CMA6134 COMPUTATIONAL METHODS

Coding Assignment

Title: Queue Simulator

Tutorial - T22L

Group - 625

Prepared by:

ID	Name
1221304179	Mustafa Yousif
1211104426	Soultan Toure Salifou
1211104367	Abdulrahman Mando
1211309695	Hamza Khalid

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2 Overview

The car wash simulation system aims to model and analyze the operation of a multi-bay car wash facility. It simulates the arrival of customers, their interactions with different wash bays, and the overall performance of the system, utilizing various random number generators. It has a couple of options that make each simulation varied, and paramaters like the number of washbays to simulate in any car wash, the number of customers, and even the type of random number generation used. Here are the key points:

Purpose:
The system helps car wash owners and managers understand how different factors (such as service times, arrival rates, and queue management) impact efficiency and customer experience.
By simulating various scenarios, we can optimize resource allocation, reduce wait times, and enhance overall service quality. Managers could get a rough idea how much each of their customers have to wait, and will allow them to assess the viability of adding more washbays in the future, identify the bottle necks, and explore different options for their queuing system that might result in an increase in customer satisfaction.

Components:

1. Customers: Represented by arrival times, service types, and interarrival times.
2. Wash Bays: Each washbay can only service one customer at any given time
3. Random Number Generators: Used for generating arrival times, service times. The three options are `LCG` (Linear Congruential generator), `uniform` (Uniform Number Generator), and `randi` (the inbuilt random number generator function provided by octave, which specifically geneartes integer values)
4. Metrics: We track system time, queue time, and other performance indicators, as well as as aggregate information like the mean queue time, mean system time, which washbays took the longest, etc.

Simulation Process:

1. Manager inputs the various paramaters like the number of customers, washbays, and the method by which random numbers should be generated in the simulation.
2. The Interrarival Distribution table as well as the washbay distribution tables are generated for each washbay
3. Random number generated which will be mapped to the the interarrival time (checked against the interarrival table)
4. Each customer that comes is assiged a washbay based on whichever one will empty up soonest or is already available
5. Service times are calculated, time in queue, time in system are all calculated and updated

Simulation Process:
Extra features:

- Managers can select the number of washbays to generate

Project Structure

1. main.m:
    - This part of the code accepts input from the user regarding the paramaters with which the simulation should run
    - It validated user input
2. simulate.m:
    - Contains the main code for the intitialization and running of the simulation, and is the code responsible for calculating arrival times, service times, and other relevant metrics for each customer.

3. print_table.m:
    - prints a matrix as a table, this is used for both the washbay distribution as well as the interarrival distribution
    - It displays service times, probabilities, cumulative distribution functions (CDFs), and ranges.

4. LCG.m:
    - Linear Congruential Generator (LCG) algorithm.
    - used to generate pseudo-random numbers based on a linear equation.
    - The parameters (seed, multipliers, modulus) determine the sequence of random numbers.
5. Unform.m
    - Generates uniformly generated random numbers

6. get_value.m:
    - find the corresponding value based on a random number within specified ranges.
    - mapping random numbers to specific service times or interarrival times.

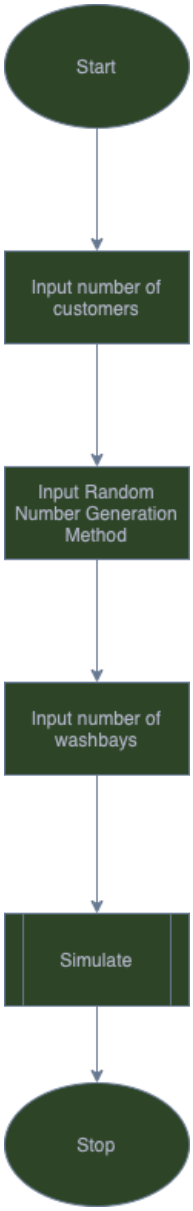
7. generate_washbays.m:
    - generates data for wash bays in a car wash system
    - define service times and probabilities for each wash bay.
    - The data is structured in a 3D matrix, where each slice corresponds to a different wash bay.

8. generate_interarrival.m:
    - generates interarrival time data for customers.
    - initialize an interarrival matrix with predefined values.

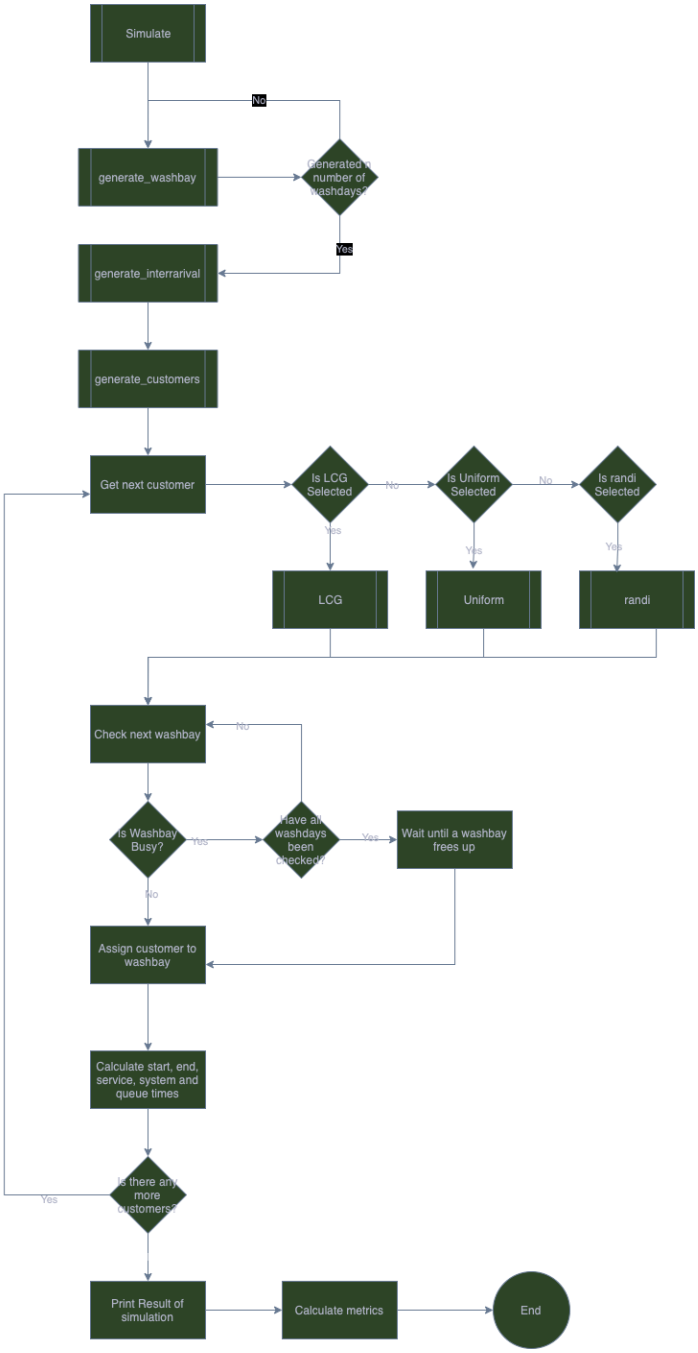
- The third and fourth columns represent cumulative probabilities and ranges for interarrival times.

9. generate_customers.m:
    - generates customer data.
    - create a matrix customers with columns for customer number, random numbers, and additional information.

3 Process Flow



This is the flow chart describing the flow fo the program as it takes inputs from the user. The validation decision is left out of this diagram for brevity and readability, and as it is not the main focus of the task.



This is the more important flowchart, discussing the simulate.m function, which takes given paramaters from main and actually runs the simulation.

1. Main (user input):

- Prompt the user to enter the number of cars as well as the number of washbays
- Validate the input (ensure the number of cars is greater than or equal to 2).
- Prompt the user to choose the random number generator type (either LCG or Uniform Distribution).
- Validate the input (type should be the name of the method).

2. Simulation - Random Number Generation:

- Generate the interarrival distribution
- Generate the distribution for each of the washbays
- Based on the chosen type:
  - Generate random numbers for inter-arrival times (time between car arrivals).
  - Generate random numbers for service types (washing only or washing and polishing).

```
Interarrival Times:
Service Time    Prob.   CDF     Range
------------    -------- ------- -------
  2             0.30    0.30      1- 30
  3             0.40    0.70     31- 70
  4             0.30    1.00     71-100
```

```
Wash Bay  1:
Service Time    Prob.   CDF     Range
-------------   -------  -------  -------
 10             0.40    0.40      1- 40
 15             0.30    0.70     41- 70
 20             0.30    1.00     71-100

Wash Bay  2:
Service Time    Prob.   CDF     Range
-------------   -------  -------  -------
 10             0.40    0.40      1- 40
 15             0.30    0.70     41- 70
 20             0.30    1.00     71-100

Wash Bay  3:
Service Time    Prob.   CDF     Range
-------------   -------  -------  -------
 10             0.40    0.40      1- 40
 15             0.30    0.70     41- 70
 20             0.30    1.00     71-100
```

3. **Simulation - Calculate Arrival Times:**
    - Based on the numbers randomly generated, map each of the random numbers to a value in the domain of the interarrival distribution
    - Calculate the actual arrival times of cars using the generated inter-arrival times.
4. **Determine the washbay for each customer:**
    - For each car:
        - Determine if theres any free washbays that are available
        - If a wash bay is available:
            - Assign the car to that bay.
            - Calculate the service time based on the service type.
            - Update the end time of the wash bay.
        - If no wash bay is available:
            - Calculate the waiting time for each wash bay.
            - Assign the car to the bay with the shortest waiting time.
            - Make car wait until that washbay is free
        - Update relevant information:
            - Waiting time for the car.
            - Service start time.
            - Service end time.
            - Total time spent in the system (arrival to departure).
        - Print relevant information about the car's arrival, service, and departure.
5. **Result Calculation:**
    - Calculate the following metrics for each wash bay:
        - Average waiting time.

- Average inter-arrival time.
- Average arrival time.
- Average time spent in the system.
- Probability of waiting in the queue.
- Average service times.

6. Output Results:

- Display the calculated results in the form of tables or other visualizations to simulate the car wash process.

Simulation:

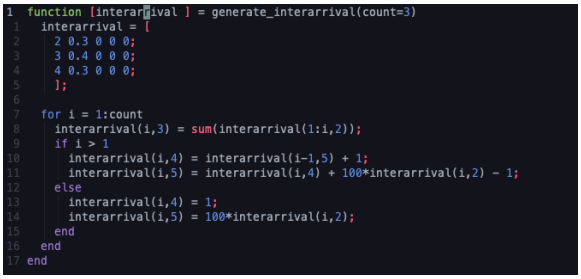
						Washbay 1					Washbay 2			
No.	Rn Arrival	Interarrival	Arrival	Rn Service	Washbay	Start	End	Service	System	Queue	Start	End	Service	S
1	56	3	0	16	1	0	10	10	10	0	0	0	0	
2	8	2	3	58	2	0	0	0	0	0	3	18	15	
3	83	4	5	55	3	0	0	0	0	0	0	0	0	
4	66	3	9	60	1	10	25	15	16	1	0	0	0	
5	95	4	12	65	2	0	0	0	0	0	18	33	15	
6	3	2	16	79	3	0	0	0	0	0	0	0	0	
7	88	4	18	42	1	25	40	15	22	7	0	0	0	
8	46	3	22	28	2	0	0	0	0	0	33	43	10	
9	88	4	25	73	1	40	60	20	35	15	0	0	0	
10	51	3	29	87	3	0	0	0	0	0	0	0	0	

4 Implementation

4.1 generate_washbays

Code	Explanation
	• Takes one paramater, which is count (the number of washbays to generate) • It generates a 3D matrix to store each of the washbay tables • The For loop at the end is responsible for getting the CDF as well as calculate the ranges for each row

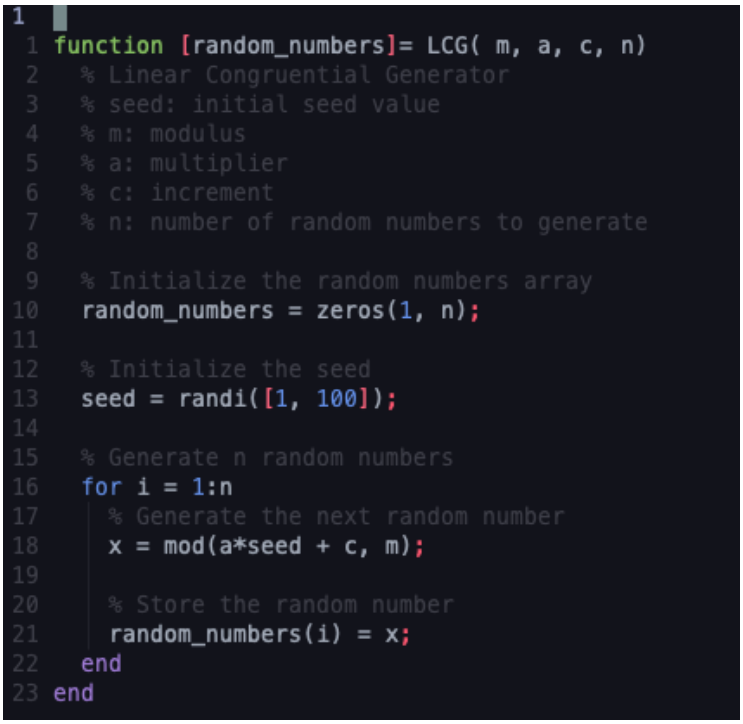
4.2 generate_interrival

Code	Explanation
	This, like the generate_washbay function, generates the distribution table for the interrarival time for the customers. This time it is in a 2D array because we only need one of this distrubtion table. It takes

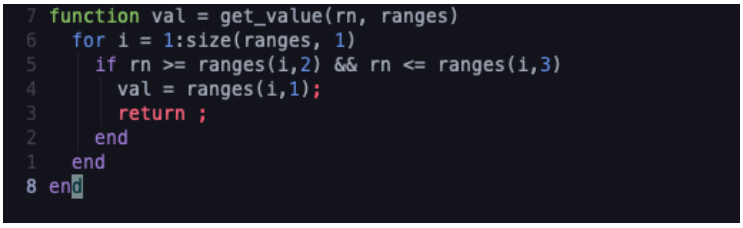
generate_random

Code	Explanation
	Thisfunction takes 4 paramaters, the first and last, which are the bounds for the random numbers generated, n, which is the number of random numbers to generate, initialized to 10 and the method, which is initialized to ‘LCG’. This function checks the required method, and then calls the appropriate function to generate the random numbers.

4.3 LCG

Code	Explanation
	• The LCG function generates pseudo-random numbers using the Linear Congruential Generator algorithm. • It takes parameters such as seed, multipliers (a), increment (c), modulus (m), and the number of random numbers to generate (n).

4.4 get_value

Code	Explanation
	This function takes 2 paramaters, the random number, and the set of ranges to check it agianst. This function is responsible for mapping each random number to the distribution table so that it is mapped to the correct domain of values.

main.m

```
function main()
  % Get customer count from user
  customer_count = input('Enter the number of customers(>2): ');
  if customer_count < 2
    disp('Invalid customer count. Please enter a number greater than 2.');
    return;
  end
  % Get washbay count from user
  washbay_count = input('Enter the number of washbays(<5): ');

  if washbay_count > 5 || washbay_count < 1
    disp('Invalid washbay count. Please enter a number between 1 and 5.');
    return;
  end
  % Get method from user
  disp('Enter the method to generate random numbers:');
  disp('1. LCG (Linear Congruential Generator)');
  disp('2. uniform (Uniform Distribution)');
  disp('3. randi (Inbuilt Random Integer Generation Function)');

  method = input('Enter the method to generate random numbers: ', 's');


  if strcmp(method, 'LCG') == 0 && strcmp(method, 'uniform') == 0 && strcmp(method, 'randi') == 0
    disp('Invalid method. Please enter a valid method.');
    return;
  end

  simulate( washbay_count, customer_count, method);
end
```

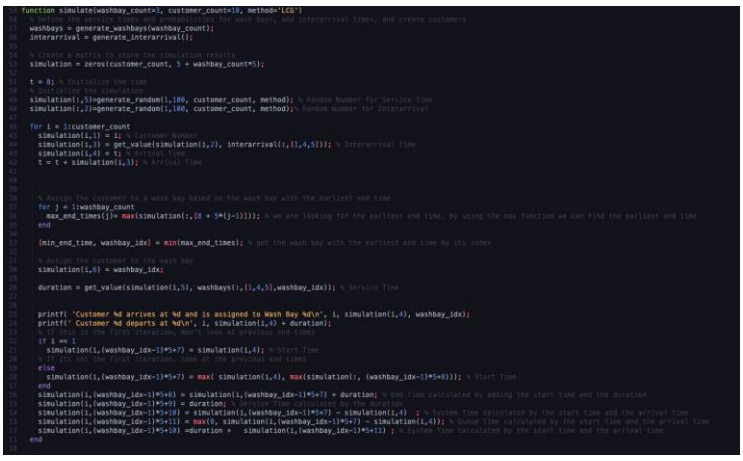
Explanation

This is the main function that takes input from the user and validates it before running the simulation.

4.5 print_table.m

Code	Explanation
	This function is responsible for taking the distribution tables we created for the washbays as well as the interrarival times as matrices and prints them out in a pretty print table.

4.6 simulate.m

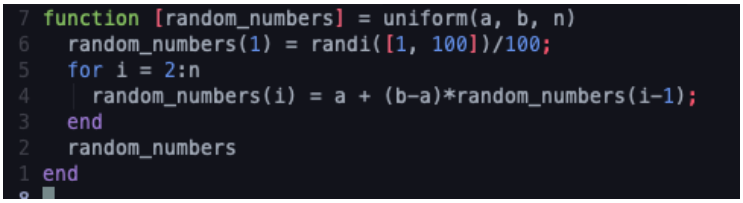
Code	Explanation
	This is the function responsible for running the simulation and takes 3 parameters, the number of washbays, the customer count and the method to use for random number generation. It calls most of the previous function defined to execute various parts of the simulation and finally prints the output.

```
  printf('\nWash Bay %2d:\n', i);
  for i = 1:washbay_count
    printf('\nWash Bay %2d:\n', i);
    print_table(washbays(:,:,i));
  end
  printf('\nSimulation:\n')
  printf('                                                  ')
  for i = 1:washbay_count
    printf('| Washbay %2d                    ', i);
  end
  fmtStr = '|%2d |  %8d|  %10d|  %5d| %9d| %9d|';
  carwashFmtStr = '|%2s | %8s | %10s | %5s | %10';
  printf('\n|No.|Rn Arrival|Interarrival|Arrival|Rn Service| Washbay  |');
  for i = 1:washbay_count
    printf('Start| End |Service |System|Queue |');
  end
  printf('\n')
  for i = 1:customer_count
    printf(fmtStr, simulation(i, 1:6));
    for j = 1:washbay_count
      values = simulation(i, (j-1)*5+7:(j-1)*5+10);
      printf('%4d | %4d| %6d | %5d |', simulation(i, (j-1)*5+ 7:(j-1)*5+11));
    end
    printf('\n')
  end
  printf('\n');

  average_system_time = mean(simulation(:,10));
  average_queue_time = mean(simulation(:,11));
  average_duration = mean(simulation(:,9));
  average_arrival = mean(simulation(:,3));
  average_interarrival = mean(interarrival(:,2));
  probabilty_to_wait_in_queue = sum(simulation(:,11) > 0) / customer_count;
  for i = 1:washbay_count
    printf('Wash Bay %d\n==============\n', i);
    printf('Average System Time: %d\n', mean(simulation(:,(i-1)*5+10)));
    printf('Average Queue Time: %d\n', mean(simulation(:,(i-1)*5+11)));
    printf('Average Duration: %d\n\n', mean(simulation(:,(i-1)*5+9)));
  end
  printf('Summary\n==============\n')
  printf('Average System Time: %d\n', average_system_time);
  printf('Average Queue Time: %d\n', average_queue_time);
  printf('Average Duration: %d\n', average_duration);
  printf('Average Arrival Time: %d\n', average_arrival);
  printf('Average Interarrival Time: %d\n', average_interarrival);
  printf('Probability to Wait in Queue: %d\n\n', probabilty_to_wait_in_queue);

end
```

4.7 unform.m

Code	Explanation
	This is the function responsible for the random number generation using the unform distribution method. It takes paramaters a, b, and the number of number sto generate, n.

```
function [random_numbers] = uniform(a, b, n)
  random_numbers(1) = randi([1, 100])/100;
  for i = 2:n
    random_numbers(i) = a + (b-a)*random_numbers(i-1);
  end
  random_numbers
end
```

5 Results

First Run

Number of customers:10
Number of washbays: 3
Method: LCG

```
octave:300> main
Enter the number of customers(>2): 10
Enter the number of washbays(<5): 3
Enter the method to generate random numbers:
1. LCG (Linear Congruential Generator)
2. uniform (Uniform Distribution)
3. randi (Inbuilt Random Integer Generation Function)
Enter the method to generate random numbers: LCG
```

```
 Customer 1 arrives at 0 and is assigned to Wash Bay 1
  Customer 1 departs at 10
 Customer 2 arrives at 3 and is assigned to Wash Bay 2
  Customer 2 departs at 13
 Customer 3 arrives at 6 and is assigned to Wash Bay 3
  Customer 3 departs at 16
 Customer 4 arrives at 9 and is assigned to Wash Bay 1
  Customer 4 departs at 19
 Customer 5 arrives at 12 and is assigned to Wash Bay 2
  Customer 5 departs at 22
 Customer 6 arrives at 15 and is assigned to Wash Bay 3
  Customer 6 departs at 25
 Customer 7 arrives at 18 and is assigned to Wash Bay 1
  Customer 7 departs at 28
 Customer 8 arrives at 21 and is assigned to Wash Bay 2
  Customer 8 departs at 31
 Customer 9 arrives at 24 and is assigned to Wash Bay 3
  Customer 9 departs at 34
 Customer 10 arrives at 27 and is assigned to Wash Bay 1
  Customer 10 departs at 37
```

Interarrival Times:

Service Time	Prob.	CDF	Range
2	0.30	0.30	1- 30
3	0.40	0.70	31- 70
4	0.30	1.00	71-100

Wash Bay 10:

Wash Bay 1:

Service Time	Prob.	CDF	Range
10	0.40	0.40	1- 40
15	0.30	0.70	41- 70
20	0.30	1.00	71-100

Wash Bay 2:

Service Time	Prob.	CDF	Range
10	0.40	0.40	1- 40
15	0.30	0.70	41- 70
20	0.30	1.00	71-100

Wash Bay 3:

Service Time	Prob.	CDF	Range
10	0.40	0.40	1- 40
15	0.30	0.70	41- 70
20	0.30	1.00	71-100

Simulation:

						Washbay 1						Washbay 2						Washbay 3					
No.	Rn Arrival	Interarrival	Arrival	Rn Service	Washbay	Start	End	Service	System	Queue	Start	End	Service	System	Queue	Start	End	Service	System	Queue	
1	48	3	0	28	1	0	10	10	10	0	0	0	0	0	0	0	0	0	0	0	
2	48	3	3	28	2	0	0	0	0	0	3	13	10	10	0	0	0	0	0	0	
3	48	3	6	28	3	0	0	0	0	0	0	0	0	0	0	6	16	10	10	0	
4	48	3	9	28	1	10	20	10	11	1	0	0	0	0	0	0	0	0	0	0	
5	48	3	12	28	2	0	0	0	0	0	13	23	10	11	1	0	0	0	0	0	
6	48	3	15	28	3	0	0	0	0	0	0	0	0	0	0	16	26	10	11	1	
7	48	3	18	28	1	20	30	10	12	2	0	0	0	0	0	0	0	0	0	0	
8	48	3	21	28	2	0	0	0	0	0	23	33	10	12	2	0	0	0	0	0	
9	48	3	24	28	3	0	0	0	0	0	0	0	0	0	0	26	36	10	12	2	
10	48	3	27	28	1	30	40	10	13	3	0	0	0	0	0	0	0	0	0	0	

```
Wash Bay 1
===============
Average System Time: 4.6
Average Queue Time: 0.6
Average Duration: 4

Wash Bay 2
===============
Average System Time: 3.3
Average Queue Time: 0.3
Average Duration: 3

Wash Bay 3
===============
Average System Time: 3.3
Average Queue Time: 0.3
Average Duration: 3

Summary
===============
Average System Time: 4.6
Average Queue Time: 0.6
Average Duration: 4
Average Arrival Time: 3
Average Interarrival Time: 0.333333
Probability to Wait in Queue: 0.3
```

Second Run

Number of customers:15
Number of washbays: 4
Method: uniform

```
octave:302> main
Enter the number of customers(>2): 15
Enter the number of washbays(<5): 4
Enter the method to generate random numbers:
1. LCG (Linear Congruential Generator)
2. uniform (Uniform Distribution)
3. randi (Inbuilt Random Integer Generation Function)
Enter the method to generate random numbers: uniform
```

```
Customer 1 arrives at 0 and is assigned to Wash Bay 1
 Customer 1 departs at 10
Customer 2 arrives at 4 and is assigned to Wash Bay 2
 Customer 2 departs at 19
Customer 3 arrives at 8 and is assigned to Wash Bay 3
 Customer 3 departs at 18
Customer 4 arrives at 11 and is assigned to Wash Bay 4
 Customer 4 departs at 21
Customer 5 arrives at 15 and is assigned to Wash Bay 1
 Customer 5 departs at 25
Customer 6 arrives at 18 and is assigned to Wash Bay 3
 Customer 6 departs at 33
Customer 7 arrives at 22 and is assigned to Wash Bay 2
 Customer 7 departs at 37
Customer 8 arrives at 25 and is assigned to Wash Bay 4
 Customer 8 departs at 35
Customer 9 arrives at 27 and is assigned to Wash Bay 1
 Customer 9 departs at 47
Customer 10 arrives at 30 and is assigned to Wash Bay 3
 Customer 10 departs at 45
Customer 11 arrives at 34 and is assigned to Wash Bay 4
 Customer 11 departs at 44
Customer 12 arrives at 38 and is assigned to Wash Bay 2
 Customer 12 departs at 58
Customer 13 arrives at 41 and is assigned to Wash Bay 4
 Customer 13 departs at 56
Customer 14 arrives at 45 and is assigned to Wash Bay 1
 Customer 14 departs at 55
Customer 15 arrives at 48 and is assigned to Wash Bay 3
 Customer 15 departs at 58
```

Interarrival Times:

Service Time	Prob.	CDF	Range
2	0.30	0.30	1- 30
3	0.40	0.70	31- 70
4	0.30	1.00	71-100

Wash Bay 15:

Wash Bay 1:

Service Time	Prob.	CDF	Range
10	0.40	0.40	1- 40
15	0.30	0.70	41- 70
20	0.30	1.00	71-100

Wash Bay 2:

Service Time	Prob.	CDF	Range
10	0.40	0.40	1- 40
15	0.30	0.70	41- 70
20	0.30	1.00	71-100

Wash Bay 3:

Service Time	Prob.	CDF	Range
10	0.40	0.40	1- 40
15	0.30	0.70	41- 70
20	0.30	1.00	71-100

Wash Bay 4:

Service Time	Prob.	CDF	Range
10	0.40	0.40	1- 40
15	0.30	0.70	41- 70
20	0.30	1.00	71-100

Simulation:

						Washbay 1					Washbay 2					Washbay 3					Washbay 4				
No.	Rn Arrival	Interarrival	Arrival	Rn Service	Washbay	Start	End	Service	System	Queue	Start	End	Service	System	Queue	Start	End	Service	System	Queue	Start	End	Service	System	Queue
1	79	4	0	36	1	0	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	96	4	4	59	2	0	0	0	0	0	4	19	15	15	0	0	0	0	0	0	0	0	0	0	0
3	51	3	8	5	3	0	0	0	0	0	0	0	0	0	0	8	18	10	10	0	0	0	0	0	0
4	89	4	11	11	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	21	10	10	0
5	52	3	15	11	1	15	25	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	89	4	18	69	3	0	0	0	0	0	0	0	0	0	0	18	33	15	15	0	0	0	0	0	0
7	62	3	22	53	2	0	0	0	0	0	22	37	15	15	0	0	0	0	0	0	0	0	0	0	0
8	12	2	25	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	35	10	10	0
9	62	3	27	88	1	27	47	20	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	74	4	30	47	3	0	0	0	0	0	0	0	0	0	0	33	48	15	18	3	0	0	0	0	0
11	76	4	34	16	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	45	10	11	1
12	64	3	38	80	2	0	0	0	0	0	38	58	20	20	0	0	0	0	0	0	0	0	0	0	0
13	90	4	41	59	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	60	15	19	4
14	58	3	45	32	1	47	57	10	12	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	12	2	48	12	3	0	0	0	0	0	0	0	0	0	0	48	58	10	10	0	0	0	0	0	0

```
Wash Bay 1
==============
Average System Time: 3.46667
Average Queue Time: 0.133333
Average Duration: 3.33333

Wash Bay 2
==============
Average System Time: 3.33333
Average Queue Time: 0
Average Duration: 3.33333

Wash Bay 3
==============
Average System Time: 3.53333
Average Queue Time: 0.2
Average Duration: 3.33333

Wash Bay 4
==============
Average System Time: 3.33333
Average Queue Time: 0.333333
Average Duration: 3

Summary
==============
Average System Time: 3.46667
Average Queue Time: 0.133333
Average Duration: 3.33333
Average Arrival Time: 3.33333
Average Interarrival Time: 0.333333
Probability to Wait in Queue: 0.0666667
```

Third Run

Number of customers:20
Number of washbays: 2
Method: randi

```
octave:305> main
Enter the number of customers(>2): 20
Enter the number of washbays(<5): 2
Enter the method to generate random numbers:
1. LCG (Linear Congruential Generator)
2. uniform (Uniform Distribution)
3. randi (Inbuilt Random Integer Generation Function)
Enter the method to generate random numbers: randi
```

```
Customer 1 arrives at 0 and is assigned to Wash Bay 1
 Customer 1 departs at 20
Customer 2 arrives at 3 and is assigned to Wash Bay 2
 Customer 2 departs at 13
Customer 3 arrives at 7 and is assigned to Wash Bay 2
 Customer 3 departs at 17
Customer 4 arrives at 10 and is assigned to Wash Bay 1
 Customer 4 departs at 20
Customer 5 arrives at 14 and is assigned to Wash Bay 2
 Customer 5 departs at 24
Customer 6 arrives at 17 and is assigned to Wash Bay 1
 Customer 6 departs at 27
Customer 7 arrives at 20 and is assigned to Wash Bay 2
 Customer 7 departs at 40
Customer 8 arrives at 23 and is assigned to Wash Bay 1
 Customer 8 departs at 33
Customer 9 arrives at 26 and is assigned to Wash Bay 1
 Customer 9 departs at 36
Customer 10 arrives at 29 and is assigned to Wash Bay 2
 Customer 10 departs at 39
Customer 11 arrives at 33 and is assigned to Wash Bay 1
 Customer 11 departs at 48
Customer 12 arrives at 35 and is assigned to Wash Bay 2
 Customer 12 departs at 55
Customer 13 arrives at 39 and is assigned to Wash Bay 1
 Customer 13 departs at 59
Customer 14 arrives at 42 and is assigned to Wash Bay 2
 Customer 14 departs at 52
Customer 15 arrives at 44 and is assigned to Wash Bay 2
 Customer 15 departs at 64
Customer 16 arrives at 46 and is assigned to Wash Bay 1
 Customer 16 departs at 66
Customer 17 arrives at 50 and is assigned to Wash Bay 2
 Customer 17 departs at 60
Customer 18 arrives at 54 and is assigned to Wash Bay 1
 Customer 18 departs at 64
Customer 19 arrives at 58 and is assigned to Wash Bay 2
 Customer 19 departs at 78
Customer 20 arrives at 61 and is assigned to Wash Bay 1
```

Interarrival Times:

Service Time	Prob.	CDF	Range
2	0.30	0.30	1- 30
3	0.40	0.70	31- 70
4	0.30	1.00	71-100

Wash Bay 20:

Wash Bay 1:

Service Time	Prob.	CDF	Range
10	0.40	0.40	1- 40
15	0.30	0.70	41- 70
20	0.30	1.00	71-100

Wash Bay 2:

Service Time	Prob.	CDF	Range
10	0.40	0.40	1- 40
15	0.30	0.70	41- 70
20	0.30	1.00	71-100

Simulation:

						Washbay 1					Washbay 2				
No.	Rn Arrival	Interarrival	Arrival	Rn Service	Washbay	Start	End	Service	System	Queue	Start	End	Service	System	Queue
1	64	3	0	89	1	0	20	20	20	0	0	0	0	0	0
2	77	4	3	12	2	0	0	0	0	0	3	13	10	10	0
3	49	3	7	9	2	0	0	0	0	0	13	23	10	16	6
4	74	4	10	12	1	20	30	10	20	10	0	0	0	0	0
5	64	3	14	1	2	0	0	0	0	0	23	33	10	19	9
6	58	3	17	9	1	30	40	10	23	13	0	0	0	0	0
7	31	3	20	87	2	0	0	0	0	0	33	53	20	33	13
8	44	3	23	29	1	40	50	10	27	17	0	0	0	0	0
9	31	3	26	36	1	50	60	10	34	24	0	0	0	0	0
10	81	4	29	17	2	0	0	0	0	0	53	63	10	34	24
11	6	2	33	55	1	60	75	15	42	27	0	0	0	0	0
12	100	4	35	79	2	0	0	0	0	0	63	83	20	48	28
13	46	3	39	82	1	75	95	20	56	36	0	0	0	0	0
14	16	2	42	11	2	0	0	0	0	0	83	93	10	51	41
15	5	2	44	89	2	0	0	0	0	0	93	113	20	69	49
16	84	4	46	81	1	95	115	20	69	49	0	0	0	0	0
17	83	4	50	28	2	0	0	0	0	0	113	123	10	73	63
18	81	4	54	10	1	115	125	10	71	61	0	0	0	0	0
19	68	3	58	93	2	0	0	0	0	0	123	143	20	85	65
20	43	3	61	22	1	125	135	10	74	64	0	0	0	0	0

```
Wash Bay 1
===============
Average System Time: 21.8
Average Queue Time: 15.05
Average Duration: 6.75

Wash Bay 2
===============
Average System Time: 21.9
Average Queue Time: 14.9
Average Duration: 7

Summary
===============
Average System Time: 21.8
Average Queue Time: 15.05
Average Duration: 6.75
Average Arrival Time: 3.2
Average Interarrival Time: 0.333333
Probability to Wait in Queue: 0.45
```