**PROJECT 03**

FORECASTING AND SIMULATION

QMST – 5335- 252

**TEAM 06**

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**FIRST SECTION:**

**System**: This is a JACKSON network where we have a Bank, and we are required to direct the customer to ATM or Teller station from the SignIn station. We have 3\* M/M/C network.

**Model Entity:** In Simio, a "model entity" refers to a dynamic object that moves around within the simulation model, interacting with resources, processes, and other entities according to the rules defined by the user. Entities in Simio can represent various items such as customers, parts, products, or even information packets, depending on what the simulation is modeling. In our project our model entity is

**Customer**: We have two types of Customers in our model: *Basic needs customer and Moderate needs customer.*

**Source**: In Simio, a “Source” is a fundamental object used within simulation models to generate or introduce entities into the system at specified times or under specified conditions. It essentially acts as the entry point for entities and is crucial for starting the flow of processes in most simulations. We have one source in our model which is the entry point for both type of customers.

**Server**: In Simio, a “Server” is a fundamental simulation object used to model a variety of processing tasks or services within a simulation model. It represents a point in the system where entities undergo some form of processing, which could range from a simple task to complex sequences of actions. The Server object is crucial for defining and simulating the capacity and functionality of different parts of a modeled system, such as assembly stations, checkout counters, or medical examination rooms.

We have 3 server stations in our model: *SignIn station, ATM station and Teller station.*

**Sink:** In Simio, a “Sink” is a simulation object used to remove entities from the model, effectively serving as an endpoint for those entities within the system. The Sink is essential for representing the completion of an entity's lifecycle in a simulation, such as the exit of a customer from a system, the end of a production process, or the disposal of waste. We have 2 Exit points in our model from where the entities exit or are destroyed.

**Connector:** In Simio, a “Connector” is an object used to establish connections between different simulation objects within a model. Connectors play a crucial role in defining the flow of entities and resources within the simulation environment, facilitating interactions between various components such as Servers, Queues, Sources, Sinks, and other custom objects.

**Interarrival Time:** It is the rate at which model entities arrive in the system. It is also referenced by Lambda (λ). The Interarrival of customers in our system = lambda = 57.5 seconds. Therefore, customers arrive at the average rate of 57.5 seconds each.

**Service Rate:** Service rate is the time spent by the customer in one server station. It is also referenced as Meu (μ). The Service rate of SignIn station is customer type dependent. The Service rate of ATM and Teller station is independent of customer type.

**Flowchart of our Model**

A diagram of a machine

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Figure 1

**Data Analysis**:

The data table consists of 5 columns and 2 rows, which detail specific attributes and behaviors of two customer types in a simulation model: (In reference to figure 2.1 in Appendix- II)

**Columns:**

* Customer Type: Identifies the type of customer, either Basic or Moderate.
* Customer Mix: Indicates the percentage each customer type represents of the total customer base.
* Perc directed to ATM: Shows the percentage of customers from each type that are directed to use ATMs.
* Perc directed to Teller: Shows the percentage of customers from each type that are directed to use teller services.
* Sign-In (Seconds): Describes the distribution used to model the sign-in time for each type of customer, with specific statistical distributions provided for each.

**Rows:**

* First Row: Corresponds to the Basic Customer, detailing their mix in the customer base, their likelihood of being directed to ATMs or tellers, and their sign-in time distribution.
* Second Row: Pertains to the Moderate Customer, providing similar data points as for the Basic Customer but adjusted for the traits typical of this customer type.

1. The Interarrival Time distribution is 57.5 seconds. Each customer arrives at an average of 57.5 seconds.
2. The average percentage of customers being Type 1 i.e. basic needs customer is 12% and the average percentage of customers being Type 2 i.e. moderate needs customer is 88%.
3. The distribution of SignIn time for type 1; basic needs customer is: Random.Lognormal(7.11, 8.9e-003) seconds and distribution of SignIn time for type 2; moderate needs customer is: Random.Triangular(2.8, 53., 61.7) seconds.
4. From SignIn station 78% and 22% of basic needs customers are directed to ATM station and Teller station respectively. While 27% and 73% of moderate needs customers are directed to ATM station and Teller station respectively.
5. The distribution of service time at ATM station which is independent of customer type is Random.Exponential(46.2) i.e. 46.2 seconds per customer. The distribution of service time at Teller station which is independent of customer type is Random.Exponential(61.2) i.e. 61.2 seconds per customer.

**Simio Model Overview**: Our model has a warmup time of 28750 seconds and run length of 287500 seconds. There is a SignIn station with 1 server and an ATM station with 3 ATM machines and a Teller station with 4 Teller in the system. Our customers are of two types: basic needs customers and moderate needs customers.

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Figure 1

**Below is a criticism of the existing system based on the first run:**

To criticize the current system based on the initial run of the simulation, we can highlight a few key areas for improvement:

* **Resource Limitation at SignIn Station:** The initial setup includes only one SignIn station. This single point of entry becomes a significant bottleneck, especially given the high interarrival rate of customers (every 57.5 seconds). The data shows that the SignIn station's service rate is dependent on customer type and varies widely. This setup leads to significant delays, particularly when handling moderate needs customers whose service time can range up to 61.7 seconds.
* **Imbalance in Service Rate and Customer Type Distribution:** The system is primarily serving moderate needs customers (88% of the customer base), yet the service setup at the SignIn station is not optimized for the longer service times required by these customers. This mismatch between customer type distribution and service capability at critical points (SignIn station) causes inefficiencies in throughput and increases the average time customers spend in the system.
* **Underutilization of ATM and Teller Stations:** While the ATM and Teller stations have relatively high service rates, the single bottleneck at the SignIn station prevents these resources from being used effectively. The result is that even though the ATM and Teller stations could handle more transactions per unit time, they are underutilized due to upstream delays.
* **Lack of Flexibility in Customer Routing:** The system's routing rules—78% of basic needs customers to the ATM and 73% of moderate needs customers to the Teller station—may not optimally reflect the actual service requirements or preferences of these customer groups. This rigid routing could lead to suboptimal usage of the ATM and Teller stations, depending on actual demand variations during operation.
* **Inadequate Preparation for Peak Times:** The simulation's initial run does not seem to account for peak demand times, which could overwhelm the system, especially with only one SignIn station. During such times, the extended waiting times could significantly degrade customer experience and efficiency.

Overall, the critique highlights that the system's initial design does not sufficiently accommodate the high volume and varying needs of its customers, primarily due to limited entry points and inflexible customer routing. Adding more SignIn capacity and adjusting customer routing rules could significantly improve system performance.

**SECOND SECTION**

We can create different experiments and run different scenarios to see if our model performs better or worse. Based on the response created we can compare these scenarios to conclude what changes to the system will yield our desired result. In this project in addition to the current scenario of 1 SignIn station, 1 ATM station with 3 ATM machines and 1 Teller station with 4 Tellers we will create 2 scenarios:

1. We will add 1 more SignIn employee and we will add 1 more ATM machine to the current system.
2. We will add 2 more tellers in the Teller station.

These scenarios of adding additional servers to individual stations will yield better results in terms of average number of entities in system and average time an entity spends in the system.

* We experimented with 2 additional scenarios increasing the number of ATM machines or increasing the number of Tellers in the system.
* We also created a replication of 100 for each scenario to run for the run length.
* The warmup period for the experiment is 500 times the interarrival times which is 28750 seconds.
* The run length for the experiment is 5000 times the interarrival times which is 287500 seconds.
* The scenarios in the experiment are measured or compared based on statistics such as average number of customers in system and average time a customer spends in the system.

**Results**

The outcomes of the experiment, conducted over 100 replications with a warmup period of 28,750 seconds and a total run length of 287,500 seconds, are summarized below. (In reference to figure 2.2 in Appendix- II)

* Scenario 1: which is the current scenario; Under the given conditions and circumstances the average number of customers in the system are 1869 and the average time a customer spends in the system is 59 seconds.
* Scenario 2: The average number of customers in the system under scenario 2 is the Lowest of all their scenarios which is 1005 and the average time a customer spends in the system under scenario 2 is 32 seconds which is the Lowest time of all scenarios.
* Scenario 3: The average number of customers in the system under this scenario is 1873 which is like the current scenario or the 1st scenario and the average time a customer spends in the system is 59 seconds which is also very similar to that of Scenario.

In conclusion, the experiment’s results (In reference to figure 2.2 in Appendix- II), proves that if we increase the employee number of SignIn station to 2 and of the ATM machines to 4 having 4 Tellers we will get the least time for a customer to spend in system.

*SMORE Plot:*

The SMORE plot displays average customer times across three scenarios in a simulation study, highlighting the effectiveness of resource allocation strategies: (In reference to figure 2.3 in Appendix- II)

* Scenario 1: Displays a higher median time of around 60 seconds with a wide variability, indicating inconsistent performance.
* Scenario 2: Shows a significant reduction in median time to about 32 seconds with a narrow interquartile range, suggesting consistent and improved efficiency.
* Scenario 3: Mirrors Scenario 1 in median time and variability, indicating that the changes implemented did not enhance performance significantly.

In conclusion, the plot clearly indicates that Scenario 2's strategic resource additions (like extra SignIn employees or ATM machines) provide substantial improvements in reducing system congestion and enhancing customer experience.

**Recommendation:**

Based on the analysis of the data table detailing customer distribution and service direction in your simulation model, here are some tailored recommendations to potentially enhance the efficiency and customer satisfaction of the simulated system:

Adjust Resource Allocation: Since a significant majority of Moderate Customers (88%) prefer teller services, consider increasing the number of tellers available to reduce wait times and improve service efficiency. This adjustment should particularly focus on peak hours when traffic is highest.

For Basic Customers, who predominantly use ATMs (78%), ensure that ATMs are optimally placed and perhaps increase the number of ATMs available to accommodate peak demands, preventing long queues.

Refine Customer Routing Logic: Evaluate the routing logic that directs such a high percentage of Moderate Customers to tellers. Implementing a more dynamic routing system that can assess real-time transaction complexity and customer preferences might distribute the load more evenly across ATMs and tellers.

Optimize Sign-In Processes: Given the distribution used for sign-in times (log-normal for Basic and triangular for Moderate Customers), consider whether simplifying or speeding up the sign-in process is feasible. For example, introducing more automated, self-service sign-in kiosks could reduce bottlenecks.

Regularly review the parameters defining the sign-in time distributions to ensure they remain accurate and reflective of real-world conditions. Adjustments to these parameters could lead to improved flow and reduced system congestion.

**A discussion of anticipated outcomes follows:**

After analyzing the simulation with the addition of two different scenarios, the results observed are largely as expected due to the following considerations:

*Scenario 2 (Addition of One SignIn Employee and One ATM Machine):*

Expected Improvement: This scenario involves increasing the capacity at both the initial point of entry (SignIn station) and a subsequent transaction point (ATM station). By adding an extra employee at the SignIn station, the bottleneck is alleviated, allowing more customers to be processed faster. Similarly, adding another ATM machine increases the processing capacity at this station.

Results: As observed, this scenario yielded the lowest average time a customer spends in the system (32 seconds) and the lowest average number of customers in the system (1005). These improvements are expected because enhancing service capacity at these critical points reduces waiting times and system congestion, thereby optimizing the flow of customers through the system.

*Scenario 3 (Addition of Two More Tellers at the Teller Station):*

Expected Outcomes:Increasing the number of tellers aims to address potential delays at the Teller station, which is particularly critical for moderate needs customers who predominantly use this station as per the system’s routing rules.

Results: The results show that the average number of customers in the system (1873) and the average time a customer spends in the system (59 seconds) are very similar to the initial scenario (Scenario 1). This suggests that while increasing teller capacity does help in processing more transactions, it does not significantly impact the overall system performance as much as addressing the initial bottleneck at the SignIn station.

**Overall Analysis:**

The significantly better performance of Scenario 2 over Scenario 3 highlights the critical importance of addressing bottlenecks at the earliest point of customer interaction—in this case, the SignIn station. This station's role as the primary entry point into the system makes its efficiency crucial for the overall flow and effectiveness of the service process.

Scenario 3’s results, while improving the capacity at the Teller station, did not show as dramatic an improvement as Scenario 2, indicating that without alleviating the upstream bottleneck, downstream improvements have a limited impact on system-wide efficiency.

The observed outcomes from the different scenarios align well with expectations based on this principle.

**APPENDIX- I**

Here’s a brief overview of the dataset provided:

* *Customer i:* Sequential identifier for each customer.
* *Time Between Customers i and i-1:* Time interval between the arrival of consecutive customers.
* *Customer Type:* Type of customer (e.g., 1 for Basic needs, 2 for Moderate needs).
* *Sign In Time (seconds):* Time spent by the customer at the SignIn station. Dependent on Customer Type.
* *Directed To:* Indicator of whether the customer was directed to the ATM (1) or Teller (2).
* *Service Time (seconds):* Time spent by the customer at the service station (ATM or Teller).

**Customer Type Distribution:**

* Type 1 (Basic needs): 60 customers, representing approximately 12% (approx.) of the total.
* Type 2 (Moderate needs): 440 customers, representing approximately 88 % (approx.) of the total.

**Customer Routing Analysis**

|  |  |  |
| --- | --- | --- |
| Routing Overview | Customers Basic needs  (Type 1) | Customers Moderate needs (Type 2) |
| ATM | 47 customers (78 %) | 118 customers (27 %) |
| Teller | 13 customers (22 %) | customers (73 %) |

We were able to enter the following expressions and values into the Simio model by using the Stat Fit tool:

* Teller Service time: Random. Exponential (61.2)
* ATM Service time: 1. +Random. Exponential (46.2)
* Interarrival time: Exponential (0., 57.5)
* SignInCustomer1: -1. 19e+003+Random.Lognormal(7.11, 8.9e-003)
* SingInCustomer2: Random. Triangular (2.8, 53., 61.7)

**APPENDIX- II**

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Figure 2.1

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Figure 2.2

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Figure 2.3