Team 8 Mobile Air Quality Sampling Plan

Introduction: Computational Over Manual Approach

Rather than relying on traditional manual route planning with paper maps and guesswork, we employed a modeling and computational approach to design the most optimal mobile air quality sampling plan. By creating a digital sandbox of the Drumm Avenue neighborhood road network and applying specialized algorithms, we were able to generate an efficient sampling plan that meets all requirements while maximizing data collection quality.

This computational approach not only ensures comprehensive coverage but also optimizes the driver's time - meaning they'll have more time for that much-needed coffee break instead of driving in circles trying to figure out which roads they've missed!

Code Repository

All the designed code and output could be found at the following address: https://github.com/certaindragon3/ENVR101_team8_problemsloving2

Note that:

1. **`readme.md` in the repository provide a more comprehensive explanation of the code and output, combined with manual for code reproducibility.**
2. **Output files in `/output` provides a detailed optimal sampling plan for reference.**

Implementation Methodology

Simplifying Constraints

Before diving into the code implementation, we made strategic simplifications to make the problem tractable:

1. **Fixed Vehicle Speed**: We set a constant speed of 8 m/s (28.8 km/h) throughout the sampling process, balancing between the suggested optimal speed (5 m/s) and the maximum allowable speed (10 m/s). This simplification makes time calculations more reliable.
2. **Exact Time Windows**: We designed routes to fit precisely within the available 4-hour windows (8:00 AM - 12:00 PM and 1:00 PM - 5:00 PM), maximizing data collection efficiency.
3. **Practical Road Network**: While we aimed for complete road coverage, we prioritized creating cohesive routes that minimize fragmentation and unnecessary backtracking.

Technical Implementation

The project implementation followed these key steps:

1. **Road Network Creation**: Using `sandbox_creation.py`, we extracted the road network data from OpenStreetMap and created a GeoPackage (GPKG) file containing accurate road geometries, intersections, and distances.
2. **Star Location Mapping**: QGIS was employed to precisely place the four fixed sampling locations (marked as stars) based on their geographic coordinates within the study area.
3. **Algorithm Design**: The core of our solution, `algorithm.py`, implements several sophisticated techniques:

   - **Balanced Road Allocation**: Divides roads between morning and afternoon sessions to ensure complete coverage
   - **Star Location Priority**: Guarantees all four fixed sampling locations are visited with their required 20-minute stops
   - **Time-Constrained Routing**: Creates routes that exactly fit the 4-hour time windows
   - **Connected Path Generation**: Ensures routes are practical to follow with minimal fragmentation

   The algorithm automatically balances coverage needs with time constraints, producing an efficient sampling plan that meets all requirements.

Sampling Plan Results

**Please Note:

1. **The star points are referred to as “Star 1,” “Star 2,” “Star 3,” and “Star 4,” respectively, in order from north to south.**
2. **Our sampling plan includes two modes: “connector” and “sampling.” In the connector mode, the driver is simply traveling between locations without collecting samples. In the sampling mode, the driver is actively conducting sampling tasks. As a result, some routes in the plan may appear disconnected, since not all travel segments involve sampling.**

Morning Sampling Plan (8:00 AM - 12:00 PM)

The morning sampling route covers 11 unique roads and includes visits to two fixed sampling locations (Star 1 and Star 2). The route starts at East Q Street and Drumm Avenue at 8:00 AM and concludes at Sanford Avenue at 12:00 PM, utilizing the full 4-hour window. Key sampling locations include:

- Drumm Avenue (multiple segments)
- East O Street (with fixed sampling at 8:30 AM)
- Watson Avenue
- East Sandison Street

- East Cruces Street
- Sanford Avenue

The morning session also prioritizes covering Drumm Avenue segments, providing critical data on this area of primary concern.

Morning Detailed Schedule

road_name	start_time	end_time	type
['East Q Street', 'Drumm Avenue']	08:00	08:05	sampling
Connector: ['East Q Street', 'Drumm Avenue']	08:05	08:10	connector
Connector: Drumm Avenue	08:10	08:15	connector

road_name	start_time	end_time	type
Connector: Drumm Avenue	08:15	08:20	connector
Connector: East O Street	08:20	08:25	connector
East O Street	08:25	08:30	sampling
FIXED SAMPLING at location 122709562	08:30	08:50	star_stop
East O Street	08:50	08:55	sampling
Connector: East O Street	08:55	09:00	connector
Connector: Watson Avenue	09:00	09:05	connector
Watson Avenue	09:05	09:10	sampling
Watson Avenue	09:10	09:15	sampling
Connector: East Cruces Street	09:15	09:20	connector
Connector: East Cruces Street	09:20	09:25	connector
Connector: East Cruces Street	09:25	09:30	connector
Drumm Avenue	09:30	09:35	sampling
FIXED SAMPLING at location 122602601	09:35	09:55	star_stop
East Sandison Street	09:55	10:00	sampling
Connector: East Sandison Street	10:00	10:05	connector
Connector: East Sandison Street	10:05	10:10	connector
Connector: Watson Avenue	10:10	10:15	connector
Connector: Watson Avenue	10:15	10:20	connector
Connector: Watson Avenue	10:20	10:25	connector
Watson Avenue	10:25	10:30	sampling
Connector: East O Street	10:30	10:35	connector
Connector: East O Street	10:35	10:40	connector
Connector: Drumm Avenue	10:40	10:45	connector
Drumm Avenue	10:45	10:50	sampling
Connector: ['East Q Street', 'Drumm Avenue']	10:50	10:55	connector
East Q Street	10:55	11:00	sampling
Blinn Avenue	11:00	11:05	sampling
East Sandison Street	11:05	11:10	sampling
Gamble Avenue	11:10	11:15	sampling
East Cruces Street	11:15	11:20	sampling
Drumm Avenue	11:20	11:25	sampling
Drumm Avenue	11:25	11:30	sampling
East Colon Street	11:30	11:35	sampling

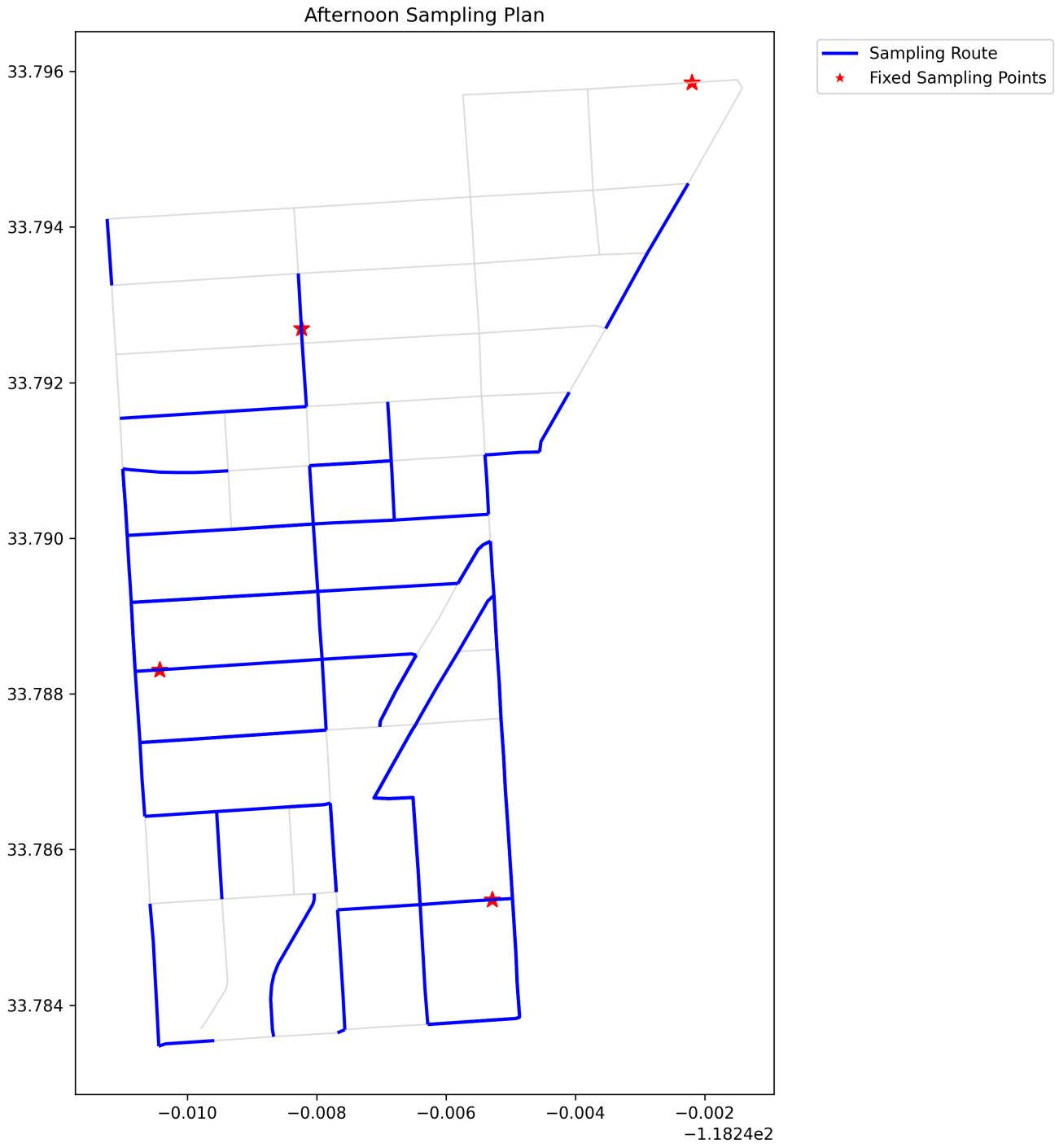
road_name	start_time	end_time	type
Blinn Avenue	11:35	11:40	sampling
Connector: East O Street	11:40	11:45	connector
Connector: East O Street	11:45	11:50	connector
Sanford Avenue	11:50	11:55	sampling
Sanford Avenue	11:55	12:00	sampling

Afternoon Sampling Plan (1:00 PM - 5:00 PM)

The afternoon sampling route complements the morning route by covering 10 additional unique roads and the remaining two fixed sampling locations (Star 3 and Star 4). Beginning at East Robidoux Street at 1:00 PM and ending at Watson Avenue at 5:00 PM, this route also maximizes the available time window. Key sampling locations include:

- Sanford Avenue (with fixed sampling at 1:20 PM)
- Blinn Avenue (with fixed sampling at 2:30 PM)
- East Denni Street
- East L Street
- East Young Street
- Flint Avenue

Combined with the morning route, this ensures comprehensive coverage of all target roads in the study area.



Afternoon Detailed Plan

road_name	start_time	end_time	type
East Robidoux Street	13:00	13:05	sampling
Connector: Watson Avenue	13:05	13:10	connector
Connector: East L Street	13:10	13:15	connector
Sanford Avenue	13:15	13:20	sampling
FIXED SAMPLING at location 123114461	13:20	13:40	star_stop
Sanford Avenue	13:40	13:45	sampling
Connector: East M Street	13:45	13:50	connector

road_name	start_time	end_time	type
Connector: Watson Avenue	13:50	13:55	connector
Connector: Watson Avenue	13:55	14:00	connector
Connector: East L Street	14:00	14:05	connector
Connector: East L Street	14:05	14:10	connector
Connector: ['Coil Avenue', 'Mahar Avenue', 'East Young Street']	14:10	14:15	connector
Connector: East Denni Street	14:15	14:20	connector
Connector: Blinn Avenue	14:20	14:25	connector
Blinn Avenue	14:25	14:30	sampling
FIXED SAMPLING at location 122696213	14:30	14:50	star_stop
East Denni Street	14:50	14:55	sampling
Connector: East Denni Street	14:55	15:00	connector
Blinn Avenue	15:00	15:05	sampling
Blinn Avenue	15:05	15:10	sampling
Connector: Blinn Avenue	15:10	15:15	connector
Blinn Avenue	15:15	15:20	sampling
Connector: East Denni Street	15:20	15:25	connector
Connector: ['Coil Avenue', 'Mahar Avenue', 'East Young Street']	15:25	15:30	connector
Connector: East L Street	15:30	15:35	connector
Connector: East L Street	15:35	15:40	connector
Connector: East L Street	15:40	15:45	connector
Connector: Sanford Avenue	15:45	15:50	connector
Sanford Avenue	15:50	15:55	sampling
Connector: East M Street	15:55	16:00	connector
Connector: Watson Avenue	16:00	16:05	connector
Watson Avenue	16:05	16:10	sampling
East L Street	16:10	16:15	sampling
Sanford Avenue	16:15	16:20	sampling
East Young Street	16:20	16:25	sampling
Flint Avenue	16:25	16:30	sampling
Connector: Flint Avenue	16:30	16:35	connector
East Young Street	16:35	16:40	sampling
East Young Street	16:40	16:45	sampling

road_name	start_time	end_time	type
Watson Avenue	16:45	16:50	sampling
Connector: Watson Avenue	16:50	16:55	connector
Connector: Watson Avenue	16:55	17:00	connector

Weekly Implementation

Since this sampling plan represents an optimized solution that meets all requirements, we recommend implementing the same plan from Monday through Friday. This consistency offers several advantages:

1. Simplified logistics for the sampling team
2. Standardized data collection across all weekdays
3. Comparable temporal patterns for scientific analysis
4. Reliable schedule for equipment preparation and maintenance

Justification Against Requirements

Our sampling plan fully satisfies all four key requirements specified for this project:

1. **Time Constraints**:
   - Sampling is conducted during weekdays (Monday to Friday)
   - Each session fits perfectly within the specified working hours (8:00 AM - 12:00 PM and 1:00 PM - 5:00 PM)
   - The lunch break (12:00 PM - 1:00 PM) is respected with no sampling activities
2. **Vehicle Speed**:
   - The plan assumes a constant 8 m/s speed, which falls within the required range (5-10 m/s)
   - This speed ensures accurate air pollutant concentration measurement while maintaining efficient coverage
3. **Spatiotemporally Balanced Samples**:
   - All 18 roads within the sampling area are visited at least once
   - Roads are distributed between morning and afternoon sessions
   - Over the week, the combination of morning and afternoon routes ensures comprehensive coverage
4. **Fixed Location Sampling**:
   - All four star locations receive dedicated 20-minute stops:
     - Star 1: 8:30 AM - 8:50 AM
     - Star 2: 9:35 AM - 9:55 AM
     - Star 3: 1:20 PM - 1:40 PM
     - Star 4: 2:30 PM - 2:50 PM

Conclusion

We believe that modeling and computation outperforms manual guesswork!