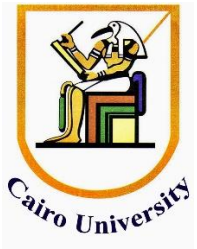


Cairo University

Faculty of Computers and Artificial Intelligence

Simulation and Modeling Project

Name	ID
Mahmoud Ramadan Mohamed	20210369
Amr Abdelaziz Farrag	20210277
Kerolos wageh Farouk	20210307
Ayman Ashraf Mounir	20210079

TASK 1: Supermarket Multi-Channel Queue

Part 1: Problem Formulation & Objectives

Problem Formulation: The code simulates a cashier system with express and regular customers. It aims to analyze customer arrival patterns, waiting times, and service times in a cashier scenario.

Objectives:

1. Model both express and regular customer types.
2. Track customer-related data such as arrival time, waiting time, and service time.
3. Provide a graphical user interface (GUI) for user interaction.
4. Display simulation results in a tabular format.

Cashier Process Description:

1. Cashier Types:

- **Express Cashier: Serves customers with 12 items or less.**
- **Regular Cashier: Serves customers regardless of the number of items.**

2. Customer Types:

- **Regular Customer: Has more than 12 items.**
- **Express Customer: Has 12 items or less.**

3. Regular Customer Process:

- **Identify Customer Type.**
- **If Regular Customer, proceed to the queue for Regular Cashier.**

4. Express Customer Process:

- **Identify Customer Type.**
- **If Express Customer:**
  - **Check if the queue length of Express Cashier is below 1.5 times the queue length of Regular Cashier.**
    - **If yes, join the queue for Express Cashier.**
    - **If no, join the queue for Regular Cashier.**

Part 2: <u>System components :</u>

1. **Entities:**
   - **Customers:** Two types - express customers (with 12 items or less) and regular customers (more than 12 items).
   - **Cashier**
2. **Attributes:**
   - **Customer Type:** Express or Regular.
   - **Number of Items:** indicates the type of customer which indicates which queue he will join.
   - **Cashier Efficiency.**
3. **Activities:**
   - **Checkout Process:** Involves the process of scanning items, payment, and bagging , then leaving the queue(represented is service time).
   - **Queue State:** Variables describing the number of customers in each queue (express and regular), the number of items in each customer's cart, cashier availability (occupied or idle).

4. **Events:**
    - **Customer Arrival:** Customers arriving at the checkout area.
    - **Customer joins a queue:** according to his number of items that changes the state of the queue.
    - **Customer leaves a queue:** changes the state of the queue.

Regular Completion Time	Express Completion Time	Service Start Time	Regular Queue	Express Queue	Waiting Time	Arrival Time	Type	Customer
0	6	4	0	0	0	4	exp	1
0	7	6	0	0	0	6	exp	2
12	7	7	0	0	0	7	reg	3
12	9	7	0	0	0	7	exp	4
12	12	9	0	0	0	9	exp	5
12	14	12	0	1	3	9	exp	6
17	14	12	0	1	0	12	reg	7
20	14	17	1	1	5	12	reg	8
23	14	20	2	1	7	13	reg	9
23	20	17	2	0	0	17	exp	10

Part 3: System Analysis

1. Cumulative Distribution Tables: Utilizes cumulative distribution to model time between arrivals and service times.
2. Calendar Table: Represents a calendar table for 10 customers, displaying their arrival times, waiting times, and service times.

Part 4: Experimental Design Parameters

1. In each iteration, the generated random numbers are seeded with number of that iteration, and the customers array is shuffled also according to that seed, So that we can make sure of reproducibility.
2. The customers are either *Express* or *Regular*, and mentioned percentages are 60% *Express*, and 40% *Regular*. And these values are constants.
3. User can decide number of customers, and number of iterations of the simulation.

Part 5: Results Analysis

1. Service Time Analysis:
   - Express Customers: Average service time is 1.88 minutes.
   - Regular Customers: Average service time is 5.33 minutes.
2. Waiting Time Analysis:

- Express Cashier Queue: Average waiting time is 0.34 minutes.
- Regular Cashier Queue: Average waiting time is 2.9 minutes.

3.Queue Length Analysis:

- Express Cashier Queue: Maximum length is 2.
- Regular Cashier Queue: Maximum length is 3.

4. Probability of Waiting in Express Queue:

- Probability is 0.11.

5. Cashier Idle Time Analysis:

- Express Cashier: Portion of idle time is 0.45.
- Regular Cashier: Portion of idle time is 0.20.

6. Theoretical vs Experimental Service Time:

- Express Customers: Theoretical is 2 minutes, experimental is 1.88 minutes (Difference: 0.12 minutes).
- Regular Customers: Theoretical is 5.2 minutes, experimental is 5.33 minutes (Difference: 0.13 minutes).

7. Inter-Arrival Time Analysis:

   - Theoretical: 1.86 minutes.
   - Experimental: 1.85 minutes.

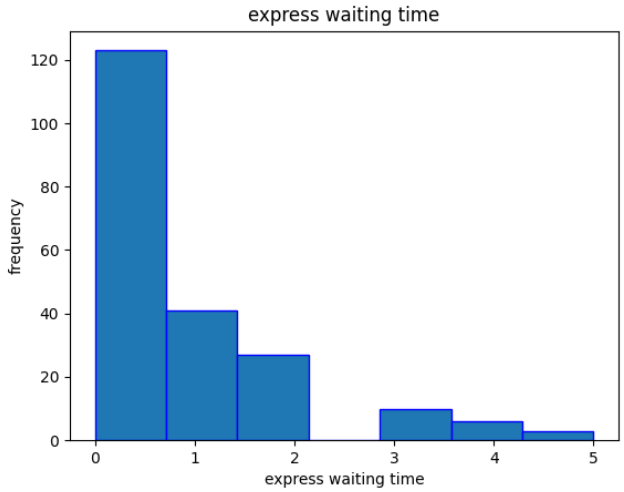
8. Effect of Queue Length on Waiting Time and Idle Time:

- Regular Waiting Time: Increases with an increase in the regular cashier queue length.
- Express Cashier Idle Time: Increases with an increase in the portion of idle time.
- Regular Cashier Idle Time: Decreases with an increase in the portion of idle time.

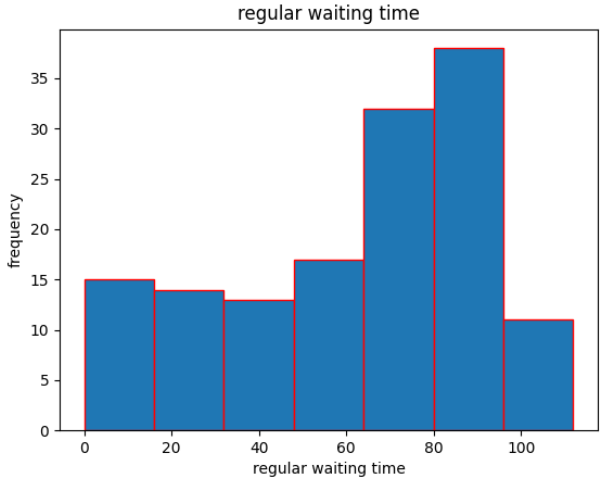
- Probability of Waiting in Express Queue: Decreases.
- Average Inter-Arrival and Service Times: Remain consistent.

Results of 350 iterations in 10 Days:

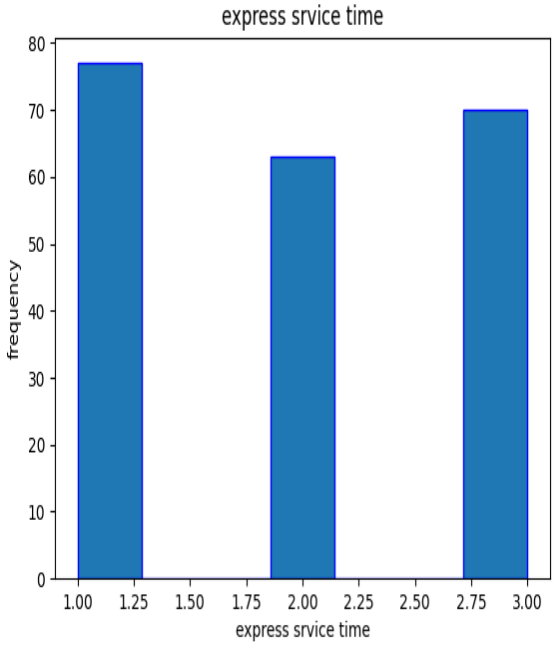
- Average Inter-Arrival Time 1.85 minutes
- Average Express Waiting Time 1.07 minutes



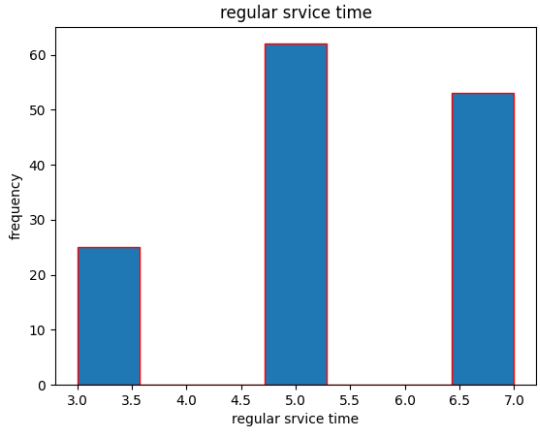
- Average Regular Waiting Time 0.7 minutes



- Average Express Service Time 1.9 minutes



- Average Regular Service Time 5.1 minutes



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- Maximum Express Queue Length 298
- Maximum Regular Queue Length 140
- Probability of Waiting in Express Queue 0.3
- Portion of Idle Time of the Express Cashier 0.37
- Portion of Idle Time of the Regular Cashier 0.6

Conclusion

- We aim to simulate the real world scenarios in our code.
- This documentation provides an overview of the cashier simulation code, its objectives, components, analysis methods, experimental parameters, and results analysis. The GUI facilitates user interaction.

Inventory Management System Project Report Components

Part 1: Problem Formulation & Objectives

Problem Formulation:

The project addresses the need for an effective inventory management system for a car dealership. The goal is to optimize the balance between showroom and inventory capacities, minimize costs, and maximize net profits.

Objectives:

Develop a simulation model for the inventory management system.

Optimize inventory levels, considering showroom and inventory capacities.

Analyze the impact of selling prices, shipping costs, and holding costs on net profit.

Investigate the effect of lead time variability on inventory management.

Evaluate the overall performance of the inventory management system.

Part 2:

System Components:

1. **Entities:**
   - Showroom capacity
   - Inventory capacity
   - Selling car price
   - Shipping order cost
   - Holding car cost
   - Review period
   - Simulation days
2. **Attributes:**
   - Showroom max capacity: the maximum capacity of the cars' showroom. In our case equals to 5
   - Inventory max capacity: the maximum capacity of the cars' inventory. In out case equals to 10
   - Customer demand's distribution.
   - Order lead time.
3. **Activities:**
   - **Order placement :** waiting for the order to arrive according to order lead time

4. **State:**

- **Inventory State:** current number of cars available in the inventory.
- **Showroom State:** current number of cars available in the showroom.

System analysis including cumulative distribution tables, calendar table (for 10 days):

Days	Showroom	Inventory	Random demand	demand	Random lead time	Lead time	Profit
1	4	3->2	0.44	1	-	-	4000
2	5	6->4	0.7	2	-	-	-9000
3	5	4->3	0.2	1	0.7	2	2000
4	5	3->0	0.94	3	-	-	25000
5	5	10 -> 9	0.53	1	-	-	-24000
6	5	9->7	0.63	2	-	-	8000
7	5	7	0.12	0	-	-	-12000
8	5	7->6	0.48	1	-	-	-1000
9	5	6->3	0.9	3	0.31	1	19000
10	5	10->8	0.79	2	-	-	-13000
total							-1000

demand	Demand probability	cumulative distribution demand	Lead time	Lead time probability	cumulative distribution demand
0	0.2	0.2	0	0	0
1	0.34	0.54	1	0.4	0.4
2	0.36	0.9	2	0.35	0.75
3	0.1	1	3	0.25	1

Part 3:

Experimental Design Parameters:

Showroom and inventory capacities, selling prices, shipping costs, holding costs, review period, and simulation days.

Justification of experiment parameters values:

Explanation of the chosen values for each parameter based on the simulation's objectives and realistic considerations.

Part 4:

Results Analysis

Graphs & Discussions for the Following Questions:

Average Ending Units:

Graph and discussion on average ending units in the showroom and inventory.

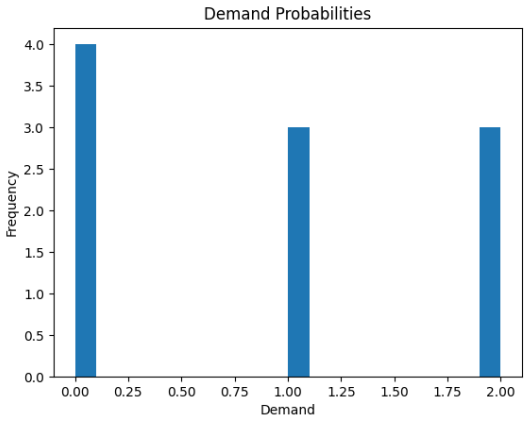
Shortage Days:

Graph and discussion on the number of days with inventory shortages.

Average Net Profit:

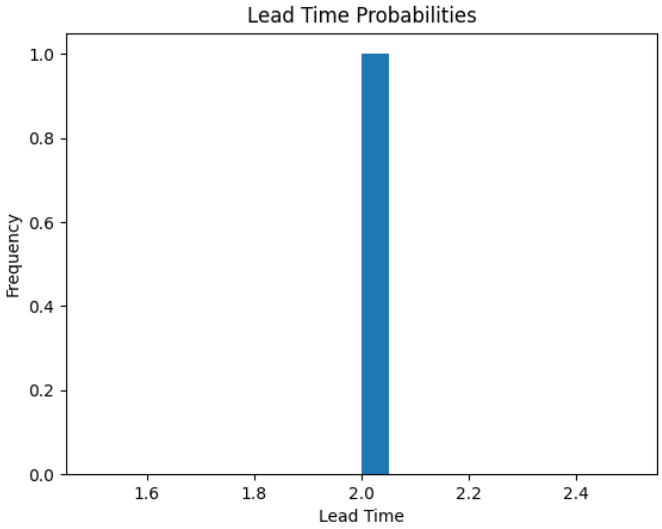
Graph and discussion on average net profit per day.

Comparison of Experimental vs Theoretical Average Demand:



Graph and discussion comparing the experimental and theoretical average demand.

Comparison of Experimental vs Theoretical Average Lead Time:



Graph and discussion comparing the experimental and theoretical average lead time.

Final Results:

```
Average Ending Units in Showroom: 4.9
Average Ending Units in Inventory: 5.1
Shortage Days: 0
Average Net Profit per Day: -5000.0

Experimental Average Demand: 0.9
Theoretical Average Demand: 1.36
Experimental Average Demand Not Equal to Theoretical Average Demand

Experimental Average Lead Time: 2.0
Theoretical Average Lead Time: 1.85
Experimental Average Lead Time Not Equal to Theoretical Average Lead Time
```

Day	Showroom	Inventory	Daily Demand	Lead Time	Net Profit Day
1	4	3	0	1	-7000
2	5	7	0	0	-32000
3	5	5	2	0	10000
4	5	4	1	0	1000
5	5	4	0	0	-9000
6	5	4	0	2	-9000
7	5	3	1	1	2000
8	5	9	1	0	-24000
9	5	7	2	0	8000
10	5	5	2	0	10000

Conclusion

The simulation provides insights into the showroom's operational performance, identifying average ending units, shortage days, and net profit trends. The comparison between experimental and

theoretical values helps assess the accuracy of the simulation model. Further analysis and adjustments to parameters can enhance the system's efficiency and profitability.