C++ Programming

Waste Management System using C++ with Multi-Route Optimization Algorithms (Screenshots)

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20509407
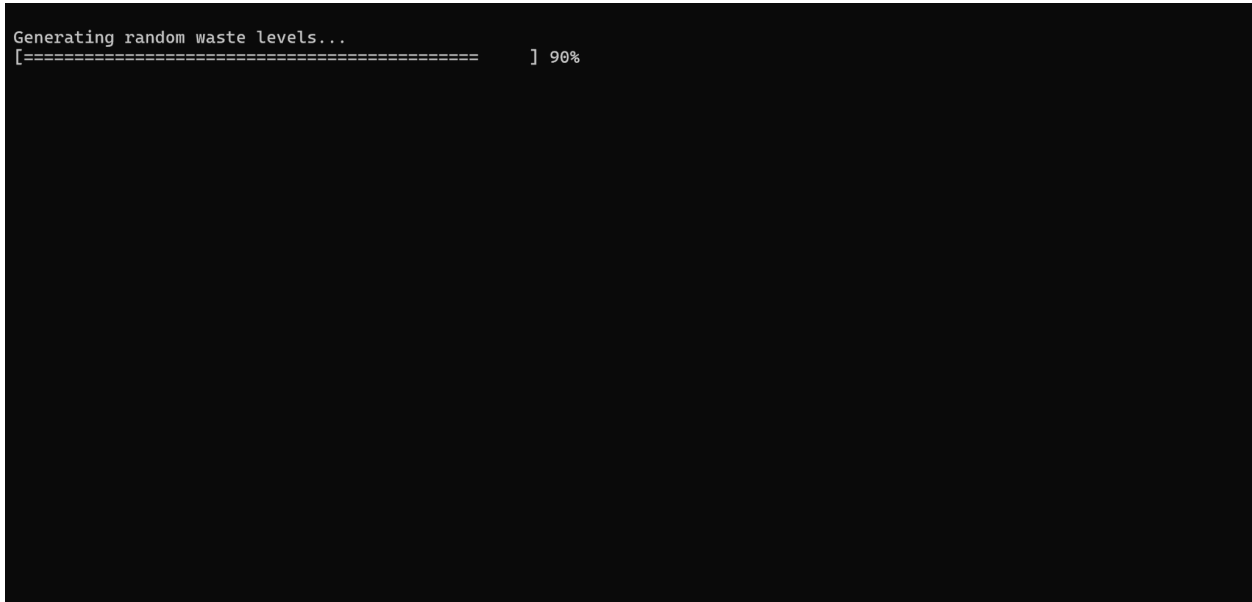
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Table Of Contents

1. System Initialization in Progress

```
Generating random waste levels...
[========================================         ] 90%
```

Description: This screenshot highlights the startup phase of the Waste Management project. It features a dynamic loading screen, where random waste levels are being generated. The progress bar, shown at 90% completion, indicates the near readiness of the system, setting the stage for the program's functionality.

2. Main Menu - Waste Management System (waste.cpp)

```
================================================
    WASTE COLLECTION MANAGEMENT SYSTEM
            WITH AI FEATURES
================================================
Date: Mon Apr 21 22:37:38 2025

Main Menu:
1. Generate Random Waste Levels
2. View Waste Locations Information
3. Select Route Algorithm
4. Execute Selected Route
5. Save Locations Info to File
6. View AI Predictions
7. Compare Route Costs
8. Select Most Cost-Effective Route
9. Waste Pattern Analytics Dashboard
10. View Collection History
11. Help
12. Save ALL Data
13. Load ALL Data
14. Delete ALL Data
0. Exit

Current Route Algorithm: Regular (Non-Optimized)

Enter your choice: |
```

Description: The central hub of your waste management system provides seamless access to 14 powerful functions. Each option empowers users to manage waste levels, analyze patterns, and optimize routes. The menu also highlights the currently active route algorithm, adding clarity for users.

This interface is user-friendly and robust, offering everything from route execution to AI-driven analytics, ensuring efficient waste management solutions.

3(a) Function Triggered: Generate Random Waste Levels

```
================================================
        WASTE COLLECTION MANAGEMENT SYSTEM
                 WITH AI FEATURES
================================================
Date: Mon Apr 21 22:37:38 2025

Main Menu:
1. Generate Random Waste Levels
2. View Waste Locations Information
3. Select Route Algorithm
4. Execute Selected Route
5. Save Locations Info to File
6. View AI Predictions
7. Compare Route Costs
8. Select Most Cost-Effective Route
9. Waste Pattern Analytics Dashboard
10. View Collection History
11. Help
12. Save ALL Data
13. Load ALL Data
14. Delete ALL Data
0. Exit

Current Route Algorithm: Regular (Non-Optimized)

Enter your choice: 1
```

Description: This screenshot captures the user's selection of option 1 from the main menu, activating the "Generate Random Waste Levels" function. The system utilizes algorithmic randomness to simulate waste data, providing a foundation for subsequent analysis and decision-making. The current route algorithm is clearly indicated as "Regular (Non-Optimized," ensuring users remain informed during operations.

3(b)Random Waste Levels Successfully Generated

```
Generating random waste levels...
[==========================================] 100%

=============================================
Generating Random Waste Levels
=============================================
Location                Previous %     New %
---------------------------------------------
Kuala Lumpur Central     19             34
Petaling Jaya            72             69
Shah Alam                27             90
Subang Jaya              97             46
Ampang                   15             12
Klang                    62             92
Cheras                   99             25
Puchong                  25             82
Putrajaya                33             56
Cyberjaya                98             89
=============================================

SUCCESS: Waste levels generated successfully!

Random waste levels generated.
Press any key to continue . . .
```

Description: This screenshot shows the outcome of the "Generate Random Waste Levels" function. A detailed table presents updated waste levels for various locations, comparing the previous percentages with the newly generated figures. The success message, highlighted in green, confirms the process completion, assuring users of accurate data generation.

4. Waste Location Overview - Insights at a Glance

```
=============================================
    WASTE COLLECTION MANAGEMENT SYSTEM
           WITH AI FEATURES
=============================================
Date: Mon Apr 21 22:44:38 2025
==================================================
        Current Waste Locations Information
==================================================
Location                  Waste Level %      AI Prediction (24h)      Trend
-----------------------------------------------------------------------------------
Kuala Lumpur Central      34 %               33 %                     Stable
Petaling Jaya             69 %               68 %                     Stable
Shah Alam                 90 %               89 %                     Stable
Subang Jaya               46 %               45 %                     Stable
Ampang                    12 %               11 %                     Stable
Klang                     92 %               91 %                     Stable
Cheras                    25 %               24 %                     Stable
Puchong                   82 %               81 %                     Stable
Putrajaya                 56 %               55 %                     Stable
Cyberjaya                 89 %               88 %                     Stable
==================================================
Press any key to continue . . .
```

Description: This screenshot displays the results of selecting option 2, "View Waste Location Information." The interface showcases a comprehensive table detailing waste levels, AI predictions for the next 24 hours, and trend stability across 10 locations. Color-coded indicators help users quickly assess critical locations, ensuring informed decision-making for waste collection and resource allocation.

5(a)Route Algorithm Selection - Precision Meets Adaptability

```
===========================================
     WASTE COLLECTION MANAGEMENT SYSTEM
             WITH AI FEATURES
===========================================
Date: Mon Apr 21 22:47:54 2025

Select Route Algorithm:
1. Regular (Non-Optimized) Route
2. Optimized Route
3. Greedy Route
4. Traveling Salesman Problem (TSP) Route
5. Minimum Spanning Tree (MST) Route
6. Reinforcement Learning (RL) Route
7. External Factors AI-based Route
8. Return to Main Menu

Enter your choice:
```

Description: This screenshot showcases the menu for selecting route algorithms within the waste management system. The user has access to seven distinct options, ranging from regular (non-optimized) routes to advanced AI-driven methods such as reinforcement learning and external factors-based optimization. Each algorithm is designed to cater to specific needs, balancing efficiency and environmental considerations.

The inclusion of cutting-edge approaches like TSP, MST, and AI-based routes reflects the system's versatility in tackling real-world challenges. Once a choice is made, users can seamlessly implement their selected algorithm to enhance waste collection processes.

5(b) Route Algorithm Updated: External Factors AI-Based Route

Activated

```
==========================================
      WASTE COLLECTION MANAGEMENT SYSTEM
              WITH AI FEATURES
==========================================
Date: Mon Apr 21 22:50:36 2025

Main Menu:
1. Generate Random Waste Levels
2. View Waste Locations Information
3. Select Route Algorithm
4. Execute Selected Route
5. Save Locations Info to File
6. View AI Predictions
7. Compare Route Costs
8. Select Most Cost-Effective Route
9. Waste Pattern Analytics Dashboard
10. View Collection History
11. Help
12. Save ALL Data
13. Load ALL Data
14. Delete ALL Data
0. Exit

Current Route Algorithm: External Factors AI-based

Enter your choice: |
```

Description: This screenshot illustrates the user's selection of option 7, resulting in the current route algorithm being switched to "External Factors AI-Based Route." The interface promptly reflects the update, emphasizing adaptability to external variables like traffic patterns, environmental constraints, and urban planning factors

6(a) Route Execution in Progress: AI-Optimized Details Displayed

```
========================================
     WASTE COLLECTION MANAGEMENT SYSTEM
              WITH AI FEATURES
========================================
Date: Mon Apr 21 22:53:03 2025
Calculating optimal route... .....
Route calculation complete!

External Factors AI-based Route Information
========================================
Complete Route: Waste Collector HQ -> Klang -> Shah Alam -> Cyberjaya -> Puchong -> Petaling Jaya -> Putrajaya -> Subang Jaya -> Kuala Lumpur Centra
l -> Cheras -> Waste Collector HQ

Route Costs Summary:
Total Distance: 166 km
Total Time: 5.09744 hours
Total Fuel Cost: 471.847 RM
Total Wages: 50.9744 RM
Total Cost: 522.821 RM
========================================

Would you like to see a visual map of the route? (y/n): y
```

Description: This page captures the results of executing the selected route, showcasing the optimal waste collection path calculated by the system. Key route details include:

- **Route Overview: Waste Collector HQ → Klang → Shah Alam → Cyberjaya → Puchong → Petaling Jaya → Putrajaya → Subang Jaya → Kuala Lumpur Central → Cheras → Waste Collector HQ.**
- **Summary of Costs:**
  - **Total Distance: 166 km**
  - **Total Time: 5.097 hours**
  - **Total Fuel Cost: 471.847 RM**
  - **Total Wages: 50.974 RM**
  - **Total Cost: 522.821 RM**

6(b) ASCII Map Generated - Visualizing the Optimal Route

```
Would you like to see a visual map of the route? (y/n): y

    ASCII MAP VISUALIZATION OF ROUTE
    (H=HQ, O=Visited, .=Unvisited, !=High Priority)
    ============================================================




                            !-O
                            |--
                     O-   |||-!
                      ---|||| |
                       -||-|-
                 !-----H || -O
                  --   |  ||--
                   -  |  |||
                 . -|  | O
                    --|
                    O !




    ============================================================

    LOCATION LEGEND:
    (30,10): Waste Collector HQ - 0%
    (36,10): Kuala Lumpur Central - 34%
    (34,13): Petaling Jaya - 69%
    (31,15): Shah Alam - 90%
    (29,15): Subang Jaya - 46%
    (26,13): Ampang - 12%
    (24,10): Klang - 92%
    (26,7 ): Cheras - 25%
    (29,5 ): Puchong - 82%
    (31,5 ): Putrajaya - 56%
    (34,7 ): Cyberjaya - 89%

External Factors Analysis:
------------------------
Weather Condition: 35.00% impact
```

Description: This screenshot displays the ASCII map created after pressing "Y" to confirm route visualization. The map outlines the waste collection path with symbols denoting key statuses: 'H' for HQ, 'O' for visited locations, '.' for unvisited ones, and '!' highlighting high-priority areas.

The location legend provides detailed insights, including coordinates, current waste percentages, and location names such as Klang, Petaling Jaya, and Cyberjaya.

6(c)External Factors Analysis: Unique Insights for AI-Based Routing

```
External Factors Analysis:
-------------------------
Weather Condition: 35.00% impact
Traffic Congestion: 28.00% impact
Time of Day Factor: 80.00% impact
Seasonal Factor: 30.00% impact
Road Condition: 57.60% impact

Environmental impact analysis saved to 'environmental_impact.txt'
Press any key to continue . . .
```

Description: This screenshot highlights the detailed external factors analysis, a unique feature exclusively available for the "External Factors AI-Based Route." It showcases the quantified impacts of key variables, including:

- Weather Condition: 35.00% impact
- Traffic Congestion: 28.00% impact
- Time of Day Factor: 80.00% impact
- Seasonal Factor: 30.00% impact
- Road Condition: 57.60% impact

The analysis provides a comprehensive understanding of how these dynamic factors influence the route, enhancing strategic decision-making. Furthermore, the environmental impact insights have been saved in a file named environmental_impact.txt for future reference.

7(a)Data Saved: Locations Info File Created

```
============================================
     WASTE COLLECTION MANAGEMENT SYSTEM
             WITH AI FEATURES
============================================
Date: Mon Apr 21 22:59:21 2025

Main Menu:
1. Generate Random Waste Levels
2. View Waste Locations Information
3. Select Route Algorithm
4. Execute Selected Route
5. Save Locations Info to File
6. View AI Predictions
7. Compare Route Costs
8. Select Most Cost-Effective Route
9. Waste Pattern Analytics Dashboard
10. View Collection History
11. Help
12. Save ALL Data
13. Load ALL Data
14. Delete ALL Data
0. Exit

Current Route Algorithm: External Factors AI-based

Enter your choice: 5

SUCCESS: Locations info saved to 'locations_info.txt'
Press any key to continue . . .
```

Description: This screenshot illustrates the functionality of option 5, which allows users to save detailed location information into a .txt file. Upon selection, the system successfully generates and stores data in locations_info.txt. This file contains crucial insights, including current waste levels, predicted trends, and associated analytics, ensuring users have access to structured and retrievable records.

7(b) Contents of `locations_info.txt`: Structured Waste and

Distance Data

```
≡ locations_info.txt
 1    Waste Locations Information
 2    ===========================
 3
 4    Location                       Waste Level %
 5    --------------------------------------------------
 6    Waste Collector HQ             0
 7    Kuala Lumpur Central           34
 8 +  Petaling Jaya                  69
 9    Shah Alam                      90
10    Subang Jaya                    46
11    Ampang                         12
12    Klang                          92
13    Cheras                         25
14    Puchong                        82
15    Putrajaya                      56
16    Cyberjaya                      89
17
18    Distance Matrix (km)
19    ====================
20
21    From\To              Waste Collector HQKuala Lumpur CentralPetaling Jaya  Shah Alam      Subang Jaya      A
22    Waste Collector HQ   0            12            15            22            18            14
23    Kuala Lumpur Central12            0             8             18            14            10
24    Petaling Jaya        15           8             0             10            8             13
25    Shah Alam            22           18            10            0             9             22
26    Subang Jaya          18           14            8             9             0             18
27    Ampang               14           10            13            22            18            0
28    Klang                28           24            16            12            15            30
29    Cheras               16           12            15            24            17            12
30    Puchong              20           16            12            15            10            20
31    Putrajaya            25           23            20            26            18            25
32    Cyberjaya            28           25            22            24            16            27
33
```

Description: This `.txt` file presents two vital sections for the Waste Management System:

1. **Waste Locations Information**
2. **Distance Matrix (km)**

8. AI Predictions: Simulating Waste Level Trends Across Locations

```
============================================
    WASTE COLLECTION MANAGEMENT SYSTEM
           WITH AI FEATURES
============================================
Date: Mon Apr 21 23:04:49 2025

AI Predictions for Waste Levels:
=========================================================================
Would you like to simulate trending waste levels? (y/n): y
Trending waste levels simulated.

Location               Current %        24 Hours %       48 Hours %       72 Hours %       Trend
----------------------  ---------------  ---------------  ---------------  ---------------  ----------------------
Kuala Lumpur Central   34 %             34 %             34 %             34 %             Stable
Petaling Jaya          69 %             68 %             68 %             68 %             Stable
Shah Alam              90 %             89 %             89 %             89 %             Stable
Subang Jaya            46 %             45 %             45 %             45 %             Stable
Ampang                 12 %             12 %             12 %             12 %             Stable
Klang                  92 %             91 %             91 %             91 %             Stable
Cheras                 25 %             24 %             24 %             24 %             Stable [ANOMALY]
Puchong                82 %             82 %             82 %             82 %             Stable [ANOMALY]
Putrajaya              56 %             55 %             55 %             55 %             Stable
Cyberjaya              89 %             88 %             88 %             88 %             Stable

Press any key to return to main menu...
```

Description: This screen showcases the "View AI Predictions" functionality, providing simulated waste level forecasts for the next 24, 48, and 72 hours. Each location is accompanied by a trend indicator, offering insights into stability and anomalies:

- Stable Trends: Locations like Kuala Lumpur Central and Shah Alam maintain consistent waste levels across the simulation period.
- Anomaly Detection: Cheras and Puchong flag unusual patterns, prompting further analysis to identify underlying causes.

9(a) Comprehensive Route Cost Comparison - Maximizing

Efficiency

```
=========================================
       WASTE COLLECTION MANAGEMENT SYSTEM
              WITH AI FEATURES
=========================================
Date: Mon Apr 21 23:15:57 2025

Route Cost Comparison:
=================================================================
Route Type               Distance (km)   Time (h)      Fuel (RM)      Wages (RM)      Total (RM)
-----------------------------------------------------------------
External Factors AI-based  132            4.03          373.84         40.31           414.14
Greedy                     125            3.12          312.50         31.25           343.75
Minimum Spanning Tree (MST) 105           2.62          262.50         26.25           288.75
Optimized                  64             1.60          160.00         16.00           176.00
Regular (Non-Optimized)    140            3.50          350.00         35.00           385.00
Reinforcement Learning (RL) 125           3.12          312.50         31.25           343.75
Traveling Salesman Problem (TSP) 107      2.67          267.50         26.75           294.25
=================================================================

Cost Savings Analysis:
----------------------
Most cost-effective route: Optimized

Switching from External Factors AI-based to Optimized saves: 238.14 RM
(57.50% reduction)

Switching from Greedy to Optimized saves: 167.75 RM
(48.80% reduction)

Switching from Minimum Spanning Tree (MST) to Optimized saves: 112.75 RM
(39.05% reduction)

Switching from Regular (Non-Optimized) to Optimized saves: 209.00 RM
(54.29% reduction)

Switching from Reinforcement Learning (RL) to Optimized saves: 167.75 RM
(48.80% reduction)

Switching from Traveling Salesman Problem (TSP) to Optimized saves: 118.25 RM
(40.19% reduction)

SUCCESS: Route comparison data saved to 'route_comparison.txt'
```

Description: This screenshot highlights the results of option 7, "Compare Route Cost," executed after all route algorithms have been utilized. It presents a detailed cost analysis for each route, including metrics such as total distance, time, fuel cost, wages, and overall expenses. Key takeaways:

- **Optimized Route:** The most cost-effective option with a total cost of 176.00 RM, achieving significant savings compared to other algorithms.
- **Cost Savings Analysis:** Highlights percentage reductions when switching from other routes to the optimized one, showcasing savings of up to 57.50%.

This feature empowers users to make data-driven decisions, prioritizing both economic efficiency and sustainability in waste collection. Route comparison details are saved in `route_comparison.txt` for easy reference.

9(b) Cost Simulation Menu - Engage for Optimal Insights

```
Options:
1. Select the most cost-effective route
2. Return to main menu
Enter your choice: 1

Finding the most cost-effective route...

SUCCESS: Selected the most cost-effective route: Optimized

Total cost: 176.00 RM (Fuel: 160.00 RM, Wages: 16.00 RM)

SUCCESS: Most cost-effective route data saved to 'most_cost_effective_route.txt'

Do you want to simulate waste collection using this route? (y/n): y

Simulating waste collection along the selected route...
========================================================
Location                      | Before | After
--------------------------------------------------------
Subang Jaya                   | 90    % | 0%
Ampang                        | 91    % | 0%
Cheras                        | 81    % | 0%
========================================================
Total locations visited: 4
Total locations collected: 3

SUCCESS: Waste collection simulation completed successfully!

Press any key to return to main menu...
```

Description: Following the detailed route cost comparison, the system prompts the user with a menu asking if they wish to simulate waste collection along the most cost-effective route. This menu allows the user to dive deeper into operational execution, offering real-time waste collection results and updates.

Upon choosing "Y" to simulate, the user is presented with:

- Waste Collection Status: Before and after data for locations like Subang Jaya, Ampang, and Cheras.
- Simulation Summary: Total locations visited versus collected, showcasing efficiency in route execution.

10. Optimal Route Selection - Efficiency at Its Peak

```
===========================================
     WASTE COLLECTION MANAGEMENT SYSTEM
             WITH AI FEATURES
===========================================
Date: Mon Apr 21 23:21:09 2025

Finding the most cost-effective route...

SUCCESS: Selected the most cost-effective route: Optimized

Total cost: 176.00 RM (Fuel: 160.00 RM, Wages: 16.00 RM)

SUCCESS: Most cost-effective route data saved to 'most_cost_effective_route.txt'

Do you want to simulate waste collection using this route? (y/n): y

Simulating waste collection along the selected route...
=========================================================
Location                      | Before | After
---------------------------------------------------------
=========================================================
Total locations visited: 4
Total locations collected: 0

SUCCESS: Waste collection simulation completed successfully!
Press any key to continue . . .
```

Description: This screen displays the outcome of option 8, where the system identifies and selects the most cost-effective route if it wasn't chosen previously in option 7. The optimized route comes with a detailed breakdown of costs:

- Total Cost: 176.00 RM
    - Fuel: 160.00 RM
    - Wages: 16.00 RM

Upon confirmation, the system saves the route data to the file most_cost_effective_route.txt and offers users the choice to simulate waste collection along this route. During simulation, 4 locations were visited, but waste wasn't collected at any.

11(a) Waste Pattern Analytics Dashboard - AI Insights at Work

```
=========================================
    WASTE COLLECTION MANAGEMENT SYSTEM
            WITH AI FEATURES
=========================================
Date: Mon Apr 21 23:25:15 2025

============================================================
              WASTE PATTERN ANALYTICS DASHBOARD
============================================================

----- SUMMARY STATISTICS -----
Average Waste Level:            27.40%
High Priority Locations:        2
Detected Anomalies:             4

----- WASTE PATTERN ANALYSIS -----
Location                Current %    Trend         Days to Capacity    Pattern Type
-------------------------------------------------------------------------------------
Kuala Lumpur Central    0 %          Stable        48                  Moderate Variability [ANOMALY]
Petaling Jaya           0 %          Stable        48                  Consistent [ANOMALY]
Shah Alam               14 %         Stable        41                  Consistent [ANOMALY]
Subang Jaya             11 %         Stable        42                  Highly Variable
Ampang                  0 %          Stable        48                  Highly Variable
Klang                   84 %         Stable        6                   Moderate Variability
Cheras                  51 %         Stable        22                  Highly Variable
Puchong                 2 %          Stable        47                  Highly Variable
Putrajaya               22 %         Stable        37                  Moderate Variability
Cyberjaya               90 %         Stable        3                   Consistent [ANOMALY]

----- WASTE TREND VISUALIZATION -----
Top Waste Growth Locations:
   No significant growth trends detected

----- INSIGHTS & RECOMMENDATIONS -----
ΓÇó URGENT: 2 location(s) require immediate attention
ΓÇó 1 location(s) should be scheduled within the next 48 hours
ΓÇó Anomalies detected at: Kuala Lumpur Central, Petaling Jaya, Shah Alam, Cyberjaya
   Recommend investigation of sudden waste level changes
ΓÇó Recommendation: Current collection schedule is adequate for waste volumes
```

Description: This screen showcases the "Waste Pattern Analytics Dashboard," a powerful tool for analyzing waste trends and patterns across multiple locations. The dashboard offers:

- **Summary Statistics:** Key metrics, including average waste levels (27.40%), high-priority locations (2), and anomalies detected (4).
- **Waste Pattern Analysis:** Each location is detailed with waste levels, stability trends, days to capacity, and pattern types. Anomalies are flagged for urgent review.
- **Trend Visualization:** Identifies top waste growth locations and overall stability.
- **Insights & Recommendations:** Pinpoints 2 locations requiring immediate attention, anomalies at Kuala Lumpur Central, Petaling Jaya, Shah Alam, and Cyberjaya, and advises investigations into sudden waste changes.

11(b) Waste Pattern Analytics Dashboard - ASCII Map Visualization

```
----- ROUTE MAP VISUALIZATION -----

    ASCII MAP VISUALIZATION OF ROUTE
    (H=HQ, O=Visited, .=Unvisited, !=High Priority)
    ============================================================




                            .  .

                       .          *


                  *         H        .


                     .           .

                        .  .




    ============================================================

    LOCATION LEGEND:
    (30,10): Waste Collector HQ — 0%
    (36,10): Kuala Lumpur Central — 0%
    (34,13): Petaling Jaya — 0%
    (31,15): Shah Alam — 14%
    (29,15): Subang Jaya — 11%
    (26,13): Ampang — 0%
    (24,10): Klang — 84%
    (26,7 ): Cheras — 51%
    (29,5 ): Puchong — 2%
    (31,5 ): Putrajaya — 22%
    (34,7 ): Cyberjaya — 90%

Press any key to return to the main menu...
```

Description: In addition to the detailed analytics, the dashboard generates an ASCII map to visually represent waste patterns across locations. The map uses symbols to denote statuses:

- 'H' for HQ
- 'O' for visited locations
- '.' for unvisited locations
- '!' for high-priority areas

The accompanying legend provides coordinates and waste percentages for each location, such as Klang (84%), Cyberjaya (90%), and Cheras (51%). This visual tool enhances user understanding of waste distribution and priority areas, supporting strategic decision-making.

12(a) Collection History - Comprehensive Record of Waste

Management

```
============================================
     WASTE COLLECTION MANAGEMENT SYSTEM
             WITH AI FEATURES
============================================
Date: Mon Apr 21 23:29:23 2025


=====================================================
                    COLLECTION HISTORY
=====================================================

Kuala Lumpur Central:
---------------------
Date & Time              Amount Collected
-------------------------------------------
2025-04-21 23:25:07        79.00              %
-------------------------------------------
Total collections: 1
Total waste collected: 79.00%

Petaling Jaya:
---------------
Date & Time              Amount Collected
-------------------------------------------
2025-04-21 23:25:07        83.00              %
-------------------------------------------
Total collections: 1
Total waste collected: 83.00%

Subang Jaya:
------------
Date & Time              Amount Collected
-------------------------------------------
2025-04-21 23:18:46        90.00              %
-------------------------------------------
Total collections: 1
Total waste collected: 90.00%

Ampang:
-------
Date & Time              Amount Collected
-------------------------------------------
2025-04-21 23:25:07        77.00              %
2025-04-21 23:18:46        91.00              %
```

Description: Upon selecting option 10, "View Collection History," the system displays a detailed log of waste collection activities across various locations. Each entry includes:

- Date & Time: Precise timestamps for each collection event.
- Amount Collected: Percentage of waste successfully collected during each session.

- Total Collections: The number of collection events per location.
- Total Waste Collected: Aggregated waste percentages for each location.

For example, Ampang shows two collection events with a total waste collected of 168.00%, while Kuala Lumpur Central has one event with 79.00% collected. This feature ensures users have access to structured and retrievable records, supporting efficient tracking and analysis of waste management operations.

12(b) Exporting Collection History - Structured Records at Your Fingertips

```
Cheras:
-------
Date & Time              Amount Collected
----------------------------------------
2025-04-21 23:18:46      81.00               %
----------------------------------------
Total collections: 1
Total waste collected: 81.00%

Options:
1. Export Collection History to File
2. Return to Main Menu
Enter your choice: 1

SUCCESS: Collection history exported to 'collection_history.txt'

Press any key to return to the main menu...
```

Description: After viewing the collection history for a specific location, users have the option to export this data into a `.txt` file. Once selected, the system successfully generates and saves the file named `collection_history.txt`. This file contains essential details, including timestamps, waste percentages collected, and total events for each location.

13(a) Help Function - Guided Overview of Main Menu Options

```
============================================
     WASTE COLLECTION MANAGEMENT SYSTEM
             WITH AI FEATURES
============================================
Date: Mon Apr 21 23:33:02 2025


========================================================
                    HELP DOCUMENTATION
========================================================


----- CORE FEATURES -----

1. Generate Random Waste Levels:
   Simulates real-world data by generating random waste levels (0-100%)
   for all collection locations. Use this to test different scenarios.

2. View Waste Locations Information:
   Displays all waste collection locations with their current waste levels,
   AI predictions for the next 24 hours, and trend analysis.
   - Green: Low waste levels (<40%)
   - Yellow: Medium waste levels (40-69%)
   - Red: High waste levels (70%+)

3. Select Route Algorithm:
   Choose from 7 different routing algorithms:
   - Regular: Visits locations with waste level ГёÑ40% within 30km
   - Optimized: Visits locations with waste level ГёÑ60% within 20km
   - Greedy: Visits locations with waste level ГёÑ30%, always choosing
     the nearest location next
   - TSP: Visits locations with waste level ГёÑ25% using the Traveling
     Salesman Problem algorithm to find the shortest path
   - MST: Visits locations with waste level ГёÑ35% using a Minimum
     Spanning Tree to find an efficient route
   - RL: Visits locations with waste level ГёÑ30% using Reinforcement
     Learning to optimize the route based on past experiences
   - External Factors AI-based: Optimizes routes based on external factors
     like weather, traffic, time of day, and seasonal variations

4. Execute Selected Route:
   Calculates and displays the optimized collection route using the
   selected algorithm. Shows distance, time, fuel cost, and wage cost.
   The route information is also saved to 'route_info.txt'.
   You can also visualize the route on a map after execution.
```

Description: The "Help" feature, accessible via option 11, provides users with a detailed guide to the core functionalities of the Waste Collection Management System. Each main menu option is described with clarity, highlighting its purpose and application. For example:

- Generate Random Waste Levels: Explains how to simulate data for testing scenarios.
- Select Route Algorithm: Details the available algorithms and their unique approaches, such as AI-based or optimization-focused methods.
- Execute Selected Route: Guides users through route execution, cost analysis, and visualization options.

13(b) Help Function - Analytics & AI Features Overview

```
----- ANALYTICS & AI FEATURES -----

5. Save Locations Info to File:
   Exports the current waste location data to 'locations_info.txt',
   including waste levels, predictions, and distances.

6. View AI Predictions:
   Shows AI-powered predictions for waste levels over the next 72 hours.
   Includes trend analysis and anomaly detection.
   You can also simulate trending waste data for demonstrations.

7. Compare Route Costs:
   Compares the costs of different routing algorithms side by side,
   showing potential savings by switching to the most cost-effective route.
   You need to execute at least 2 different routes to use this feature.

8. Select Most Cost-Effective Route:
   Automatically selects the most cost-effective route strategy
   based on previous route comparisons and simulates waste collection.
   This feature requires executing at least 2 different routes to compare costs.
   After selecting the most efficient route, you can simulate waste collection,
   which will set the waste levels of visited locations to 0.

9. Waste Pattern Analytics Dashboard:
   Comprehensive dashboard that analyzes historical waste data,
   identifies patterns, and provides actionable insights including:
   - Days until bins reach capacity
   - Waste pattern classification
   - Trend visualization
   - Prioritized recommendations
   - Visual map representation of waste locations and routes

10. View Collection History:
   Displays a detailed history of all waste collections performed,
   including dates, times, and amounts collected at each location.
   Options to export the collection history to a text file.
   This data is valuable for long-term waste trend analysis.
```

Description: The continuation of the "Help" function provides users with insights into advanced analytics and AI-driven features of the Waste Management System. These include:

- Save Locations Info to File: Exports waste location data to `locations_info.txt`, including waste levels, predictions, and distances.
- View AI Predictions: Displays AI-powered forecasts for waste levels over the next 72 hours, along with trend analysis and anomaly detection. Users can simulate trending waste data for demonstrations.
- Compare Route Costs: Compares costs of different routing algorithms side by side, highlighting potential savings. Requires execution of at least two routes for comparison.
- Select Most Cost-Effective Route: Automatically selects the most efficient route based on previous comparisons and simulates waste collection. Sets waste levels of visited locations to 0.

- Waste Pattern Analytics Dashboard: Analyzes historical waste data, identifies patterns, and provides actionable insights, including days until bins reach capacity, trend visualization, and prioritized recommendation

13(c) Help Function - Advanced Features and Tips for Optimal Use

```
----- DATA MANAGEMENT -----

12. Save ALL Data:
   Saves all current waste data, including locations, waste levels,
   historical data, collection history, and distance matrix to a binary file.
   Creates a bundle file containing all supplementary data files.
   A manifest file is also created to track all saved components.

13. Load ALL Data:
   Loads previously saved waste data from binary files.
   Options to load only core data or all data including supplementary files.
   This restores all locations, waste levels, historical data, and collection history.

14. Delete ALL Data:
   Permanently deletes saved data files.
   Options to delete only core data or all related data files.
   Use with caution as this operation cannot be undone.

----- SYSTEM OPERATIONS -----

11. Help: Display this help information

0. Exit: Close the application

----- ADDITIONAL INFORMATION -----
Cost calculations include both fuel (RM 2.50/km) and driver wages (RM 10.00/hour)
Route comparisons help identify the most cost-effective collection strategy
Anomalies are detected when waste levels deviate significantly from historical trends
All routes begin and end at the Waste Collector HQ
The External Factors route considers weather, traffic, time of day and seasonal variations
The RL (Reinforcement Learning) route improves over time as more routes are executed
Your data is saved to 'waste_data.dat' by default

----- TIPS FOR OPTIMAL USE -----
Execute multiple route types before comparing costs
Check the analytics dashboard regularly to identify problematic locations
Consider using the 'RL Route' for long-term optimization
Always save your data before closing the application
The External Factors route provides significant benefits during bad weather or traffic

Press any key to return to the main menu...
```

Description: The continuation of the "Help" function provides users with insights into additional features and practical tips for maximizing the Waste Management System's capabilities. These include:

- **Export Files:** Explains how to save data, such as collection history and location information, into `.txt` files for future reference.
- **ASCII Map Visualization:** Guides users on generating and interpreting ASCII maps for route execution and waste pattern analytics.
- **External Factors Analysis:** Highlights the unique insights provided by the AI-based route algorithm, including weather, traffic, and road conditions.

- **Simulation Options:** Encourages users to simulate waste collection after executing routes to validate efficiency and resource allocation.
- **Tips for Optimal Use:** Advises users to execute multiple route types, check the analytics dashboard for trends, and save data before exiting the application.

14(a) Save All Data - Effortless File Management

```
============================================
      WASTE COLLECTION MANAGEMENT SYSTEM
               WITH AI FEATURES
============================================
Date: Mon Apr 21 23:38:27 2025

Save ALL Data Options:
1. Save to default file (waste_data.dat)
2. Save to a custom file
3. Return to main menu

Enter your choice:
```

Description: Selecting option 12 brings the user to a menu offering versatile data-saving options, ensuring seamless management of critical system outputs. The menu provides the following choices:

1. **Save to Default File (waste_data.dat):** Automatically stores all data in a predefined file for quick and consistent access.
2. **Save to Custom File:** Offers the flexibility to specify a custom file name for tailored data organization.
3. **Return to Main Menu:** Allows the user to exit without performing a save operation.

14(b) Saving All Data: Default Option Selected

```
Saving data...
Saving complete data to waste_data.dat...            ] 0%
[=============================================] 100%

SUCCESS: Complete data saved successfully to waste_data.dat
[=============================================] 100%

SUCCESS: All data saved successfully!
- Core data saved to: waste_data.dat
- Additional files bundled in: waste_data.dat_bundle.txt
- Manifest created at: waste_data.dat_manifest.txt
Total files saved: 8 (including core data)
Press any key to continue . . .
```

File	Status
☰ collection_history.txt	U
☰ environmental_impact.txt	U
☰ external_factors_history.dat	U
☰ most_cost_effective_route.txt	U
☰ qtable.txt	U
☰ route_comparison.txt	U
☰ route_info.txt	U
☰ waste_data.dat	U
☰ waste_data.dat_bundle.txt	U
☰ waste_data.dat_manifest.txt	U
G+ waste.cpp	M
☰ waste.exe	M

Description:

Files Saved:

- ○ `collection_history.txt`
- ○ `environmental_impact.txt`
- ○ `external_factors_history.dat`
- ○ `most_cost_effective_route.txt`
- ○ `qtable.txt`
- ○ `route_comparison.txt`
- ○ `route_info.txt`
- ○ `waste_data.dat`
- ○ `waste_data.dat_bundle.txt`
- ○ `waste_data.dat_manifest.txt`

2. **Process of Saving:**
   - ○ The system efficiently saves all data in `waste_data.dat`.
   - ○ Additional files bundled in `waste_data.dat_bundle.txt`.
   - ○ A manifest file (`waste_data.dat_manifest.txt`) summarizing contents.
   - ○ Success message confirming eight files saved in total.

15(a) Load ALL Data Menu - Seamless Data Retrieval

```
==========================================
      WASTE COLLECTION MANAGEMENT SYSTEM
             WITH AI FEATURES
==========================================
Date: Mon Apr 21 23:43:34 2025

Load ALL Data Options:
1. Load core data only (from waste_data.dat)
2. Load ALL data (core + additional files from bundle)
3. Load from a custom file
4. Return to main menu

Enter your choice:
```

Description: Selecting option 13 brings the user to the "Load ALL Data" menu, offering flexible options for retrieving previously saved data. The menu includes:

1. **Load Core Data Only:** Retrieves essential information from `waste_data.dat`, focusing on waste levels and basic analytics.
2. **Load ALL Data:** Combines core data with additional files from `waste_data.dat_bundle.txt`, ensuring comprehensive insights.
3. **Load from Custom File:** Allows users to specify a custom file name for tailored data retrieval.
4. **Return to Main Menu:** Provides an option to exit without loading data.

15(b) Loading All Data - Comprehensive Retrieval Completed

```
========================================
     WASTE COLLECTION MANAGEMENT SYSTEM
             WITH AI FEATURES
========================================
Date: Mon Apr 21 23:43:34 2025

Load ALL Data Options:
1. Load core data only (from waste_data.dat)
2. Load ALL data (core + additional files from bundle)
3. Load from a custom file
4. Return to main menu

Enter your choice: 2
This will overwrite current data. Continue? (y/n): y
[                                            ] 0%
Loading core data from waste_data.dat...
Loading data from waste_data.dat...
[============================================] 100%

SUCCESS: Data loaded successfully from waste_data.dat
Loading additional files from bundle...          ] 50%
Extracting: environmental_impact.txt
Extracting: external_factors_history.dat
Extracting: qtable.txt
Extracting: route_info.txt
Extracting: collection_history.txt
Extracting: route_comparison.txt
Extracting: most_cost_effective_route.txt

SUCCESS: Route comparison data loaded successfully!

SUCCESS: Most cost-effective route data found. This data can be accessed through the 'Select Most Cost-Effective Route' menu option.
[============================================] 100%

SUCCESS: All data loaded successfully!
- Core data loaded from: waste_data.dat
- Additional files extracted from bundle
Press any key to continue . . .
```

Description: Upon selecting option 2, the system initiates the "Load ALL Data" process, which includes both core data and additional files from the bundle. Here's an outline of what happens:

1. **Confirmation Prompt:**
   The system prompts the user to confirm if they want to overwrite existing data, ensuring no accidental overwrites.
2. **Core Data Loading:**
   Data from `waste_data.dat` is retrieved first. A progress bar indicates the loading process, with a success message confirming core data was loaded successfully.
3. **Additional Files Extraction:**
   The system proceeds to extract supplemental files from the bundle, such as:
   - `environmental_impact.txt`
   - `external_factors_history.dat`
   - `route_info.txt`
   - `collection_history.txt`
   - `route_comparison.txt`
   - `most_cost_effective_route.txt`
4. **Data Accessibility Confirmation:**
   - The system confirms the availability of key data, like route comparison information and the most cost-effective route.
   - A success message reassures the user that all data has been loaded seamlessly.

16(a) Delete ALL Data - Comprehensive Data Removal Menu

```
============================================
     WASTE COLLECTION MANAGEMENT SYSTEM
             WITH AI FEATURES
============================================
Date: Mon Apr 21 23:46:56 2025

Delete ALL Data Options:
1. Delete core data file only (waste_data.dat)
2. Delete ALL data files (core + bundle + manifest)
3. Delete a custom file
4. Return to main menu

Enter your choice: |
```

Description: Selecting option 14 brings the user to the "Delete ALL Data" menu, offering flexible options for removing data files. The menu includes:

1. Delete Core Data File Only: Removes the primary file `waste_data.dat`, retaining supplementary files for future use.
2. Delete ALL Data Files: Deletes the core file along with all bundled files, including `waste_data.dat_bundle.txt` and `waste_data.dat_manifest.txt`.
3. Delete a Custom File: Allows users to specify a file name for targeted deletion.
4. Return to Main Menu: Provides an option to exit without deleting any files.

Upon confirming deletion, the system displays a progress bar and success message, ensuring users are informed of the operation's completion. This feature emphasizes user control and data management precision.

16(b) Option 2: Delete ALL Data Files - Comprehensive Cleanup

Process

```
===========================================
     WASTE COLLECTION MANAGEMENT SYSTEM
              WITH AI FEATURES
===========================================
Date: Mon Apr 21 23:46:56 2025

Delete ALL Data Options:
1. Delete core data file only (waste_data.dat)
2. Delete ALL data files (core + bundle + manifest)
3. Delete a custom file
4. Return to main menu

Enter your choice: 2
Are you sure you want to delete these files? This cannot be undone. (y/n): y

SUCCESS: Data file deleted successfully: waste_data.dat
Core data file deleted: waste_data.dat
Bundle file deleted: waste_data.dat_bundle.txt
Manifest file deleted: waste_data.dat_manifest.txt

Deleting additional files...
File deleted: environmental_impact.txt
File deleted: external_factors_history.dat
File deleted: qtable.txt
File deleted: route_info.txt
File deleted: collection_history.txt
File deleted: route_comparison.txt
File deleted: most_cost_effective_route.txt

SUCCESS: Data files deleted successfully
Press any key to continue . . .
```

Description: Upon selecting option 2, "Delete ALL Data," the system initiates a complete cleanup of all files generated during the session. The process involves:

1. **Confirmation Prompt:**
   The user is asked to confirm the deletion by typing 'y'. This step ensures that no accidental deletions occur.
2. **Deletion Progress:**
   The system deletes the following files one by one:
   - waste_data.dat
   - waste_data.dat_bundle.txt
   - waste_data.dat_manifest.txt
   - environmental_impact.txt
   - external_factors_history.dat
   - qtable.txt

- ○ `route_info.txt`
- ○ `collection_history.txt`
- ○ `route_comparison.txt`
- ○ `most_cost_effective_route.txt`

3. **Success Confirmation:**

   A message is displayed confirming the successful deletion of all files. The user is then prompted to press any key to return to the main menu.

17(a) Exit Confirmation - Save Data Before Quitting

```
================================================
      WASTE COLLECTION MANAGEMENT SYSTEM
              WITH AI FEATURES
================================================
Date: Mon Apr 21 23:50:58 2025
Are you sure you want to exit the system? (y/n): y
Would you like to save all data before exiting? (y/n): n
```

Description: When the user selects option 0 to exit the system, they are prompted with a confirmation message to ensure intentional action. The process includes:

1. **Exit Confirmation Prompt:**
   - The system asks, *"Are you sure you want to exit the system? (y/n):"*
   - If the user types 'y', the system proceeds to the next step.
2. **Save Data Prompt:**
   - The system inquires, *"Would you like to save all data before exiting? (y/n):"*
   - If the user selects 'y', all data is saved to the default file `waste_data.dat` or a custom file, depending on the user's previous settings.
3. **Exit Process:**
   - If the user confirms both prompts, the system saves the data (if chosen) and exits gracefully.
   - If the user selects 'n' for either prompt, the system cancels the exit or skips saving data, returning to the main menu.

17(b) Exit Successful - Session Terminated

```
================================================
      WASTE COLLECTION MANAGEMENT SYSTEM
              WITH AI FEATURES
================================================
Date: Mon Apr 21 23:52:33 2025


  Thank You for using the Waste Collection Management System!!!
              Have a nice day :) !!

Press any key to exit...
```

Description: The system has successfully exited, and the screen displayed the message:
"Thank You for using the Waste Collection Management System!!! Have a nice day :) !!"

This farewell reinforces a user-friendly experience by ending on a positive and polite note, ensuring the session concludes gracefully.