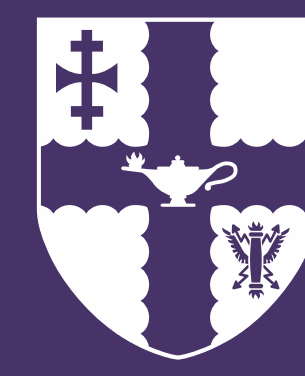


Vehicle Emission Modelling for Air Quality Predictions

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1. Introduction

- Air pollution is a major environmental and health concern globally, with road transportation being a key urban source of oxides of nitrogen (NO_x), particulate matter (PM), carbon monoxide (CO), while also contributing to the formation of secondary pollutants such as ozone (O_3).
- Vehicle emissions depend on many parameters such as vehicle type, fuel type, engine technology, vehicle age and driving behaviour.
- Modelling approaches often treat vehicle activity simulation, emission modelling, dispersion and background modelling as separate areas. This highlights the need for a time resolved and unified modelling framework.
- This research contributes to the development of a broader air quality digital twin framework by integrating vehicle emission estimation with local dispersion modelling.

2. Aims and Objectives

- Reviewing existing literature on emission generation, emission standards, measuring techniques, and modelling techniques to identify current approaches and research gaps.
- Development of a time resolved emission modelling framework which integrates vehicle activity, emission estimation, dispersion and background modelling within a unified system.
- Implementation of a vehicle-specific, time-resolved simulation that uses vehicle identification data to estimate emissions using EMEP/EEA emissions data, simulate local pollutant dispersion, and combine with background air quality measurements.

3. Modelling Methodology

- A model has been constructed to simulate vehicles travelling across the university, dynamically estimate their emissions and model their dispersion across the local area, assuming vehicles entering the university are counted and their registration plates are recorded.

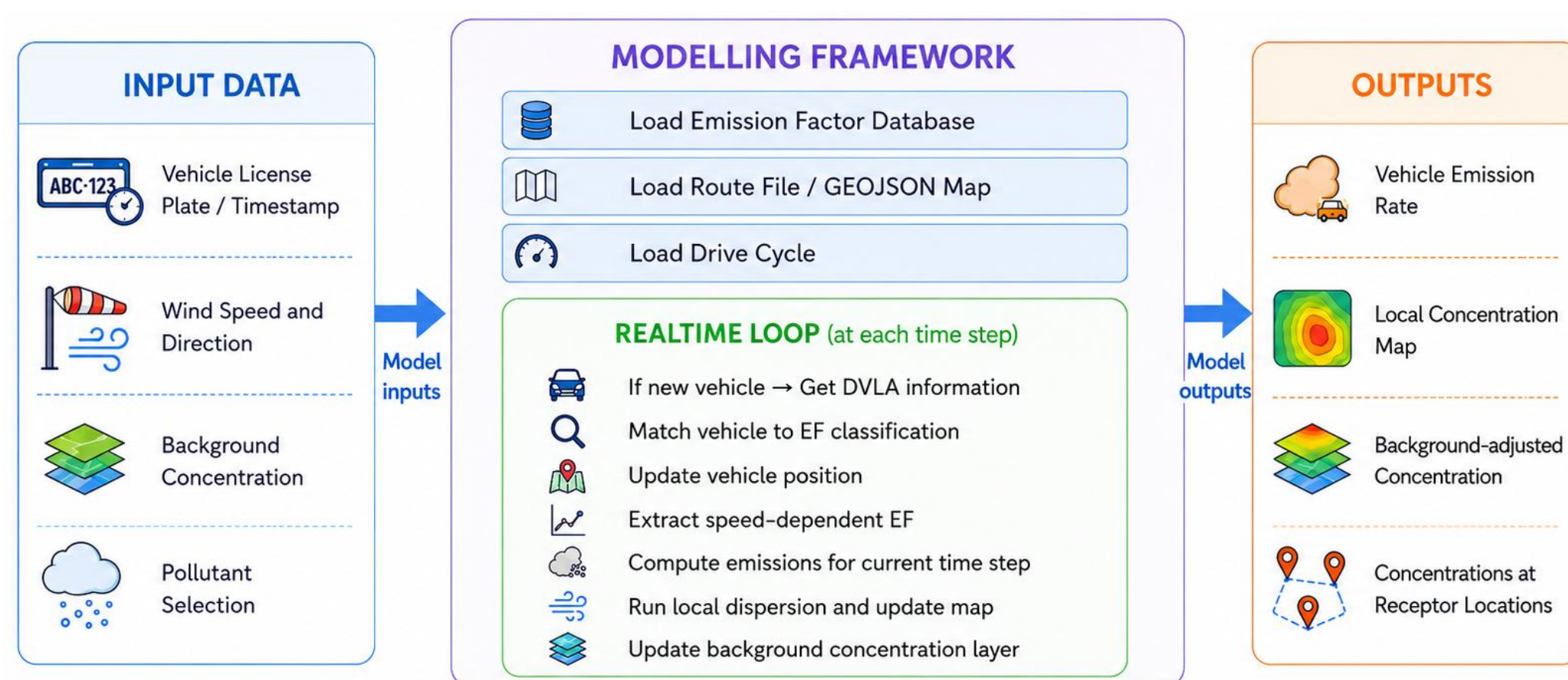


Figure 1: Time resolved modelling framework structure

- The model operates as a near real time time-stepped simulation.
- Each vehicle is treated as a dynamic object with vehicle specific trajectory (spatial position), vehicle information, and emission characteristics.
- This enables high resolution temporal and spatial simulation of pollutant concentrations of NO_x , PM and CO .
- Ten vehicles were simulated travelling independently along the route, with a 60-second separation between each vehicle, starting from the west entrance.
- All vehicles followed the same GPS-recorded drive cycle and completed the journey in 364 seconds.

4. Results

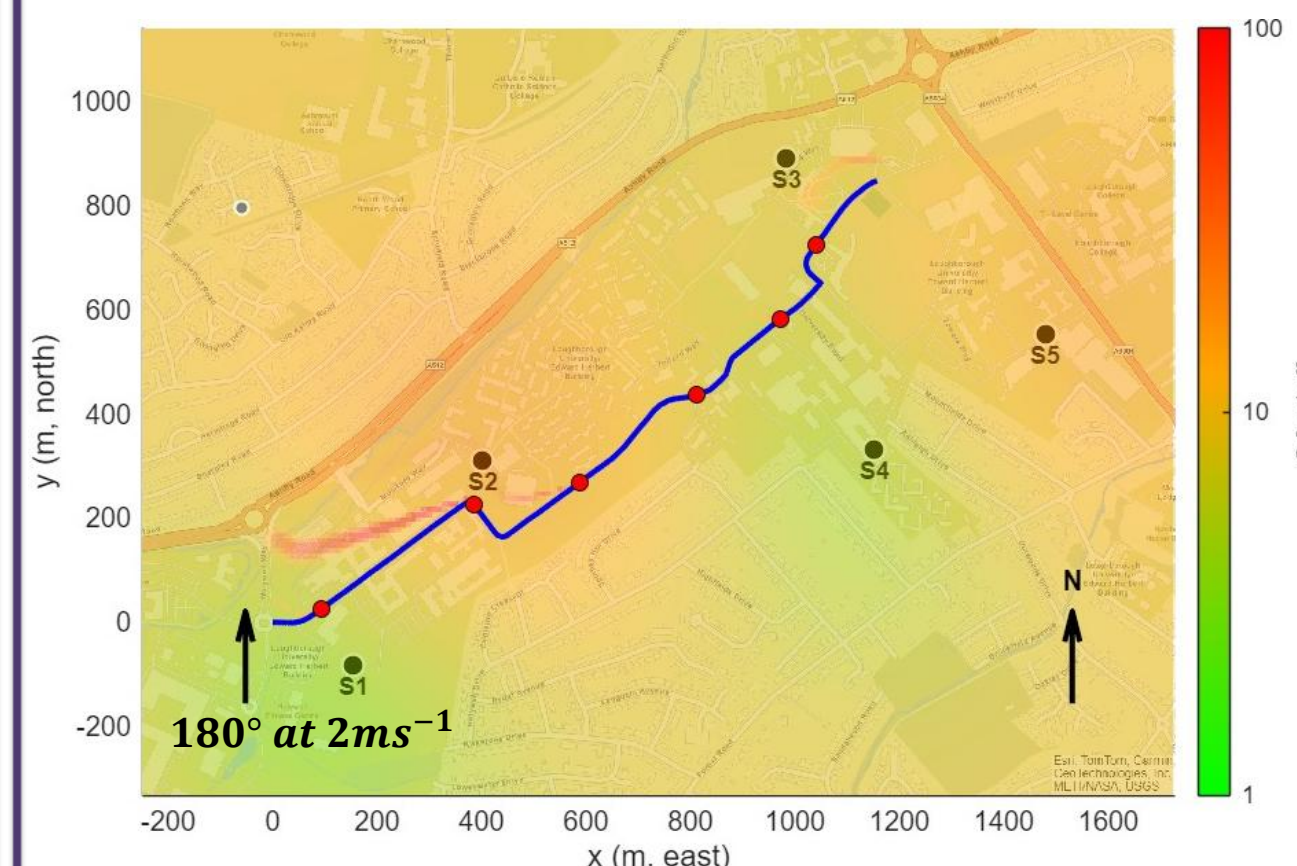


Figure 2: NOx Concentration map (Points denotes moving vehicles)

Table 1: DVLA Vehicle Information

Veh ID	Make	Fuel Type	Engine CC	YOM	Type Appr oval
1	HONDA	HYBRID	1339	2006-11	M1
2	FORD	DIESEL	1997	2017-11	M1
3	PEUGEOT	ELECTRIC	0	2023-10	M1
4	FORD	DIESEL	1996	2023-02	N1
5	FORD	PETROL	998	2014-03	M1
6	FORD	DIESEL	1560	2012-09	M1
7	OPTARE	DIESEL	4250	2007-07	M2
8	MERCEDES ES-BENZ	DIESEL	5132	2019-12	N2
9	VOLVO	DIESEL	10837	2017-03	N3
10	HONDA	PETROL	125	2025-09	L3

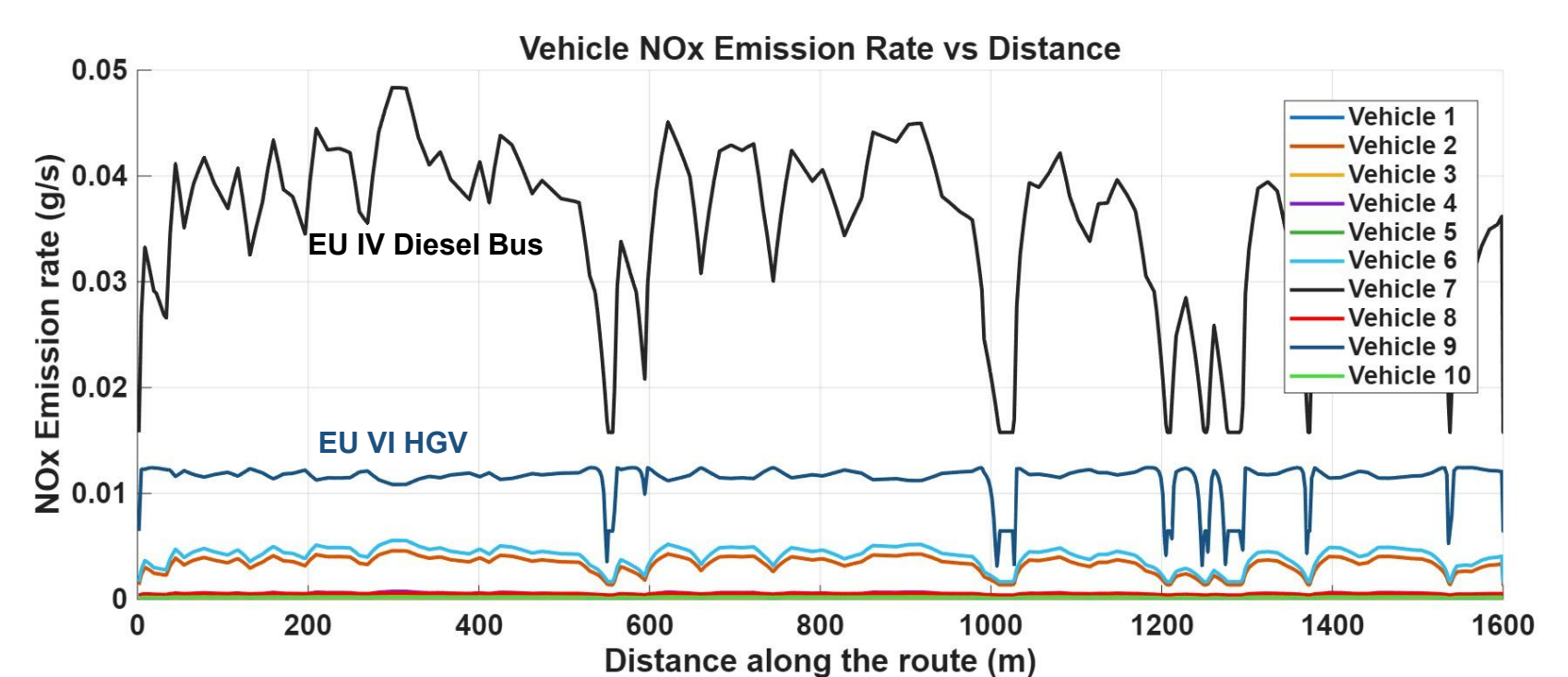


Figure 3: Emission rates of vehicles

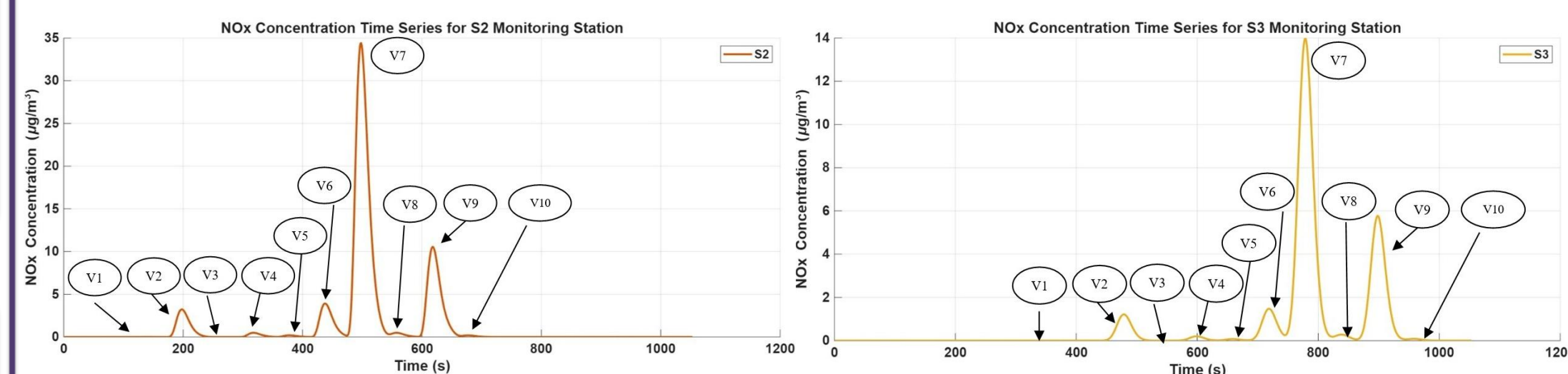


Figure 4: NOx Concentration profiles at receptor S2 and S3 and corresponding vehicles

- Both locations show a similar temporal trend; however, S2, located closer to the road, experiences higher concentration peaks than S3 due to greater pollutant dispersion with distance.
- NO_x concentration peaks at S2 above $30 \mu g/m^3$ for a Euro IV diesel bus and other vehicles were individually contributing to peaks less than $10 \mu g/m^3$.
- It was observed very low concentration spikes of particulate matter (PM), which are less than $0.3 \mu g/m^3$ for the entire fleet.

5. Conclusions & Future Work

- This study addresses the research objectives through the development of a unified end-to-end modelling framework that combines dynamic vehicle activity, drive-cycle-based emission estimation using emission data, and modelling of local pollutant dispersion.
- Results showed the uncertainty of measurement of vehicle level contribution from ambient sampling since predicted exhaust PM concentrations at receptor locations were very low.
- Limitations include the lack of non-tailpipe emissions, and dispersion does not consider vehicle induced turbulence, wake effects, or atmospheric influences such as sunlight.
- The future focus will be on addressing these limitations by exploring research direction in lifecycle effects, uncertainty analysis and further experimental validation using source-based sampling with low-cost sensor systems.

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