TMA1301 - Computational Methods

Trimester 2, 2022/2023

GROUP ASSIGNMENT

Tutorial Session: TT9L

(Dr. Nbhan D. Salih)

Name	Student ID
Pay Eong Waon	1181103284
Pay Eong Zen	1191103360
Yeong Kok Tung	1201200597
Lai Cheng Yung	1211102810
Liau Kai Ze	1211102809

Simulation Details

Overview

In this assignment, the developed simulation aims to accurately model customer arrivals and service times at 3 checkout counters in a supermarket: 2 normal counters and 1 express counter which caters to customers with fewer items. The choice of counter for each customer is determined by multiple factors:

- number of items they have, and
- the current progression of the queue.

Random Number Generation

To introduce randomness into the simulation, 4 different methods are utilised for generating customer arrival times, customer service times, and number of items per customer. Users are provided with the flexibility to select their preferred random number generator from a range of options, including the Linear Congruential Generator (LCG), Random Variate Generator for Exponential Distribution, Random Variate Generator for Uniform Distribution, and FreeMat Rand Function.
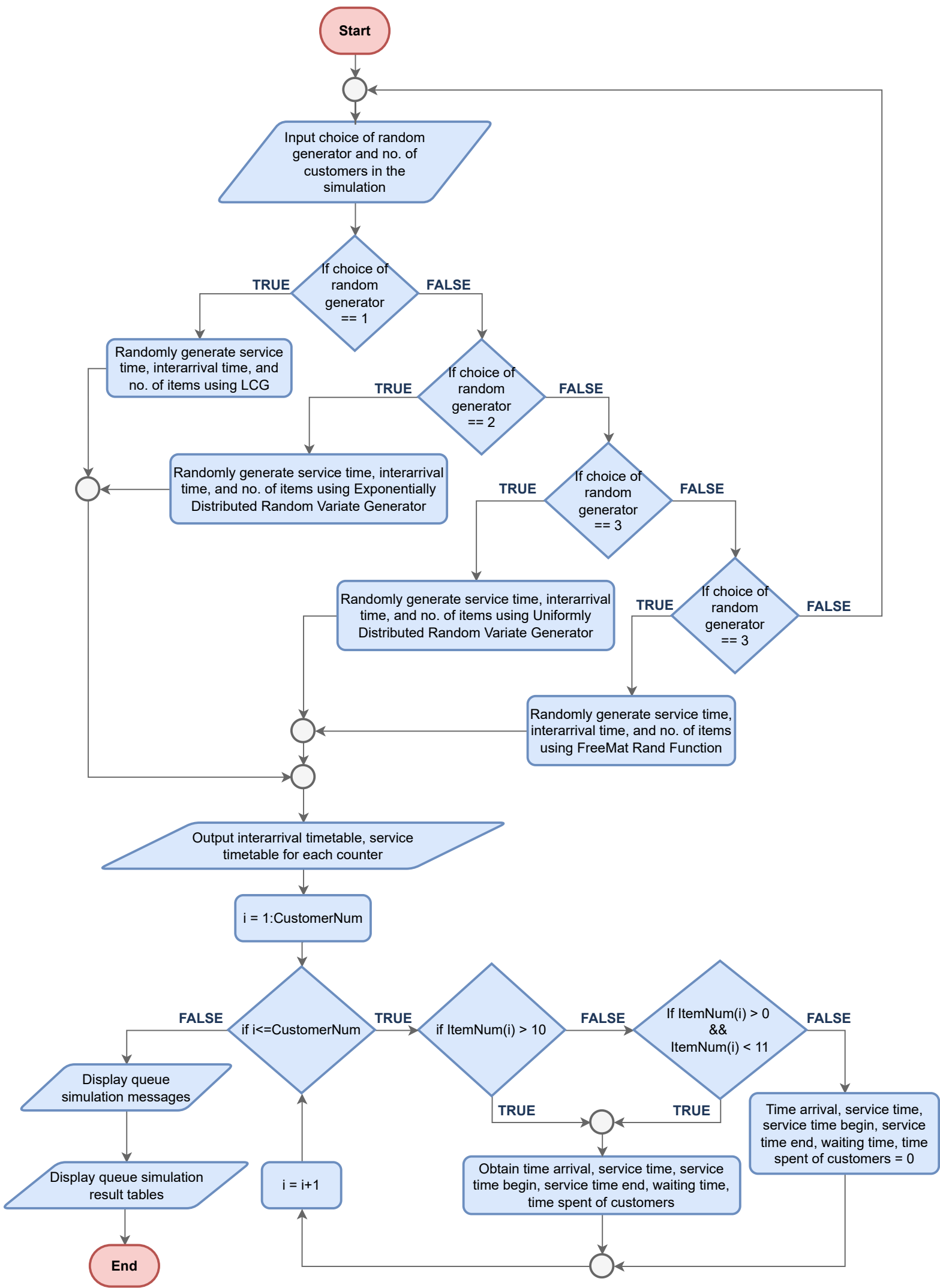
Simulation Procedure

The simulation process involves user interaction and parameter selection. Users are prompted to choose a random number generator and input the desired number of customers for the simulation. Based on these inputs, the selected generator generates random numbers for inter-arrival time, service time, and the number of items for each customer. These generated

random numbers are then organised into comprehensive tables, offering a clear overview of inter-arrival times and service times with their corresponding probabilities for each counter in the supermarket. Furthermore, the generated numbers play a crucial role in calculating various simulation details, including customer-specific information like arrival times and entry times into the respective queues. Once all the necessary calculations are completed, the simulation results are displayed. Notably, customers with fewer than 10 items will be directed to queue up at the express lane, ensuring efficient service for customers with minimal shopping needs.

Simulation Assumptions & Conditions

- Normal queue: Counter 1, Counter 2
- Express queue: Counter 3
- Choice of counter is dependent on availability upon customers' arrival.
- The service time of each customer is determined by the generated service time number.
- If one of these counters is free at the customer's arrival, the customer can immediately enter that queue.
- If both Counter 1 and Counter 2 are occupied at the customer's arrival, the customer joins the counter that will become available first.
- If the customer has between 1 and 10 items, they will go to Counter 3.
- If Counter 3 is occupied when the customer arrives, but it is projected to become available sooner than Counter 1 and Counter 2, the customer waits for Counter 3.
- Waiting time is calculated as the difference between the time the customer entered the queue and their arrival time.
- Total time spent is calculated as the difference between the end of the customer's service time and their arrival time.

Diagram Representation: Flowchart

Start

Input choice of random generator and no. of customers in the simulation

If choice of random generator == 1
- **TRUE** → Randomly generate service time, interarrival time, and no. of items using LCG
- **FALSE** → If choice of random generator == 2
  - **TRUE** → Randomly generate service time, interarrival time, and no. of items using Exponentially Distributed Random Variate Generator
  - **FALSE** → If choice of random generator == 3
    - **TRUE** → Randomly generate service time, interarrival time, and no. of items using Uniformly Distributed Random Variate Generator
    - **FALSE** → If choice of random generator == 3
      - **TRUE** → Randomly generate service time, interarrival time, and no. of items using FreeMat Rand Function
      - **FALSE**

Output interarrival timetable, service timetable for each counter

i = 1:CustomerNum

if i<=CustomerNum
- **FALSE** → Display queue simulation messages → Display queue simulation result tables → **End**
- **TRUE** → if ItemNum(i) > 10
  - **FALSE** → If ItemNum(i) > 0 && ItemNum(i) < 11
    - **FALSE** → Time arrival, service time, service time begin, service time end, waiting time, time spent of customers = 0
    - **TRUE** → Obtain time arrival, service time, service time begin, service time end, waiting time, time spent of customers
  - **TRUE** → Obtain time arrival, service time, service time begin, service time end, waiting time, time spent of customers

i = i+1

Implementation Explanation

No.	Function	Explanation
1	GeneratorChoice.m	To call the function which generates the random values needed based on the user's random generator selection.
2	main.m	To start the program with the keyword "menu".
3	menu.m	To display the user interface of the program.
4	RandomVariateExponential.m	To generate the random number for inter-arrival time, service time and no. of items using random variate exponential.
5	RandomVariateUniform.m	To generate the random number for inter-arrival time, service time and no. of items using random variate uniform.
6	LinearCongruential.m	To generate the random number for inter-arrival time, service time and no. of items using linear congruential generator.
7	RandFunction.m	To generate the random number for inter-arrival time, service time and no. of items using FreeMat's random function.
8	InterArrivalTimeTable.m	To generate the inter-arrival timetable based on the user's random generator selection.
9	ServiceTimeTable.m	To generate 3 service time-tables based on the user's random generator selection.
10	QueueSimulator.m	To calculate the values in the queue simulator, display the result of the values in table form and display the customer message list.

Results & Output

1. **Main Menu**

```
Welcome to supermarket queueing simulator!

Types of Random Number Generator
1. Linear Congruential Generator
2. Random Variate Generator for Exponential Distribution
3. Random Variate Generator for Uniform Distribution
4. Random Number Generator using Rand Function

Choose the type of random number generator: 1

Enter the number of customers in the simulator: 15
```

Displays a menu with 4 types of random number generator. The user is required to input their choice of random number generator and number of customers in the simulator. *Assume user enters 15 customers in the simulator*

2. **Random numbers generation results**

```
----- LINEAR CONGRUENTIAL GENERATOR -----

--------- Random Numbers ---------

Random number for inter-arrival time:
 23  7 77 41 51 32 78 49 16 50 24 15 42 59


Random number for service time:
 41 51 32 78 49 16 50 24 15 42 59 96 94 78 49


Random number of items acquired:
36 41 19 6 38 4 28 1 13 23 26 41 19 6 38
```

Displays the 14 random numbers for the inter-arrival time, 15 random numbers each for service time and for number of items acquired according to the number of customers in the simulator

3. Output of inter-arrival time-table

```
---------- Time-tables ----------

Inter-arrival Time Table:


-----------------------------------------------------------------
| Inter-Arrival Time | Probability |  CDF | Random Number Range |
-----------------------------------------------------------------
| 1                  | 0.30        | 0.30 | 1        -       30 |
| 2                  | 0.20        | 0.50 | 31       -       50 |
| 3                  | 0.10        | 0.60 | 51       -       60 |
| 4                  | 0.25        | 0.85 | 61       -       85 |
| 5                  | 0.15        | 1.00 | 86       -      100 |
-----------------------------------------------------------------
```

Display inter-arrival table which consists of pre-defined inter-arrival time range from 1 minute to 5 minutes, their respective probability, CDF and random number range.

4. Output of service time-table for normal counters and express counter

```
Service Time Table for Normal Counter 1:


-------------------------------------------------------------------------------
| Service Time for Normal Counter 1 | Probability |  CDF  | Random Number Range |
-------------------------------------------------------------------------------
| 5                                 | 0.35        | 0.35  | 1      -      35    |
| 6                                 | 0.25        | 0.60  | 36     -      60    |
| 7                                 | 0.15        | 0.75  | 61     -      75    |
| 8                                 | 0.20        | 0.95  | 76     -      95    |
| 9                                 | 0.05        | 1.00  | 96     -     100    |
-------------------------------------------------------------------------------

Service Time Table for Normal Counter 2:


-------------------------------------------------------------------------------
| Service Time for Normal Counter 2 | Probability |  CDF  | Random Number Range |
-------------------------------------------------------------------------------
| 4                                 | 0.25        | 0.25  | 1      -      25    |
| 5                                 | 0.30        | 0.55  | 26     -      55    |
| 6                                 | 0.20        | 0.75  | 56     -      75    |
| 7                                 | 0.15        | 0.90  | 76     -      90    |
| 8                                 | 0.10        | 1.00  | 91     -     100    |
-------------------------------------------------------------------------------

Service Time Table for Express Counter:


-------------------------------------------------------------------------------
| Service Time for Express Counter  | Probability |  CDF  | Random Number Range |
-------------------------------------------------------------------------------
| 1                                 | 0.40        | 0.40  | 1      -      40    |
| 2                                 | 0.40        | 0.80  | 41     -      80    |
| 3                                 | 0.20        | 1.00  | 81     -     100    |
-------------------------------------------------------------------------------
```

5. Display the service time-tables which consist of predefined service time, probability, CDF and random number range for 2 normal counters and 1 express counter.

6. Output of the customer simulation message list

```
--------- Simulation Messages ---------
Customer 1 arrived at minute 0 and queue at counter 1.

Service for customer 1 started at minute 0.

Departure of customer 1 at minute 6.


Customer 2 arrived at minute 1 and queue at counter 2.

Service for customer 2 started at minute 1.

Departure of customer 2 at minute 6.


Customer 3 arrived at minute 2 and queue at counter 2.

Service for customer 3 started at minute 6.

Departure of customer 3 at minute 11.


Customer 4 arrived at minute 6 and queue at counter 3.

Service for customer 4 started at minute 6.

Departure of customer 4 at minute 8.


Customer 5 arrived at minute 8 and queue at counter 1.

Service for customer 5 started at minute 8.

Departure of customer 5 at minute 14.


Customer 6 arrived at minute 11 and queue at counter 3.

Service for customer 6 started at minute 11.

Departure of customer 6 at minute 12.
```

```
Customer 7 arrived at minute 13 and queue at counter 2.

Service for customer 7 started at minute 13.

Departure of customer 7 at minute 18.


Customer 8 arrived at minute 17 and queue at counter 3.

Service for customer 8 started at minute 17.

Departure of customer 8 at minute 18.


Customer 9 arrived at minute 19 and queue at counter 1.

Service for customer 9 started at minute 19.

Departure of customer 9 at minute 24.


Customer 10 arrived at minute 20 and queue at counter 2.

Service for customer 10 started at minute 20.

Departure of customer 10 at minute 25.


Customer 11 arrived at minute 22 and queue at counter 2.

Service for customer 11 started at minute 25.

Departure of customer 11 at minute 31.


Customer 12 arrived at minute 23 and queue at counter 2.

Service for customer 12 started at minute 31.

Departure of customer 12 at minute 39.


Customer 13 arrived at minute 24 and queue at counter 1.
```

Display the arrival time, queuing counter, service begin time, departure time of each customer in the simulation.

7. Output of the overall queue simulator table

```
Queue Simulation

-----------------------------------------------------------------------
| Customer | Items   | Random number for   | Inter-arrival | Arrival |
| No.      | Bought  | inter-arrival time  | time          | time    |
-----------------------------------------------------------------------
| 1        | 36      | -                   | -             | 0       |
| 2        | 41      | 23                  | 1             | 1       |
| 3        | 19      | 7                   | 1             | 2       |
| 4        | 6       | 77                  | 4             | 6       |
| 5        | 38      | 41                  | 2             | 8       |
| 6        | 4       | 51                  | 3             | 11      |
| 7        | 28      | 32                  | 2             | 13      |
| 8        | 1       | 78                  | 4             | 17      |
| 9        | 13      | 49                  | 2             | 19      |
| 10       | 23      | 16                  | 1             | 20      |
| 11       | 26      | 50                  | 2             | 22      |
| 12       | 41      | 24                  | 1             | 23      |
| 13       | 19      | 15                  | 1             | 24      |
| 14       | 6       | 42                  | 2             | 26      |
| 15       | 38      | 59                  | 3             | 29      |
-----------------------------------------------------------------------
```

Displays the items bought, random number for inter-arrival time, inter-arrival time, and arrival time for each customer in all counters.

8. Output of the simulator in each counter

```
Counter 1

------------------------------------------------------------------------------------------------------------------------
| Customer | Random number |               COUNTER 1                         | Waiting | Time  |
| No.      | for service time | Service time | Service begin | Service end | time    | spent |
------------------------------------------------------------------------------------------------------------------------
| 1        | 41            | 6            | 0             | 6           | 0       | 6     |
| 5        | 49            | 6            | 8             | 14          | 0       | 6     |
| 9        | 15            | 5            | 19            | 24          | 0       | 5     |
| 13       | 94            | 8            | 24            | 32          | 0       | 8     |
------------------------------------------------------------------------------------------------------------------------

Counter 2

------------------------------------------------------------------------------------------------------------------------
| Customer | Random number |               COUNTER 2                         | Waiting | Time  |
| No.      | for service time | Service time | Service begin | Service end | time    | spent |
------------------------------------------------------------------------------------------------------------------------
| 2        | 51            | 5            | 1             | 6           | 0       | 5     |
| 3        | 32            | 5            | 6             | 11          | 4       | 9     |
| 7        | 50            | 5            | 13            | 18          | 0       | 5     |
| 10       | 42            | 5            | 20            | 25          | 0       | 5     |
| 11       | 59            | 6            | 25            | 31          | 3       | 9     |
| 12       | 96            | 8            | 31            | 39          | 8       | 16    |
| 15       | 49            | 5            | 29            | 34          | 0       | 5     |
------------------------------------------------------------------------------------------------------------------------

Counter 3 (Express)

------------------------------------------------------------------------------------------------------------------------
| Customer | Random number |               COUNTER 3                         | Waiting | Time  |
| No.      | for service time | Service time | Service begin | Service end | time    | spent |
------------------------------------------------------------------------------------------------------------------------
| 4        | 78            | 2            | 6             | 8           | 0       | 2     |
| 6        | 16            | 1            | 11            | 12          | 0       | 1     |
| 8        | 24            | 1            | 17            | 18          | 0       | 1     |
| 14       | 78            | 2            | 26            | 28          | 0       | 2     |
------------------------------------------------------------------------------------------------------------------------
```

Display the random number for service time, service time, time service begins and time service ends, waiting time and time spent for each customer in each counter.

9. Output of results evaluation

```
Average Waiting Time:
    0.1333

Average Inter Arrival Time:
    2.6667

Average Arrival Time:
 21

Average Time Spent:
    4.4667

Probability that a customer has to wait in the queue:
    0.0667

Average Service Time Counter 1:
    6.4000

Average Service Time Counter 2:
    4.8000

Average Service Time Counter 3 (Express):
    1.8000
```

Task Distribution

Name	Task
Pay Eong Zen	LinearCongruential.m RandomVariateExponential.m RandomVariateUniform.m
Yeong Kok Tung	RandFunction.m
Pay Eong Waon	LinearCongruential.m InterArrivalTimeTable.m ServiceTimeTable.m QueueSimulator.m
Lai Cheng Yung	QueueSimulator.m
Liau Kai Ze	QueueSimulator.m