Simulation Study of Supermarket Customer Flow

1. Experiment Characterization:

   The purpose of this simulation was to model and analyze the flow of customers in a supermarket with limited clerk lines and ATM machines. The simulation goal is to analyze certain data such as the average time spent by customers. As a consequence we can study the relationship between different values.

2. Simulation Setup:

   - The simulation environment was created using the SimPy library.
   - The supermarket has three clerk lines, while two ATM machines are available for customer use.
   - The ATM machines have a maximum cash capacity, and a money truck is called to refill the machines when the cash level fell below a threshold.
   - Customers arrive randomly at the supermarket and request clerk lines for payment. If they lacked sufficient funds, they accessed an ATM machine to withdraw cash before completing their purchase.

3. Experiment Execution:

   - The simulation was executed ten times, with different random seeds, to observe the variation in results.
   - Each run of the simulation recorded the average time spent by customers and the number of cash withdrawals made during the simulation.

4. Results:

   The following table shows the relation between the average time (in seconds) and the number of cash withdrawals for each simulation run:

Run number	Average Time (seconds)	Number of Withdrawals
1	33	2
2	96	6
3	50	4
4	50	6
5	30	3
6	50	4
7	72	5
8	38	3
9	80	6
10	51	4

Average values	55	4.3

5. Analysis and Observations:
   - The average time spent by customers varied across the different simulation runs, ranging from 30 to 96 seconds.
   - Similarly, the number of cash withdrawals varied between 2 and 6.
   - Based on these results, there appears to be a general trend that suggests a positive correlation between the average time spent by customers and the number of cash withdrawals. However, it's important to note that the relationship may not be straightforward or deterministic due to the stochastic nature of the simulation.The stochastic nature of the simulation, including random customer arrivals and random cash requirements, contributes to the observed variation in results.

There are a few possible explanations for this observed relationship:

   ● Wait time at the ATM: When customers need to withdraw cash from the ATM, there is a fixed withdrawal time specified in the simulation (`ATM_WITHDRAW_TIME`). As the number of cash withdrawals increases, more customers may need to wait for their turn at the ATM.

   ● Wait time for the money truck: The arrival of the money truck takes a fixed amount of time (`MONEY_TRUCK_TIME`). When there are more cash withdrawals, it is more likely that the ATM cash level drops below the threshold, leading to additional wait time for the money truck. This wait time contributes to the increased average time spent.

   ● Interaction with other customers: In the simulation, customers compete for limited clerk lines and ATM access. When there are more cash withdrawals, customers may experience more congestion and waiting time due to increased demand for ATM usage or longer queues at the clerk lines.

6. Conclusion:
   This simulation study provided insights into the flow of customers in a supermarket with limited clerk lines and ATM machines. The results demonstrated the variability in the average time spent by customers and the number of cash withdrawals during the simulation runs. Further analysis and experimentation can be performed to explore additional factors that may influence customer flow and cash withdrawals in such a supermarket environment.

It's important to note that while there seems to be a correlation between the number of cash withdrawals and the average time spent, the specific relationship may vary depending on various factors, such as customer arrival patterns, cash requirements, and resource availability.

To further investigate and confirm the relationship, additional experiments can be conducted by varying specific parameters, such as the number of clerk lines, ATM capacities, or the threshold for calling the money truck.

7. Additional test:
   At this point we want to increase ATMs capacity from 300 to 900.

Run number	Average Time (seconds)	Number of Withdrawals
1	25	3
2	50	5
3	50	6
4	50	7
5	42	5
6	50	4
7	50	2
8	50	8
9	40	4
10	43	7

Average values	45	5.1

Here are the results of the simulation:

First scenario: With ATM capacity of 300 euros:
   - Average time spent by each customer: 55 seconds
   - Total cash withdrawals during the simulation: 4.3

Second scenario: With ATM capacity of 900 euros:
   - Average time spent by each customer: 45 seconds
   - Total cash withdrawals during the simulation: 5.1

By comparing the two sets of results, we can observe the following:

● Average time spent by each customer decreased from 55 seconds to 45 seconds when the ATM capacity was increased from 300 to 900 euros. This suggests that the increased ATM capacity allowed customers to withdraw cash more quickly, reducing their overall waiting time in the system.

● The average number of withdrawals increased from 4.3 to 5.1 when the ATM capacity was increased. This indicates that customers were more likely to make

additional withdrawals when the ATM had a higher cash capacity available. It could be due to us reducing waiting times because the cash replenishment of the machines happens less frequently.

Overall, there is a clear relation between the ATM capacity and the average time spent by customers in the system. Increasing the ATM capacity led to a decrease in the average time spent, indicating improved efficiency and reduced waiting times. However, it's important to note that this relation may vary depending on other factors and system dynamics specific to the simulation setup.

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