**FACULTY OF COMPUTING AND INFORMATICS (FCI)**

**MULTIMEDIA UNIVERSITY**

**CYBERJAYA**

**CMA6134 - COMPUTATIONAL METHODS**

**Trimester 2023/2024**

**ASSIGNMENT**

**TITLE: CAR WASH SIMULATOR**

**LECTURE SESSION: TC2L**

**GROUP 22**

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# 1. Introduction

## 1.1 Task Distribution

| | |
|---|---|
| Ain Nur Yasmin binti Muhd Zaini | - Random number generator, with seed<br>- Generate service time and inter-arrival time probability and CDF |
| Izza Nelly binti Mohd Nasir | - Car Arrival and Queueing Logic<br>- Assignment of service type and time-based on CDF |
| Hesham Sherif Mohamed Kassem | - Calculating and displaying of the final table<br>- Report |
| Nur Arissa Hanani binti Mohamed Adzlan | - User input and interaction<br>- Displaying event messages<br>- Report |

## 2. Implementation

### 2.1 Main Function

The main function simulates a car wash system where cars arrive randomly, choose from three service types ('Automatic', 'Full-Service', and 'Detailing') based on predefined probabilities, and are processed through car wash bays. The user inputs the number of cars and selects a random number generator (either Linear Congruential Generator or the built-in rand function) to generate random service times and inter-arrival times. The simulation calculates and displays details such as car assignments, service times, waiting times, and overall statistics like average waiting time and bay utilization. The results are summarized in tables to visualize the car wash process and performance metrics.
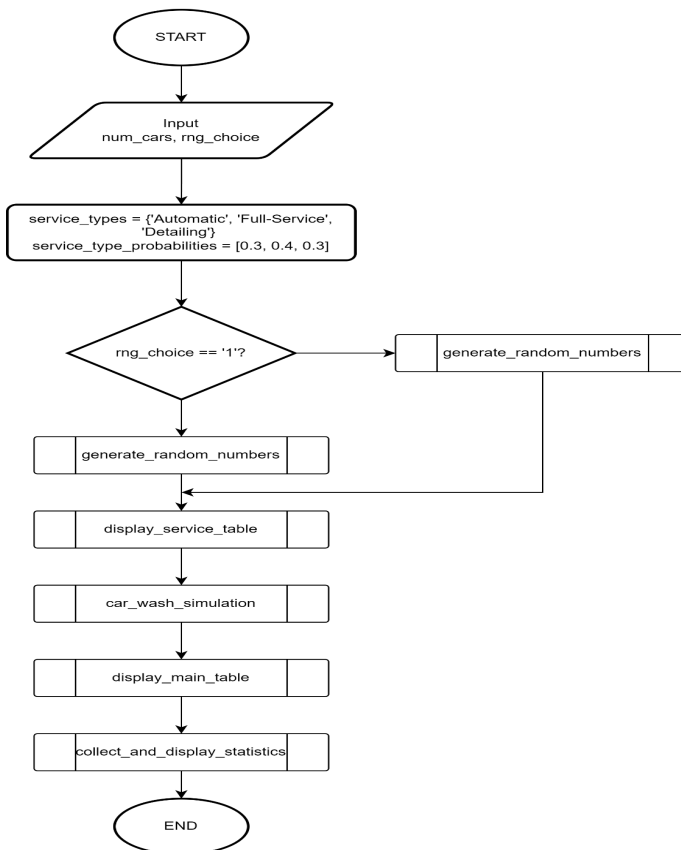


Figure 2.1 Main Function

## 2.2 Random Number Generator

The generate_random_numbers function creates random numbers for simulating car service scenarios. It uses either a specialized math method (LCG) or random number tool based on user choice (rng_choice). It calculates service times, inter-arrival times, and service types based on predefined probabilities, ensuring realistic simulation results. Error handling is included to manage incorrect user inputs. Overall, it's a tool for generating realistic random data crucial for simulating car service operations effectively.

```
                    ┌──────────────────────────┐
                    │ generate_random_numbers()│
                    └──────────────────────────┘
                                │
                    ╱──────────────────────────╱
                   ╱ get num_cars, rng_choice, ╱
                  ╱ service_type_probabilityes ╱
                 ╱────────────────────────────╱
                                │
                    ┌──────────────────────────┐
                    │  initialize service_types,│
                    │  service_cdf, service_ranges│
                    └──────────────────────────┘
                                │
                    ┌──────────────────────────┐
                    │   pre-allocate arrrays:   │
                    │      service_times,       │
                    │     inter_arrival_times,  │
                    │      car_service_types    │
                    └──────────────────────────┘
                                │
                    ┌──────────────────────────┐
                    │     check rng_choice      │
                    └──────────────────────────┘
                                │
                           ◇ rng_choice is 1 ◇ ──no──→ ◇ rng_choice is 2 ◇ ──no──→ ╱ display          ╱
                           ◇    (LCG)        ◇         ◇    (rand)        ◇          ╱ "Invalid choice. ╱
                                │                           │                      ╱ Please enter 1 for LCG or 2 for rand."╱
                               yes                         yes
```
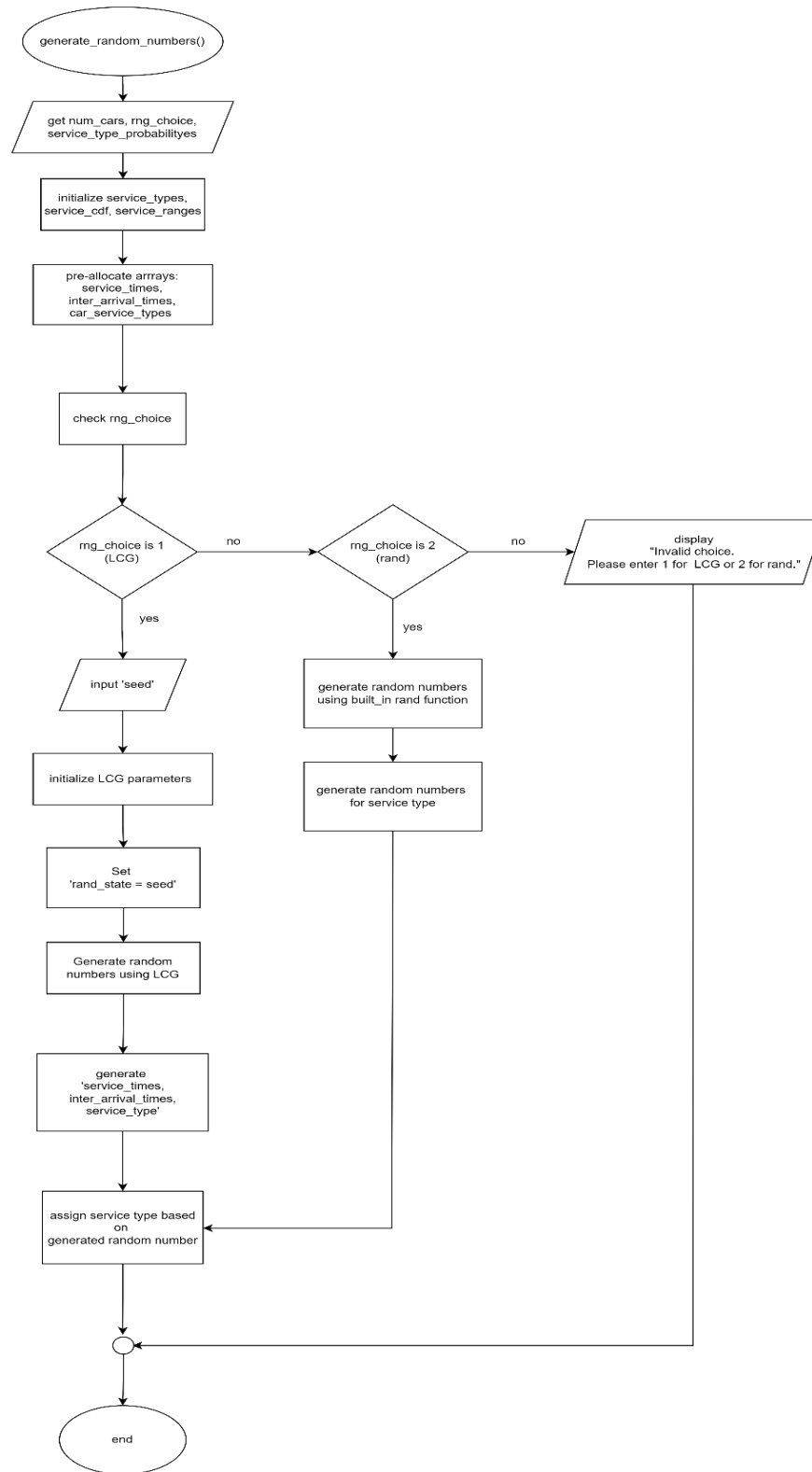
generate_random_numbers()

get num_cars, rng_choice, service_type_probabilityes

initialize service_types, service_cdf, service_ranges

pre-allocate arrrays: service_times, inter_arrival_times, car_service_types

check rng_choice

rng_choice is 1 (LCG) — no → rng_choice is 2 (rand) — no → display "Invalid choice. Please enter 1 for  LCG or 2 for rand."

yes (LCG):
input 'seed'

initialize LCG parameters

Set 'rand_state = seed'

Generate random numbers using LCG

generate 'service_times, inter_arrival_times, service_type'

yes (rand):
generate random numbers using built_in rand function

generate random numbers for service type

assign service type based on generated random number

end

Figure 2.2 Generate Random Number Flowchart

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## 2.3 Car Wash Simulation

The car_wash_simulation function simulates how cars move through a car wash with three wash bays. It starts by setting up arrays to keep track of important times like when cars arrive (arrival_times), start their service (start_times), and finish (end_times). For each car processed (num_cars times), it calculates arrival times based on how often cars show up (inter_arrival_times). It then decides which wash bay each car will use in a rotating order (bay_assignments). The function figures out when each car can start based on when the bay is free and the car's arrival (start_times). It also computes when each car will be done based on the service time for that bay (service_times). After processing all cars, it prints out details like when each car arrives, which bay it uses, when its service starts, and when it leaves. This helps understand how efficiently the car wash operates and how long cars spend in the system overall.
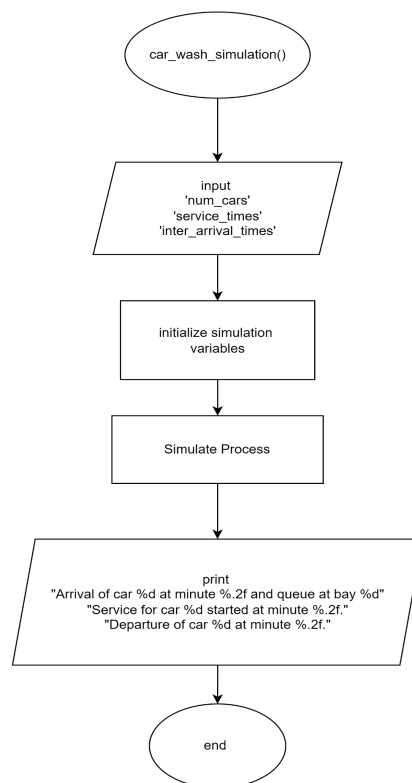


Figure 2.3 Car Wash Simulation Flowchart

## 2.4 Display Main Table

The display_main_table function is designed to show a detailed summary of a car simulation in a neat table format. It starts by introducing the table with a clear header that outlines what information will be displayed. As it goes through each car in the simulation (num_cars), it gathers essential details like when the car arrived, which bay it used, what type of service it received, how long it waited, and how long the whole service process took from start to finish. Each car's information is presented neatly in columns to make it easy to read and understand. After listing all the cars, the function wraps up with a footer to mark the end of the table, ensuring the simulation results are presented comprehensively and professionally. This table is really useful for analyzing how efficiently the car wash operates and how different factors affect each car's experience.
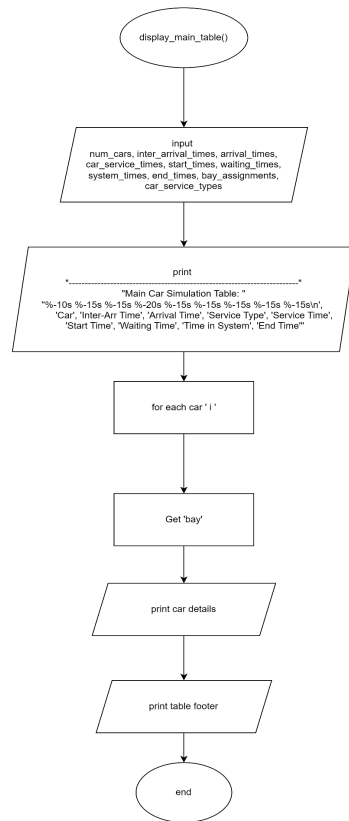


Figure 2.4 Display Main Table

## 2.5 Collect and Display Statistics Table

The collect_and_display_statistics function gathers data from a simulated car wash and displays it neatly. It tracks how long cars wait and get serviced in three different areas. Then, it calculates the chances of different service times happening in each area. The function creates tables for each area showing when cars arrive, how long they wait, and their overall service times. It also finds averages like wait time for cars and how often they arrive. This helps understand how smoothly the car wash is running. Additionally, it shows which area might need more attention to improve service times. Lastly, the function looks at the pattern of when cars arrive, showing if there are busy times or if cars come steadily. Overall, it helps see how well the car wash is doing.
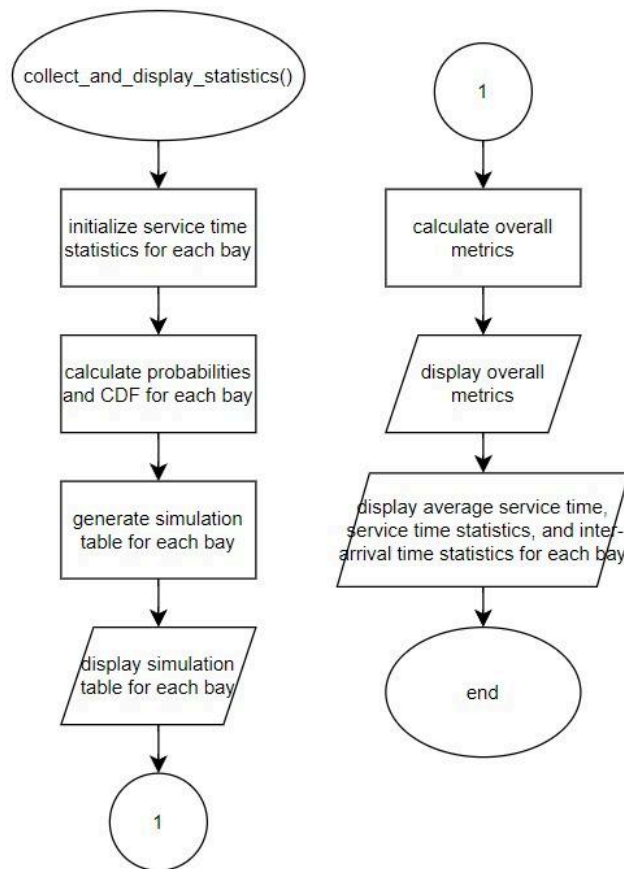


Figure 2.5 Collect and Display Statistics Table Flowchart

## 2.6 Display Service Table

The display_service_table function is all about showing information in a clear way for a simulated car wash. First, it prints a table listing different types of services offered, along with how likely each service type is to be chosen (Probability), its cumulative distribution (CDF), and the range of probabilities it covers (Range). This helps understand the distribution of service choices. Second, it displays another table that lists which service type each car received during the simulation. Each row shows a car number (Car) and the specific service type (Service Type) it got. This part gives a straightforward view of how services were assigned to cars throughout the simulation. Overall, the function gives a simple, organized look at service details and their distribution among cars in the simulated car wash scenario.
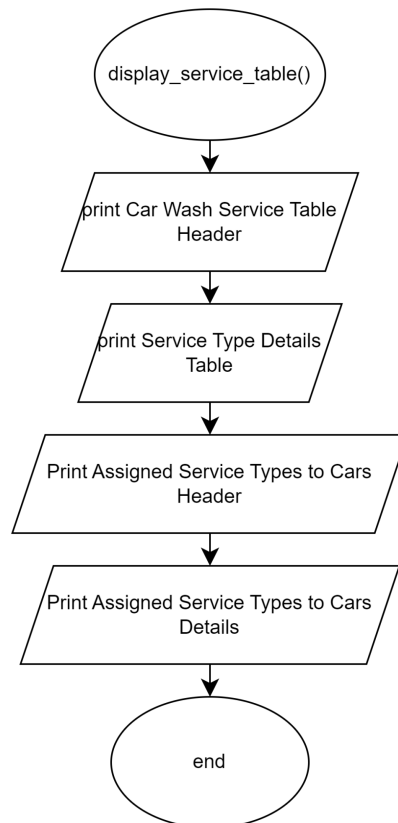


Figure 2.6 Display Service Table Flowchart

3. **Testing Result**

   **3.1  Random Number Generator using LCG**

The prompt asks the user to enter a number of cars to simulate for the car wash. Then the user chooses LCG for the random number generator by pressing 1 then the user chooses 2 for the seed.  The car wash service generates then the program assigns a service for each car. Then the program prints out the arrival of each car.

```
Enter the number of cars to simulate: 4
Choose random number generator (1 for LCG, 2 for rand): 1
Enter seed for LCG: 2
------------------------------------------------------------------------
Car Wash Service Table:
Service Type          Probability      CDF              Range
Automatic             0.30             0.30             [0, 0.30)
Full-Service          0.40             0.70             [0.30, 0.70)
Detailing             0.30             1.00             [0.70, 1.00)
------------------------------------------------------------------------
Assigned Service Types to Cars:
Car          Service Type
1            Detailing
2            Automatic
3            Detailing
4            Full-Service
------------------------------------------------------------------------
Arrival of car 1 at minute 2.56 and queue at bay 1
Service for car 1 started at minute 2.56.
Departure of car 1 at minute 5.19.
Arrival of car 2 at minute 4.75 and queue at bay 2
Service for car 2 started at minute 4.75.
Departure of car 2 at minute 5.40.
Arrival of car 3 at minute 6.54 and queue at bay 3
Service for car 3 started at minute 6.54.
Departure of car 3 at minute 10.12.
Arrival of car 4 at minute 6.73 and queue at bay 1
Service for car 4 started at minute 6.73.
Departure of car 4 at minute 14.40.
```

- In this step the program displays the table for each of the washing bays and the service that happens and how much it takes in detail.

```
--------------------------------------------------------------------------
Main Car Simulation Table:
Car        Inter-Arr Time  Arrival Time    Service Type    Service Time    Start Time      Waiting Time        Time in System    End Time
1          2.5561          2.5561          Detailing       2.6308          2.5561          0.0000              2.6308            5.1868
2          2.1896          4.7456          Automatic       0.6553          4.7456          0.0000              0.6553            5.4010
3          1.7930          6.5386          Detailing       3.5773          6.5386          0.0000              3.5773            10.1159
4          0.1942          6.7328          Full-Service    7.6700          6.7328          0.0000              7.6700            14.4028
--------------------------------------------------------------------------
Wash bay 1:
Car        Inter-Arr Time  Arrival Time    Service Time    Start Time      Waiting Time    Time in System  End Time
1          2.5561          2.5561          2.6308          2.5561          0.0000          2.6308          5.1868
4          0.1942          6.7328          7.6700          6.7328          0.0000          7.6700          14.4028
--------------------------------------------------------------------------
Wash bay 2:
Car        Inter-Arr Time  Arrival Time    Service Time    Start Time      Waiting Time    Time in System  End Time
2          2.1896          4.7456          0.6553          4.7456          0.0000          0.6553          5.4010
--------------------------------------------------------------------------
Wash bay 3:
Car        Inter-Arr Time  Arrival Time    Service Time    Start Time      Waiting Time    Time in System  End Time
3          1.7930          6.5386          3.5773          6.5386          0.0000          3.5773          10.1159
--------------------------------------------------------------------------
```

- Then lastly the program calculates the average time for waiting , arrival time and the time spent during the service and prints it out. Then it calculates the inter-arrival time for the process.

```
Overall Metrics:
Number of Cars      Avg Waiting Time    Avg Inter-Arrival Time Avg Arrival Time    Avg Time Spent      Probability Waiting
4                   0.0000              1.6832                 5.1433              3.6334              0.0000
--------------------------------------------------------------------------
Avg Service Time for Each Server:
Bay 1               Bay 2               Bay 3
3.6334              3.6334              3.6334
--------------------------------------------------------------------------
Wash Bay Statistics:
--------------------------------------------------------------------------
Wash Bay 1:
Service Time    Car             Probability     CDF             Range
2.6308          1               0.5000          0.5000          0 - 50
7.6700          4               0.5000          1.0000          50 - 100
--------------------------------------------------------------------------
Wash Bay 2:
Service Time    Car             Probability     CDF             Range
0.6553          2               1.0000          1.0000          0 - 100
--------------------------------------------------------------------------
Wash Bay 3:
Service Time    Car             Probability     CDF             Range
3.5773          3               1.0000          1.0000          0 - 100
--------------------------------------------------------------------------
Inter-Arrival Time Statistics:
Inter-Arr Time  Probability     CDF             Range
0.1942          0.2500          0.2500          0-25
1.7930          0.2500          0.5000          25-50
2.1896          0.2500          0.7500          50-75
2.5561          0.2500          1.0000          75-100
--------------------------------------------------------------------------
```

## 3.2 Random Number Generator using Rand Function

When the user inputs the number 2 as an answer which is the rand operator ; the program instantly runs the program and prints the output since the rand operation does not need a seed number.

```
--> main
Enter the number of cars to simulate: 3
Choose random number generator (1 for LCG, 2 for rand): 2
-------------------------------------------------------------------
Car Wash Service Table:
Service Type          Probability      CDF               Range
Automatic             0.30             0.30              [0, 0.30)
Full-Service          0.40             0.70              [0.30, 0.70)
Detailing             0.30             1.00              [0.70, 1.00)
-------------------------------------------------------------------
Assigned Service Types to Cars:
Car           Service Type
1             Detailing
2             Automatic
3             Detailing
-------------------------------------------------------------------
Arrival of car 1 at minute 1.79 and queue at bay 1
Service for car 1 started at minute 1.79.
Departure of car 1 at minute 5.55.
Arrival of car 2 at minute 3.53 and queue at bay 2
Service for car 2 started at minute 3.53.
Departure of car 2 at minute 4.52.
Arrival of car 3 at minute 5.99 and queue at bay 3
Service for car 3 started at minute 5.99.
Departure of car 3 at minute 8.07.
```

### 3.3 Error Trial

- The program asks the user to choose the method for the random number generator then the user inputs a wrong integer which triggers the program to print an error message which displays " Error : invalid choice " and let's the user choose a valid option.32

```
Enter the number of cars to simulate: 1
Choose random number generator (1 for LCG, 2 for rand): 0
In C:/Users/hesha/Downloads/G22_ASSIGNMENT2/G22_ASSIGNMENT/generate_random_numbers.m(generate_random_numbers) at line 73
    In C:/Users/hesha/Downloads/G22_ASSIGNMENT2/G22_ASSIGNMENT/main.m(main) at line 13
    In docli(builtin) at line 2
    In base(base)
    In base()
    In global()
Error: Invalid choice. Please enter 1 for LCG or 2 for rand.
```