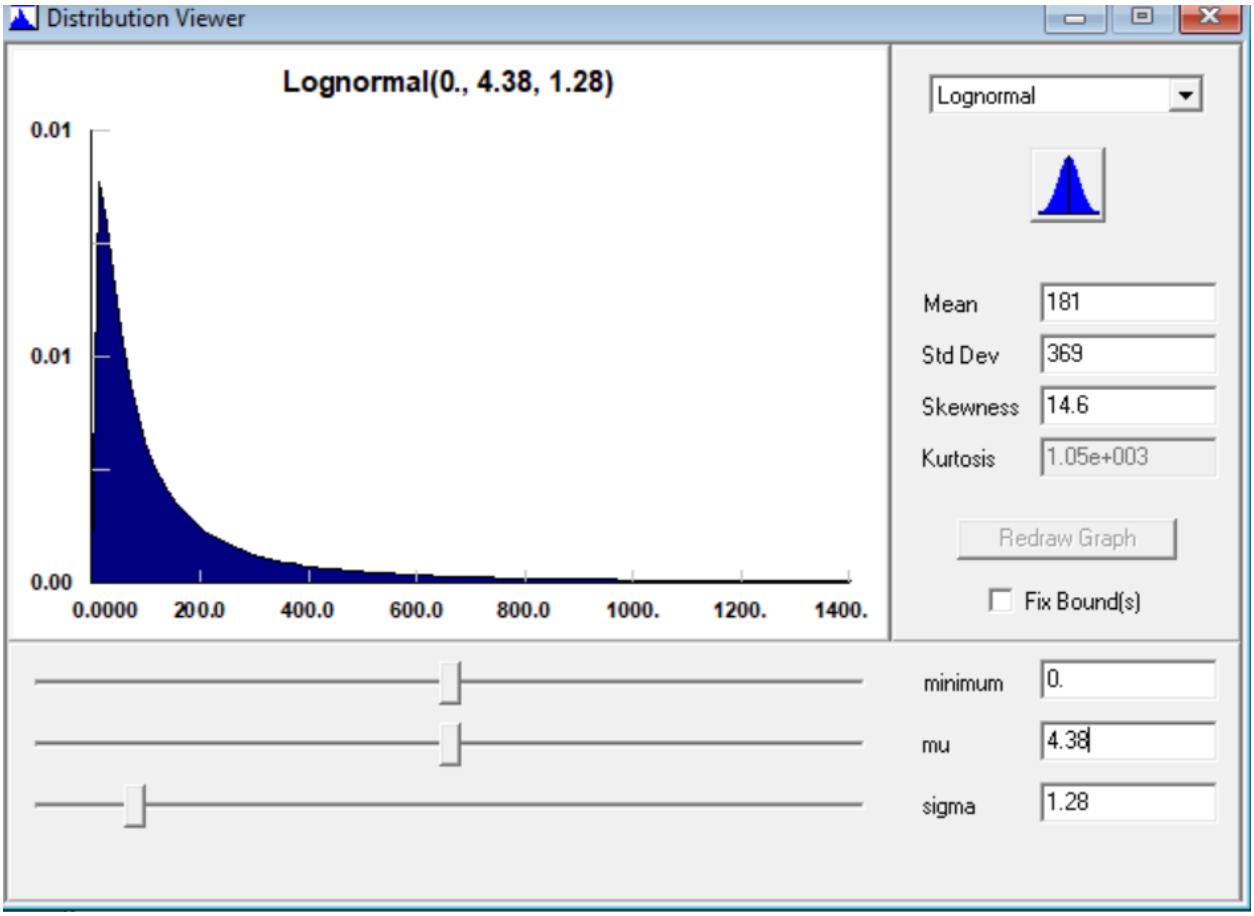
4.7 SignIn Time:



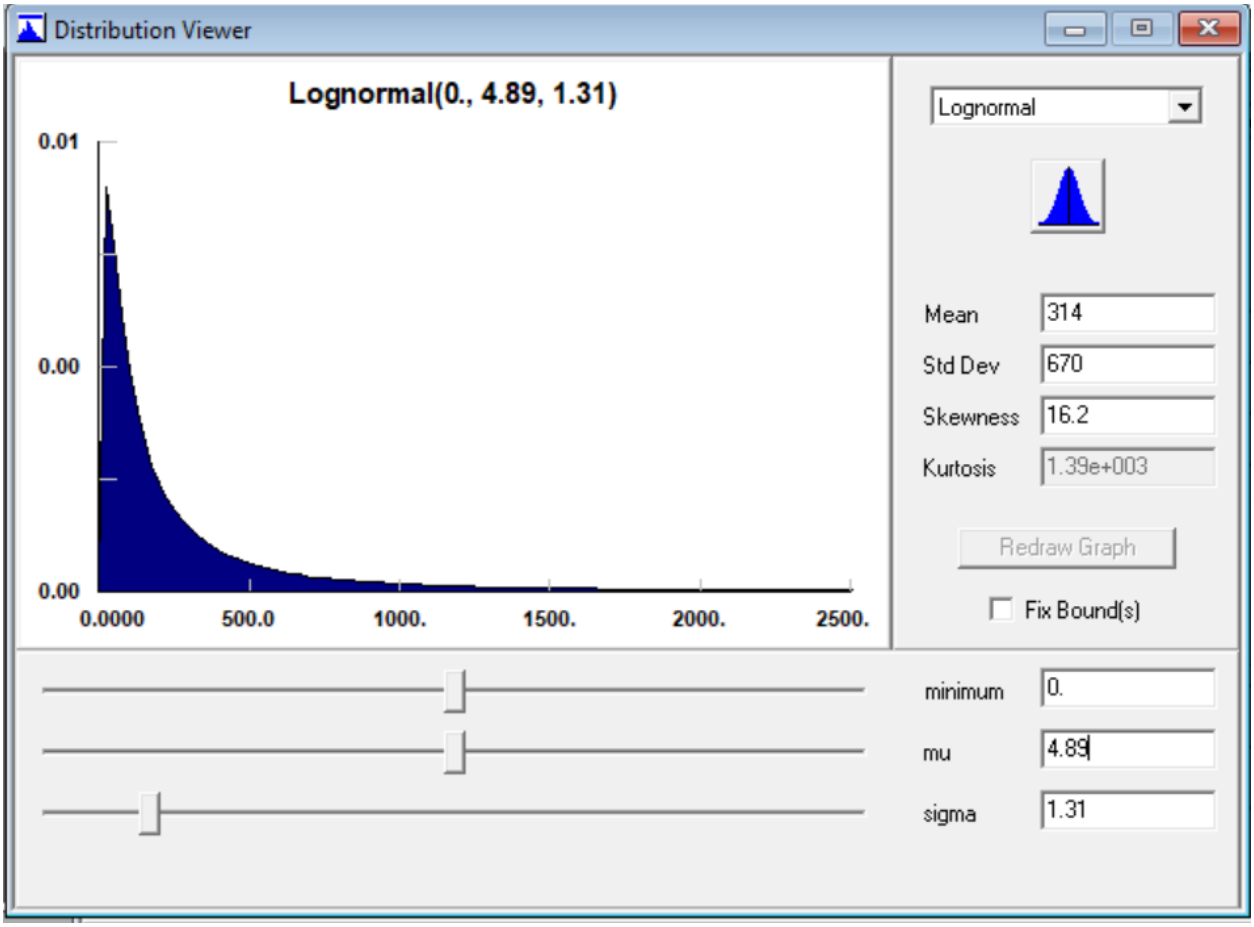
4.8 ATM:


Distribution Viewer
Lognormal(0., 3.69, 1.02)
0.02
0.01
0.00
0.000
50.0
100.
150.
200.
250.
300.
350.
Lognormal
Mean
67.4
Std Dev
91.1
Skewness
6.53
Kurtosis
128
Redraw Graph
Fix Bound(s)
minimum
0.
mu
3.69
sigma
1.02

4.9 Teller:

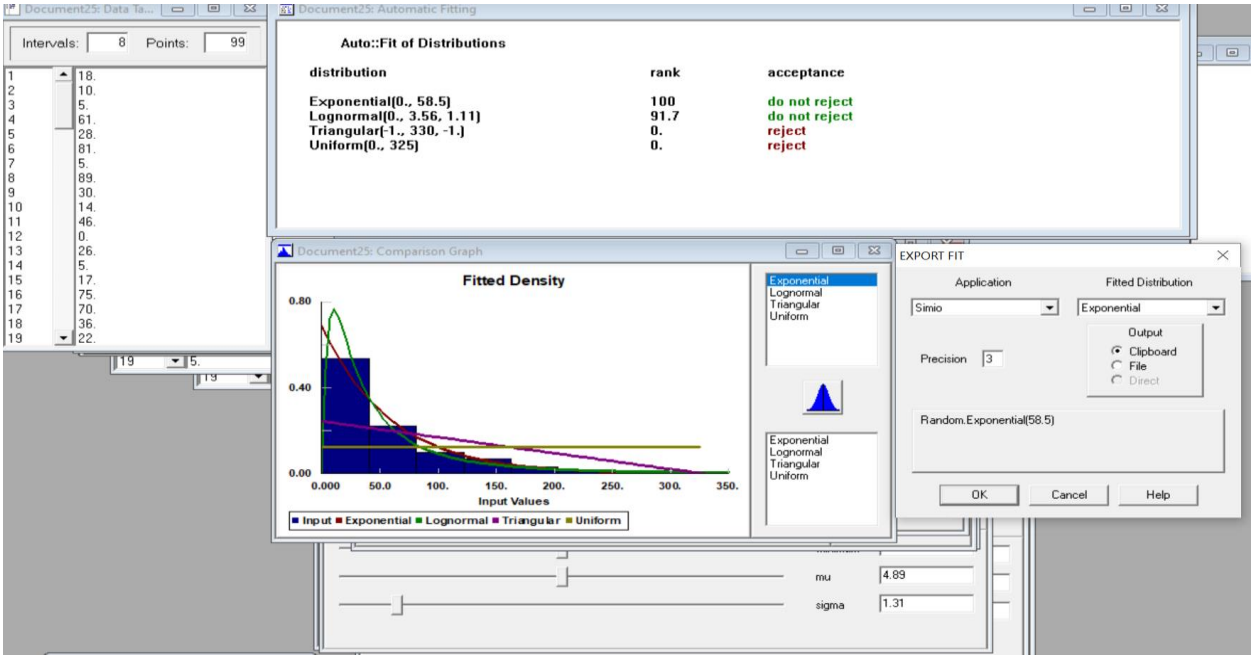

Distribution Viewer
Lognormal(0., 4.38, 1.28)
0.01
0.01
0.00
0.0000
200.0
400.0
600.0
800.0
1000.
1200.
1400.
Lognormal
Mean
181
Std Dev
369
Skewness
14.6
Kurtosis
1.05e+003
Redraw Graph
Fix Bound(s)
minimum
0.
mu
4.38
sigma
1.28

4.10 Manager:


Distribution Viewer
Lognormal(0., 4.89, 1.31)
0.01
0.00
0.00
0.0000
500.0
1000.
1500.
2000.
2500.
Lognormal
Mean
314
Std Dev
670
Skewness
16.2
Kurtosis
1.39e+003
Redraw Graph
Fix Bound(s)
minimum
0.
mu
4.89
sigma
1.31

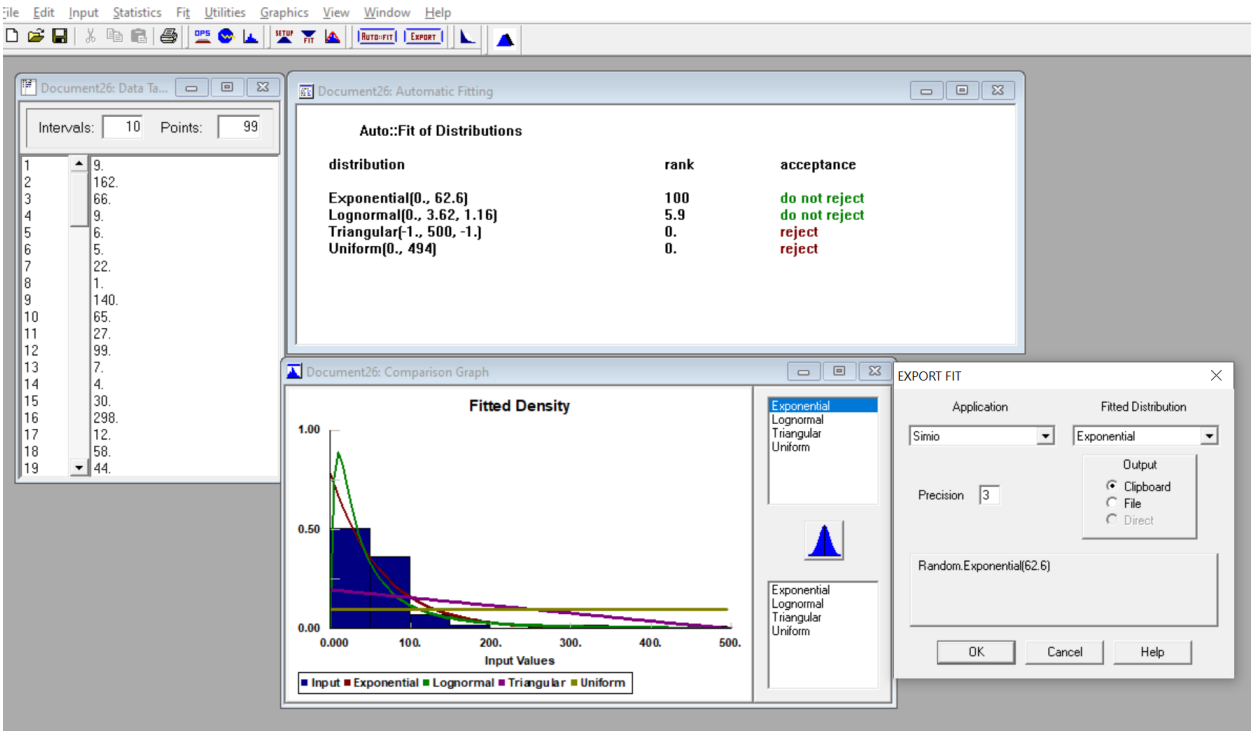
Interarrival Times for:

4.11 Type1 Customer:

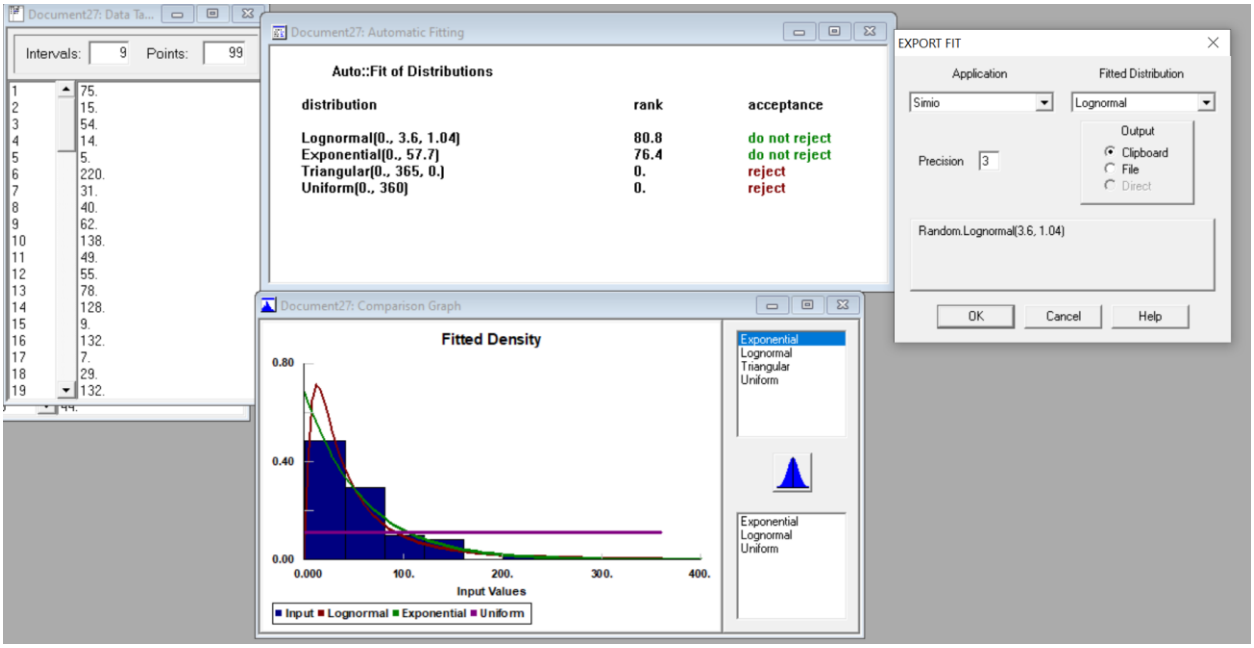


4.12 Type2 Customer:

NEXT PAGE

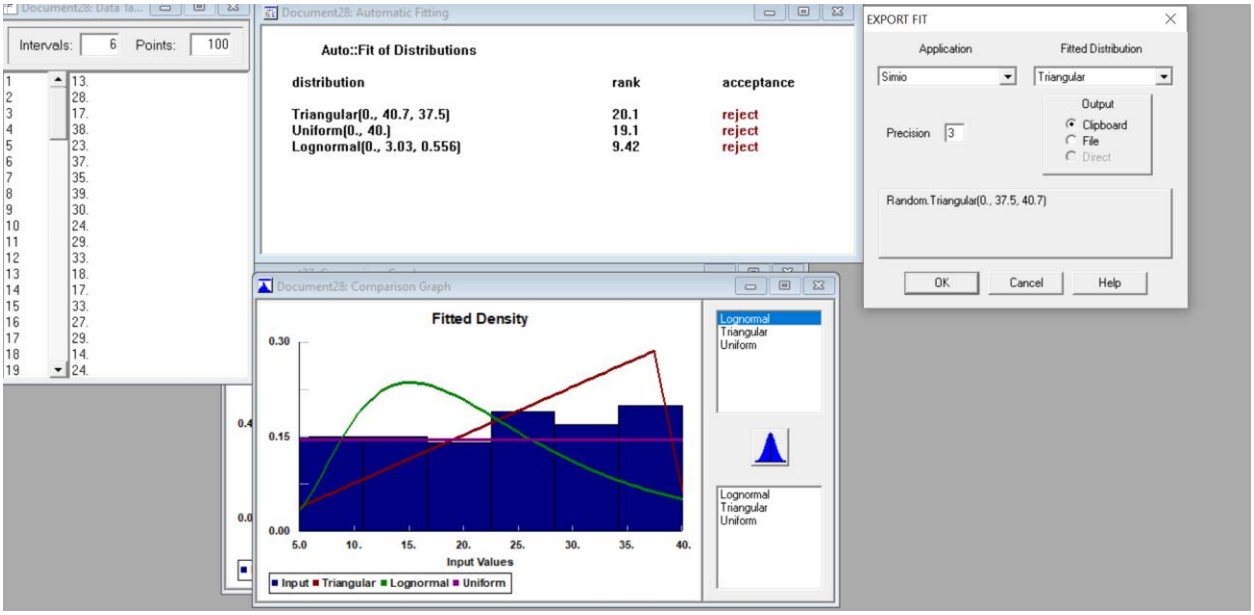


4.13 Type3 Customer:

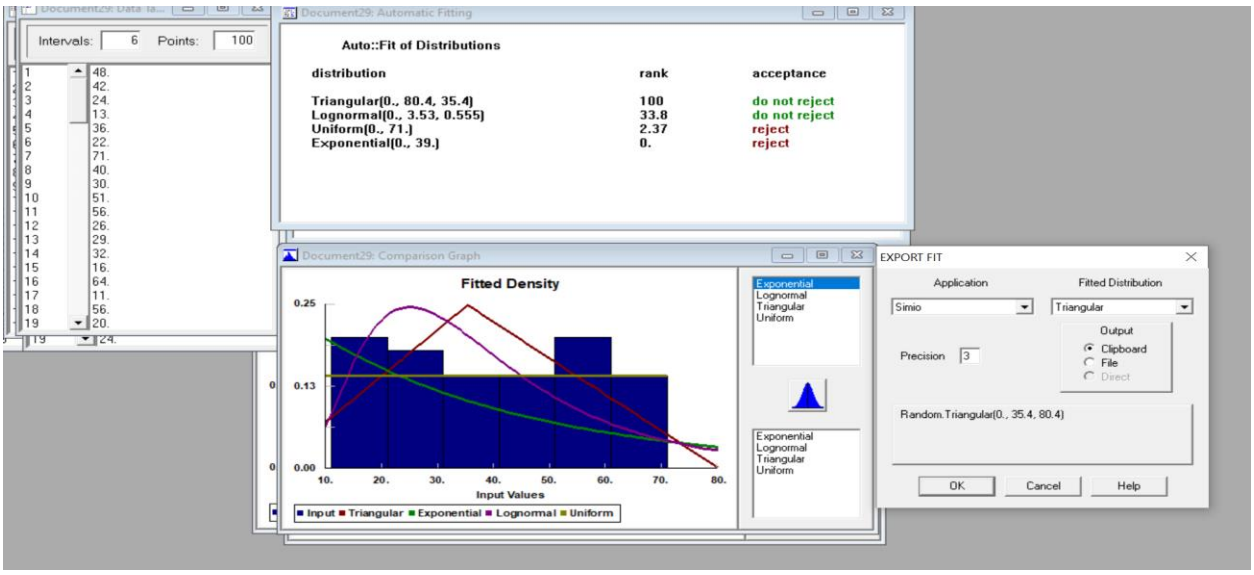


Sign In Time distributions for:

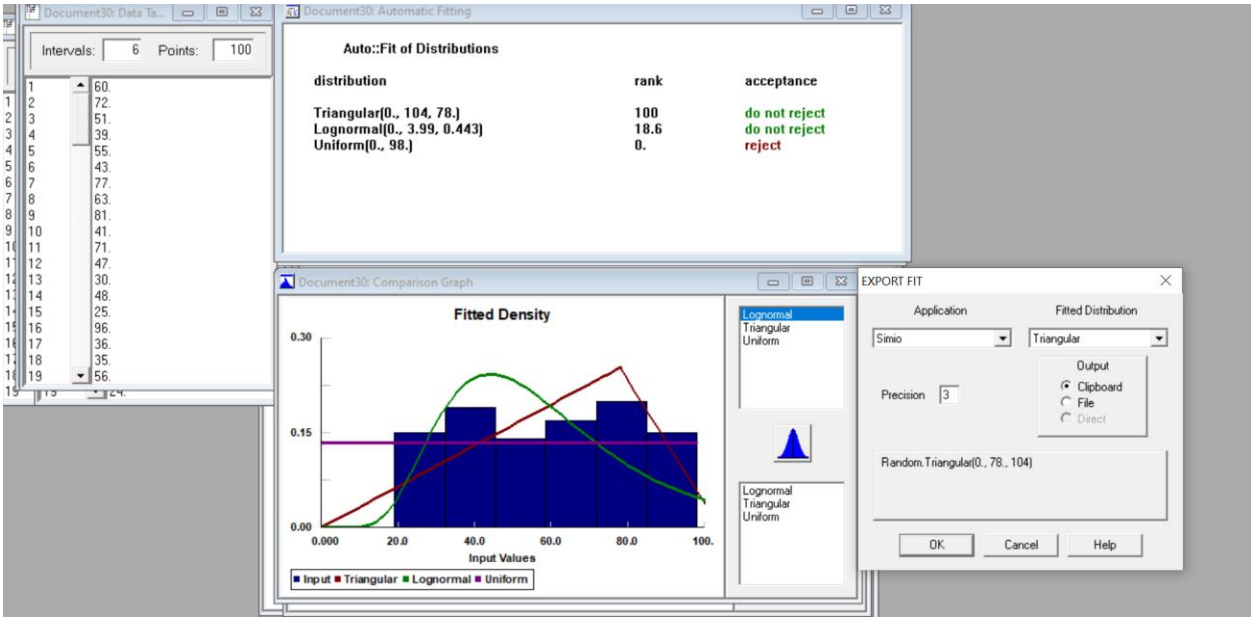
4.14 Type1Customer:



4.15 Type2 Customer:

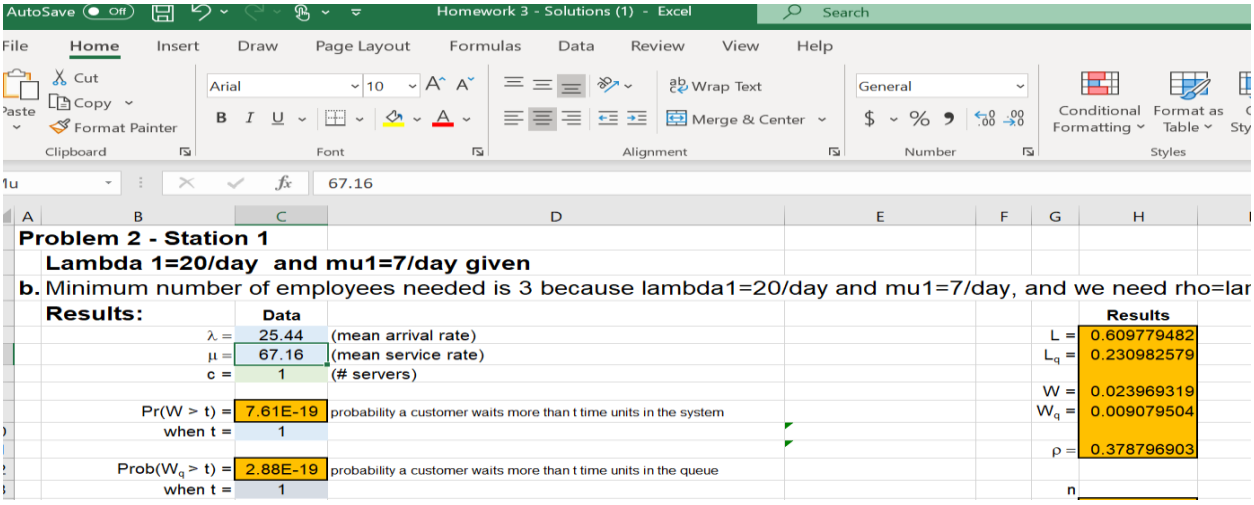


4.16 Type3 Customer:



Model Verification Values:

4.17 Sign In



4.18 ATM:

Results:	Data			Results
λ =	6.36	(mean arrival rate)	L =	0.119089577
μ =	53.41	(mean service rate)	L_q =	1.0753E-05
c =	3	(# servers)		
			W =	0.018724776
Pr(W > t) =	6.37E-24	probability a customer waits more than t time units in the system	W_q =	1.69072E-06
when t =	1			
			ρ =	0.039692941
Prob(W_q > t) =	3.89E-71	probability a customer waits more than t time units in the queue		
when t =	1		n	

4.19 Teller:

5 Minimum number of employees needed is 5 because lambda3=12/day and mu3=3/day, and we need rho=rho=

Results:	Data			Results
λ =	12.72	(mean arrival rate)	L =	0.640369464
μ =	19.8894	(mean service rate)	L_q =	0.000832827
c =	4	(# servers)		
			W =	0.050343511
Pr(W > t) =	2.31E-09	probability a customer waits more than t time units in the system	W_q =	6.54738E-05
when t =	1			
			ρ =	0.159884159
Prob(W_q > t) =	4.11E-32	probability a customer waits more than t time units in the queue		
when t =	1		n	

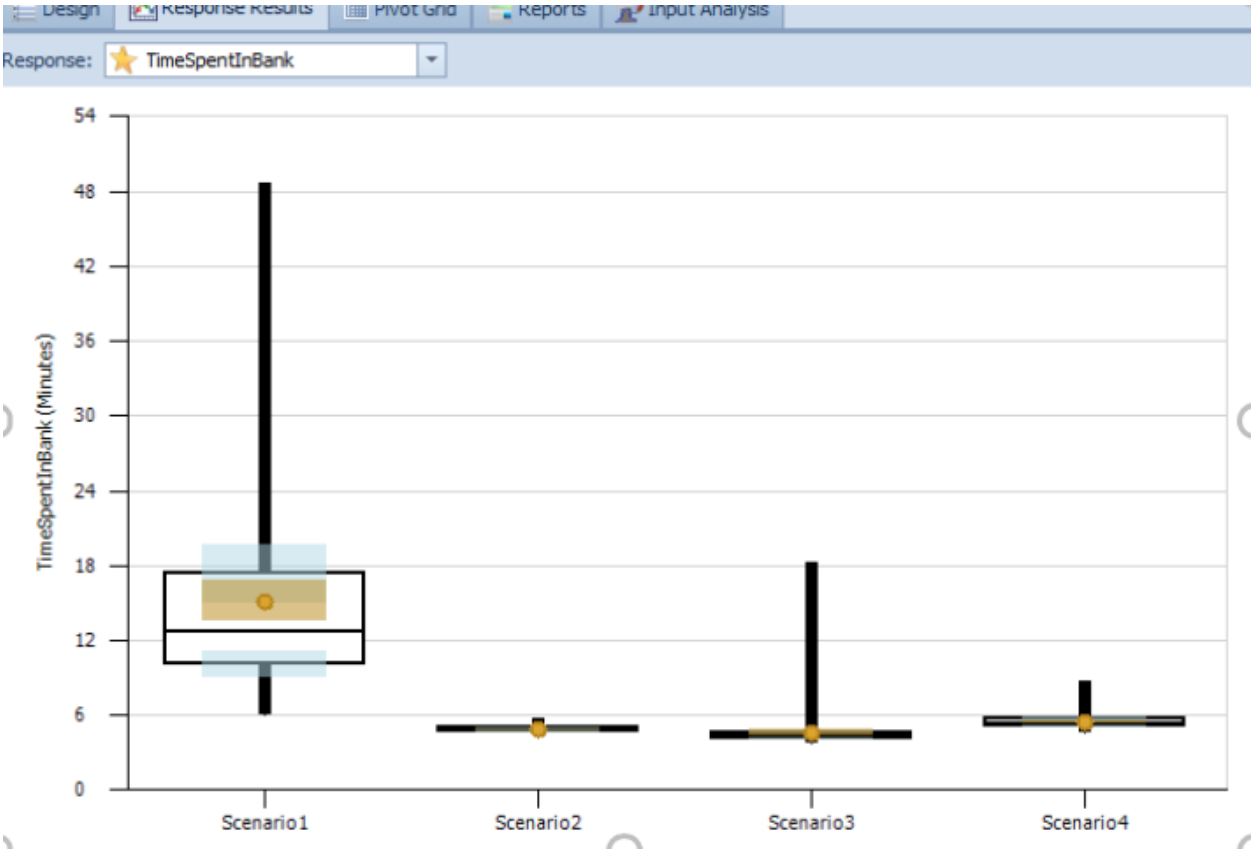
4.20 Manager:

Results:	Data			Results
λ =	6.36	(mean arrival rate)	L =	0.600971263
μ =	11.4649	(mean service rate)	L_q =	0.046234632
c =	2	(# servers)		
			W =	0.094492337
Pr(W > t) =	1.33E-05	probability a customer waits more than t time units in the system	W_q =	0.007269596
when t =	1			
			ρ =	0.277368315
Prob(W_q > t) =	7.67E-09	probability a customer waits more than t time units in the queue		
when t =	1		n	

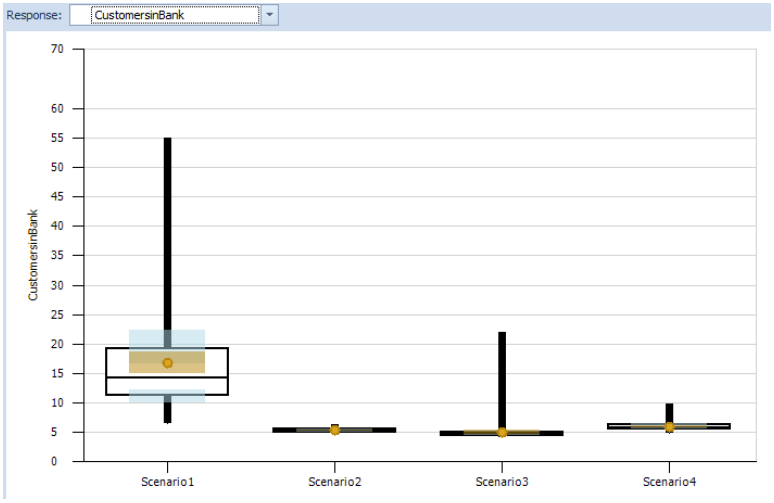
4.21 Total value evaluation:

For each station:				
L1=	0.609779	for station 1		
L2=	0.600971	for station 2		
L3=	0.640369	for station 3	L4=	0.11909
For the network:				
L=	1.97021	for the network		
W=	0.077445	for the network		

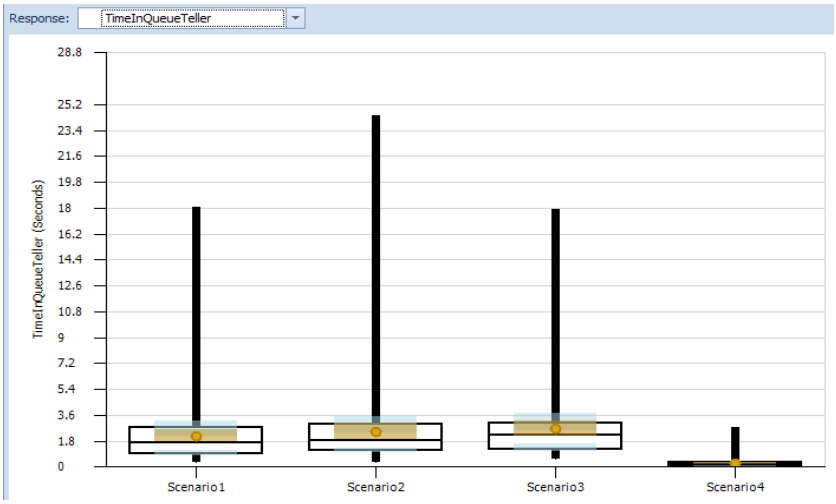
4.22 Average time customer spends in the bank



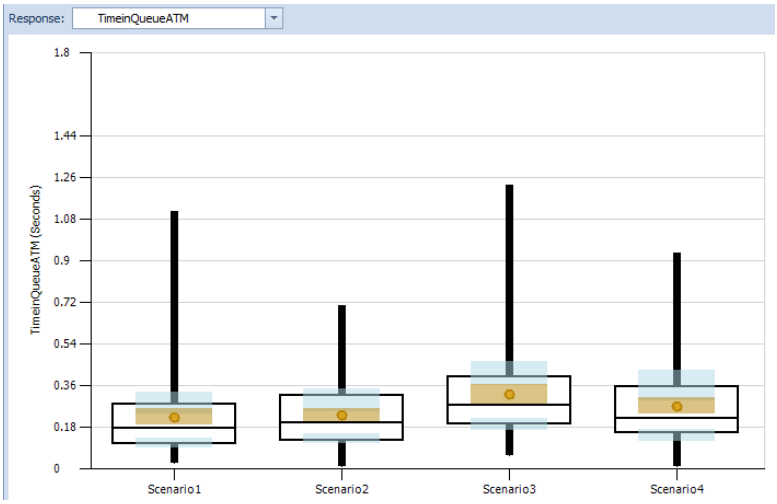
4.23 Average number of customers in the bank



4.24 Average time customer is in queue for teller



4.25 Average time customer is in queue for ATM



4.26 Average time customer is in queue for Manager