



Supplement of

Spatially resolved hourly traffic emission over megacity Delhi using advanced traffic flow data

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Supplementary Material

Table S1. A Number of 127 vehicle categories used in the current study, categorised according to fuel, engine and euro standard. The share indicates the individual fraction of the primary vehicle category. The emission factors are calculated as a function of speed. As an example, the emission factors of PME at a speed of 30 km/h are shown in the table.

S.N.	Category	Fuel	Segment	Euro Standard	Share	PM EF at 30 km/h
1	HCV	Diesel	Rigid <=7,5 t	Conventional	1.85E-19	0.365074
2	HCV	Diesel	Rigid <=7,5 t	Euro 1	5.63E-05	0.150701
3	HCV	Diesel	Rigid <=7,5 t	Euro 2	0.020315	0.070719
4	HCV	Diesel	Rigid <=7,5 t	Euro 3	0.077393	0.074589
5	HCV	Diesel	Rigid <=7,5 t	Euro 4	0.02284	0.016693
6	HCV	Diesel	Rigid 7,5 - 12 t	Conventional	2.56E-19	0.390527
7	HCV	Diesel	Rigid 7,5 - 12 t	Euro 1	7.83E-05	0.242027
8	HCV	Diesel	Rigid 7,5 - 12 t	Euro 2	0.028231	0.119236
9	HCV	Diesel	Rigid 7,5 - 12 t	Euro 3	0.107549	0.123875
10	HCV	Diesel	Rigid 7,5 - 12 t	Euro 4	0.03174	0.02739
11	HCV	Diesel	Rigid 12 - 14 t	Conventional	8.14E-20	0.423848
12	HCV	Diesel	Rigid 12 - 14 t	Euro 1	2.48E-05	0.266361
13	HCV	Diesel	Rigid 12 - 14 t	Euro 2	0.008956	0.132989
14	HCV	Diesel	Rigid 12 - 14 t	Euro 3	0.03412	0.128356
15	HCV	Diesel	Rigid 12 - 14 t	Euro 4	0.01007	0.029628
16	HCV	Diesel	Rigid 14 - 20 t	Conventional	1.63E-19	0.569855
17	HCV	Diesel	Rigid 14 - 20 t	Euro 1	4.97E-05	0.357016
18	HCV	Diesel	Rigid 14 - 20 t	Euro 2	0.017913	0.168754
19	HCV	Diesel	Rigid 14 - 20 t	Euro 3	0.068241	0.177603
20	HCV	Diesel	Rigid 14 - 20 t	Euro 4	0.020139	0.039044
21	HCV	Diesel	Rigid 20 - 26 t	Conventional	1.63E-19	0.603644
22	HCV	Diesel	Rigid 20 - 26 t	Euro 1	4.97E-05	0.489942
23	HCV	Diesel	Rigid 20 - 26 t	Euro 2	0.017913	0.237694
24	HCV	Diesel	Rigid 20 - 26 t	Euro 3	0.068241	0.22899
25	HCV	Diesel	Rigid 20 - 26 t	Euro 4	0.020139	0.050825
26	HCV	Diesel	Rigid 26 - 28 t	Conventional	1.60E-19	0.640483
27	HCV	Diesel	Rigid 26 - 28 t	Euro 1	4.90E-05	0.504886
28	HCV	Diesel	Rigid 26 - 28 t	Euro 2	0.017658	0.252503
29	HCV	Diesel	Rigid 26 - 28 t	Euro 3	0.067271	0.237848

30	HCV	Diesel	Rigid 26 - 28 t	Euro 4	0.019853	0.05407
31	HCV	Diesel	Rigid 28 - 32 t	Conventional	1.31E-19	0.727335
32	HCV	Diesel	Rigid 28 - 32 t	Euro 1	4.01E-05	0.567104
33	HCV	Diesel	Rigid 28 - 32 t	Euro 2	0.014448	0.292271
34	HCV	Diesel	Rigid 28 - 32 t	Euro 3	0.05504	0.264687
35	HCV	Diesel	Rigid 28 - 32 t	Euro 4	0.016243	0.060729
36	HCV	Diesel	Rigid >32 t	Conventional	1.31E-19	0.738985
37	HCV	Diesel	Rigid >32 t	Euro 1	4.01E-05	0.60683
38	HCV	Diesel	Rigid >32 t	Euro 2	0.014448	0.311144
39	HCV	Diesel	Rigid >32 t	Euro 3	0.05504	0.274508
40	HCV	Diesel	Rigid >32 t	Euro 4	0.016243	0.061118
41	HCV	Diesel	Articulated 34 - 40 t	Conventional	1.59E-19	0.766672
42	HCV	Diesel	Articulated 34 - 40 t	Euro 1	4.87E-05	0.638864
43	HCV	Diesel	Articulated 34 - 40 t	Euro 2	0.017547	0.330675
44	HCV	Diesel	Articulated 34 - 40 t	Euro 3	0.066849	0.290105
45	HCV	Diesel	Articulated 34 - 40 t	Euro 4	0.019728	0.062287
46	HCV	Diesel	Articulated 40 - 50 t	Conventional	1.00E-19	0.856972
47	HCV	Diesel	Articulated 40 - 50 t	Euro 1	3.05E-05	0.71696
48	HCV	Diesel	Articulated 40 - 50 t	Euro 2	0.011016	0.380123
49	HCV	Diesel	Articulated 40 - 50 t	Euro 3	0.041965	0.319116
50	HCV	Diesel	Articulated 40 - 50 t	Euro 4	0.012385	0.067546
51	Buses	Diesel	Coaches Standard <=18 t	Conventional	2.52E-19	0.586451
52	Buses	Diesel	Coaches Standard <=18 t	Euro 1	7.71E-05	0.463945
53	Buses	Diesel	Coaches Standard <=18 t	Euro 2	0.027793	0.220184
54	Buses	Diesel	Coaches Standard <=18 t	Euro 3	0.105882	0.253559
55	Buses	Diesel	Coaches Standard <=18 t	Euro 4	0.031248	0.055198

56	Buses	Diesel	Coaches Articulated >18 t	Conventional	2.07E-19	0.69466
57	Buses	Diesel	Coaches Articulated >18 t	Euro 1	6.31E-05	0.539104
58	Buses	Diesel	Coaches Articulated >18 t	Euro 2	0.02274	0.26792
59	Buses	Diesel	Coaches Articulated >18 t	Euro 3	0.086631	0.280561
60	Buses	Diesel	Coaches Articulated >18 t	Euro 4	0.025566	0.062322
61	Buses	CNG	Urban CNG Buses	Euro 1	0.000327	0.02
62	Buses	CNG	Urban CNG Buses	Euro 2	0.117911	0.01
63	Buses	CNG	Urban CNG Buses	Euro 3	0.581762	0.01
64	2W	Petrol	Motorcycles 2- stroke >50 cm ³	Conventional	0.009764	0.2
65	2W	Petrol	Motorcycles 2- stroke >50 cm ³	Euro 1	0.0329	0.08
66	2W	Petrol	Motorcycles 2- stroke >50 cm ³	Euro 2	0.092969	0.04
67	2W	Petrol	Motorcycles 2- stroke >50 cm ³	Euro 3	0.409352	0.012
68	2W	Petrol	Motorcycles 2- stroke >50 cm ³	Euro 4	0.155014	0.012
69	2W	Petrol	Motorcycles 4- stroke <250 cm ³	Conventional	0.003487	0.02
70	2W	Petrol	Motorcycles 4- stroke <250 cm ³	Euro 1	0.01175	0.02
71	2W	Petrol	Motorcycles 4- stroke <250 cm ³	Euro 2	0.033203	0.005
72	2W	Petrol	Motorcycles 4- stroke <250 cm ³	Euro 3	0.146197	0.005

73	2W	Petrol	Motorcycles 4-stroke <250 cm3	Euro 4	0.055362	0.005
74	2W	Petrol	Motorcycles 4-stroke 250 - 750 cm3	Conventional	0.000697	0.02
75	2W	Petrol	Motorcycles 4-stroke 250 - 750 cm3	Euro 1	0.00235	0.02
76	2W	Petrol	Motorcycles 4-stroke 250 - 750 cm3	Euro 2	0.006641	0.005
77	2W	Petrol	Motorcycles 4-stroke 250 - 750 cm3	Euro 3	0.029239	0.005
78	2W	Petrol	Motorcycles 4-stroke 250 - 750 cm3	Euro 4	0.011072	0.005
79	Cars	Diesel	Small	Conventional	0.000773	0.2442
80	Cars	Diesel	Small	Euro 1	0.000371	0.064233
81	Cars	Diesel	Small	Euro 2	0.002596	0.053546
82	Cars	Diesel	Small	Euro 3	0.009754	0.032402
83	Cars	Diesel	Small	Euro 4	0.054007	0.031956
84	Cars	Diesel	Medium	Conventional	0.000515	0.2442
85	Cars	Diesel	Medium	Euro 1	0.000247	0.064233
86	Cars	Diesel	Medium	Euro 2	0.00173	0.053546
87	Cars	Diesel	Medium	Euro 3	0.006503	0.032402
88	Cars	Diesel	Medium	Euro 4	0.036004	0.031956
89	Cars	Diesel	Large-SUV-Executive	Conventional	0.000429	0.2442
90	Cars	Diesel	Large-SUV-Executive	Euro 1	0.000206	0.064233
91	Cars	Diesel	Large-SUV-Executive	Euro 2	0.001442	0.053546
92	Cars	Diesel	Large-SUV-Executive	Euro 3	0.005419	0.032402
93	Cars	Diesel	Large-SUV-Executive	Euro 4	0.030004	0.031956
94	Cars	Petrol	Small	Euro 1	0.009822	0.00322
95	Cars	Petrol	Small	Euro 2	0.022288	0.00322
96	Cars	Petrol	Small	Euro 3	0.083755	0.00128
97	Cars	Petrol	Small	Euro 4	0.463736	0.00128
98	Cars	Petrol	Medium	Euro 1	0.000747	0.00322
99	Cars	Petrol	Medium	Euro 2	0.001696	0.00322
100	Cars	Petrol	Medium	Euro 3	0.006373	0.00128

101	Cars	Petrol	Medium	Euro 4	0.035284	0.00128
102	Cars	Petrol	Large-SUV-Executive	Euro 1	0.000107	0.00322
103	Cars	Petrol	Large-SUV-Executive	Euro 2	0.000242	0.00322
104	Cars	Petrol	Large-SUV-Executive	Euro 3	0.00091	0.00128
105	Cars	Petrol	Large-SUV-Executive	Euro 4	0.005041	0.00128
106	Cars	CNG	Small	Euro 4	0.2024	0.00128
107	Cars	CNG	Medium	Euro 4	0.0154	0.00128
108	Cars	CNG	Large-SUV-Executive	Euro 4	0.0022	0.00128
109	LCV	Diesel	N1-I	Conventional	5.19E-06	0.28194
110	LCV	Diesel	N1-I	Euro 1	0.001342	0.08715
111	LCV	Diesel	N1-I	Euro 2	0.029746	0.08715
112	LCV	Diesel	N1-I	Euro 3	0.183893	0.058403
113	LCV	Diesel	N1-I	Euro 4	0.067214	0.0305
114	LCV	Diesel	N1-II	Conventional	5.19E-06	0.28194
115	LCV	Diesel	N1-II	Euro 1	0.001342	0.08715
116	LCV	Diesel	N1-II	Euro 2	0.029746	0.08715
117	LCV	Diesel	N1-II	Euro 3	0.183893	0.058403
118	LCV	Diesel	N1-II	Euro 4	0.067214	0.0305
119	LCV	Diesel	N1-III	Conventional	4.89E-06	0.28194
120	LCV	Diesel	N1-III	Euro 1	0.001263	0.08715
121	LCV	Diesel	N1-III	Euro 2	0.027996	0.08715
122	LCV	Diesel	N1-III	Euro 3	0.173076	0.058403
123	LCV	Diesel	N1-III	Euro 4	0.06326	0.0305
124	LCV	CNG	N1-I	Euro 4	0.0578	0.00128
125	LCV	CNG	N1-II	Euro 4	0.0578	0.00128
126	LCV	CNG	N1-III	Euro 4	0.0544	0.00128
127	3W	CNG	3W	Euro 4	1	0.00128

Table S2 Different parameters of various road types.

Road Type	RClass1	RClass2	RClass3	RClass4	RClass5
Width	<7 m	7 to 9 m	9 to 12 m	12 to 14 m	> 14 m
c_i	1200	2400	3600	4800	7200
α	1.202	1.619	1.672	0.615	0.615
β	1.218	0.997	1.503	1.599	1.599
FFV	42	50	50	65	6565
Mean PCU/Link/Hour	1022	1549	2513	4456	4944
Mean speed	28.2	35.0	38.3	44.5	46.2
Total length in km (share %)	186 (7%)	1057 (37%)	1014 (36%)	229 (8%)	355 (12%)

Table S3 Year of implementation of different EURO/BS standards in Delhi.

Emission Norms	Year of Implementation	
	All other vehicle	Cars
Conventional	Before 2000	Before 2000
Euro/BS 1	2000 to 2005	2000 to 2001
Euro/BS 2	2005 to 2010	2001 to 2005
Euro/BS 3	2010 to 2017	2005 to 2010
Euro/BS 4	2017 to 2018	2010 to 2018

Table S4 Euro share across different vehicle categories

Euro Standard	2W	Cars	3W	Buses	HCV	LCV
Euro 0	1.39%	0.17%		0.00%	0.00%	0.00%
Euro 1	5%	1.15%		0.05%	0.05%	0.39%
Euro 2	13%	3%		17%	17%	9%
Euro 3	58%	11%		77%	64%	54%
Euro 4	22%	84%	100%	6%	19%	37%

Table S5 Vehicular share (%) across the road types

Category	RClass1	RClass2	RClass3	RClass4	RClass5
Car	30%	34%	38%	40%	44%
2w	53%	49%	46%	42%	39%
3w	7%	9%	9%	10%	9%
LCV	6%	5%	4%	4%	4%
HCV	2%	1%	1%	1%	1%
Bus	3%	3%	2%	3%	3%

Table S6 Daily emission in Mg/Day (% share) over different areas of Delhi, percentage share is shown in the bracket.

Area	PME	BC	OM	CO	NO _x	VOC	NH ₃	N ₂ O	CH ₄
Inner	1.75 (35%)	0.93 (36%)	0.7 (34%)	211 (34%)	56 (36%)	62 (35%)	0.27 (35%)	0.24 (34%)	10 (33%)
Eastside	0.72 (14%)	0.38 (14%)	0.29 (14%)	87 (14%)	22 (14%)	26 (14%)	0.09 (11%)	0.09 (12%)	4 (13%)
Outer	2.51 (50%)	1.27 (49%)	1.06 (51%)	305 (50%)	74 (48%)	87 (49%)	0.4 (52%)	0.37 (52%)	16 (53%)

Table S7 Daily emission flux in Kg/Sq km/Day over different areas of Delhi.

Area	PME	BC	OM	CO	NO _x	VOC	NH ₃	N ₂ O	CH ₄
Inner	7.2	3.82	2.87	868	231	257	1.1	1.0	44
Eastside	5.4	2.83	2.19	650	171	195	0.71	0.67	31
Outer	2.27	1.15	0.96	276	67	79	0.37	0.34	14

Table S8. Emission in Kg/km/day across different road types.

RClass	PME	BC	OM	CO	NO _x	VOC	NH ₃	N ₂ O	CH ₄
RClass1	0.89	0.46	0.37	106	25	31	0.11	0.11	5
RClass2	1.11	0.57	0.46	132	33	38	0.15	0.15	6
RClass3	1.75	0.88	0.74	224	51	66	0.27	0.24	11
RClass4	3.12	1.64	1.26	366	98	103	0.51	0.46	19
RClass5	3.26	1.74	1.29	372	108	106	0.55	0.49	20

Table S9. Emission in Kg/lanekm/day across different road types.

RClass	PME	BC	OM	CO	NO _x	VOC	NH ₃	N ₂ O	CH ₄
RClass1	0.89	0.46	0.37	106	25	31	0.11	0.11	5.37
RClass2	0.56	0.29	0.23	66	16	19	0.08	0.07	3.45
RClass3	0.58	0.29	0.25	74	17	22	0.09	0.08	3.71
RClass4	0.78	0.41	0.31	91	24	25	0.13	0.12	4.82
RClass5	0.54	0.29	0.21	62	18	17	0.09	0.08	3.37

Table S10 Emission in kg/day (% share) from different euro type vehicles.

Euro	PME	BC	OM	CO	NO _x	VOC	NH ₃	N ₂ O	CH ₄
Euro 0	311 (6.2%)	69 (2.7%)	235 (11.5%)	40199 (6.7%)	485 (0.3%)	22820 (12.9%)	3 (0.4%)	3 (0.4%)	294 (0.9%)
Euro 1	380 (7.6%)	101 (3.9%)	278 (13.6%)	94754 (15.7%)	1905 (1.2%)	26922 (15.3%)	79 (10.3%)	26 (3.7%)	1025 (3.3%)
Euro 2	895 (18.0%)	402 (15.6%)	466 (22.7%)	174412 (28.9%)	29162 (19.0%)	42922 (24.4%)	337 (44.1%)	84 (11.9%)	5909 (18.9%)
Euro 3	2423 (48.6%)	1425 (55.2%)	775 (37.8%)	200720 (33.2%)	95104 (61.8%)	62215 (35.3%)	169 (22.1%)	255 (36.3%)	16741 (53.7%)
Euro 4	973 (19.5%)	583 (22.6%)	295 (14.4%)	93999 (15.6%)	27209 (17.7%)	21391 (12.1%)	177 (23.1%)	335 (47.7%)	7230 (23.2%)

Table S11. Comparison of the VKT (in billion VKT) estimated in the current study with the previous studies over Delhi.

Vehicle category	Current Study	Malik et al. (2019)	Goel et al. (2015b)	Kumar et al. (2011)	Guttikunda and Calori., (2013)	Sahu et al., 2011
Study year	2018	2016	2012	2010	2010	2010
Buses	1.71			5.01	6.7	3.5
HCV	0.95	0.99		2.94	4.02	5.3
2W	31.63		24.73	24.05		88.5
LCV	3.14	4.44		3.59		5.7
CAR	27.36		16.56	29.82	22.4	72.2
3W	6.11			3.68	2.42	2.3

Table S12. COPERT emission factor comparison with the measured emission factor in Indian condition.

Vehicle Type		2W (g/km)				Diesel Car (g/km)				Petrol Car (g/km)			
Studies	Location	CO	HC	NO _x	PM	CO	HC	NO _x	PM	CO	HC	NO _x	PM
This Study COPERT at 34 km/h (min to max)	COPERT applied for Delhi	2.2 (0.15 - 12.8)	0.49 (0.037 - 3.74)	0.07 (0.017 - 0.33)	0.01 (0.005 - 0.04)	0.21 (0.044 - 0.73)	0.035 (0.007 - 0.26)	0.69 (0.43 - 1.33)	0.037 (0.025 - 0.073)	0.46 (0.147 - 1.853)	0.036 (0.01 - 0.25)	0.10 (0.037 - 0.26)	0.002 (0.0013 - 0.0032)
TERI/ARAI 2018	Indian Vehicle	0.39 - 4.3	0.25 - 1.18	0.16 - 0.30	0.002 - 0.04	0.15 - 0.38	0.03 - 0.07	0.29 - 0.54	0.008 - 0.03	0.82 - 0.98	0.07 - 0.09	0.04 - 0.07	0.001 - 0.002
Kuppili et al., 2021	Delhi					3.99	0.34	0.54		7.26	0.17	0.62	
Jaiprakash et al., 2018	Delhi	1.0 ± 0.6		0.07 ± 0.01		0.3 ± 0.1		1 ± 0.4		2.2		1	
Jaiprakash et al., 2017	Delhi				0.014				0.19				0.067
Adak et al., 2016	Dhanbad	1.6	0.45	0.46		0.07	0.1	0.35					
Mahesh et al., 2018	Chennai					1.28	0.13	0.59					
Mahesh et al., 2019	Chennai	6.7 ± 2.60	0.33 ± 0.12	0.217 ± 0.032									
Jaikumar et al 2017	Chennai					0.6	0.06	1.3					

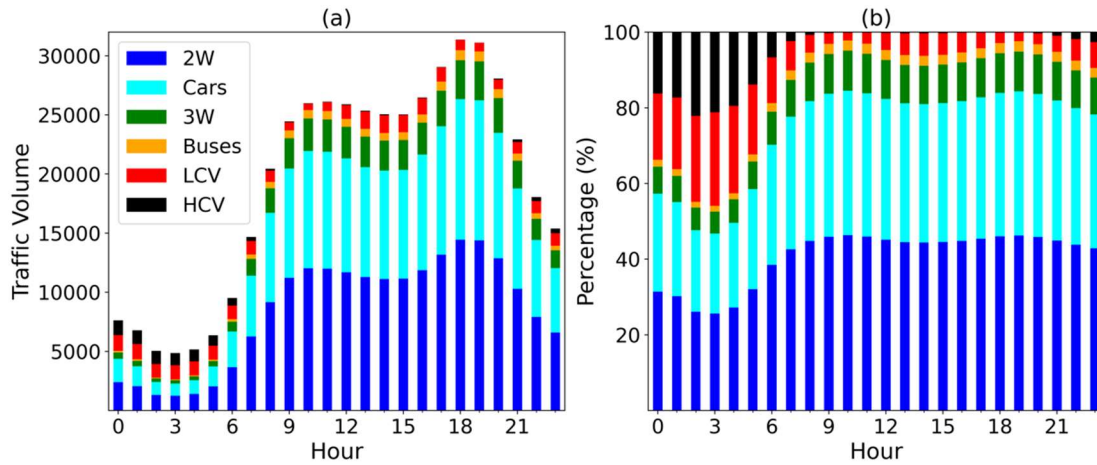


Figure S1. a) The stacked bar plot showing the estimated hourly mean traffic composition over Delhi; b) Percentage stacked plot showing average fleet share at different hours.

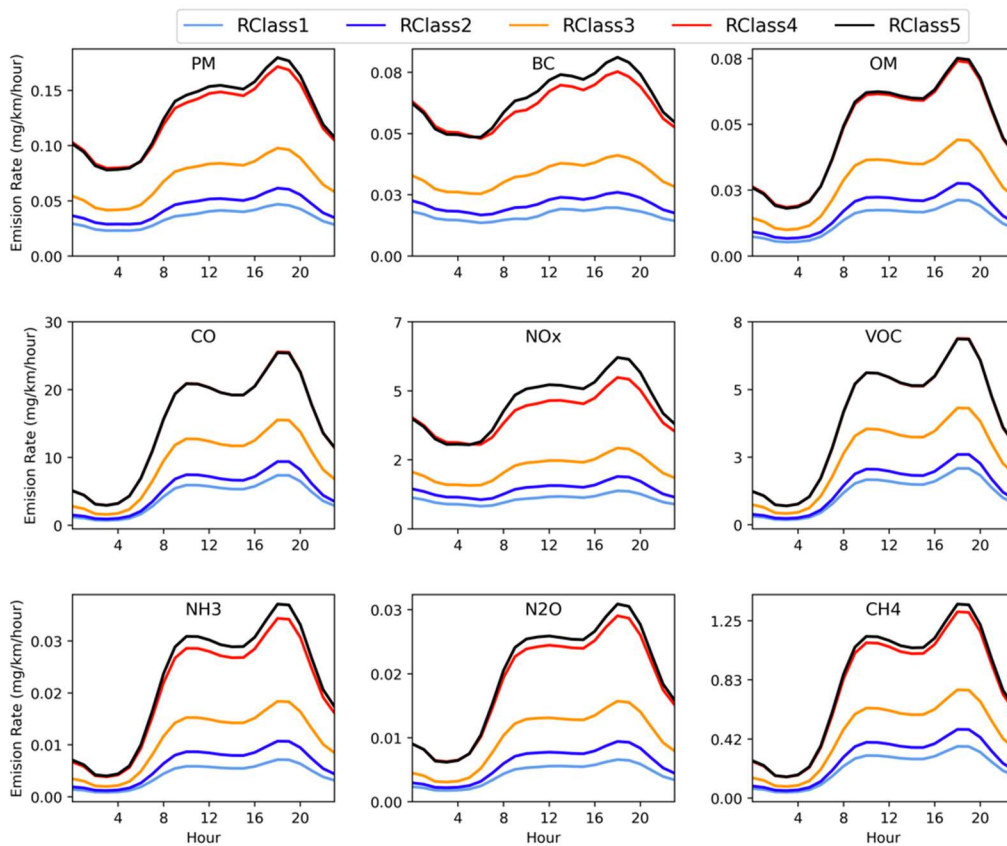


Figure S2. The line plot showing the hourly emission rate across five road classes of Delhi over Delhi.

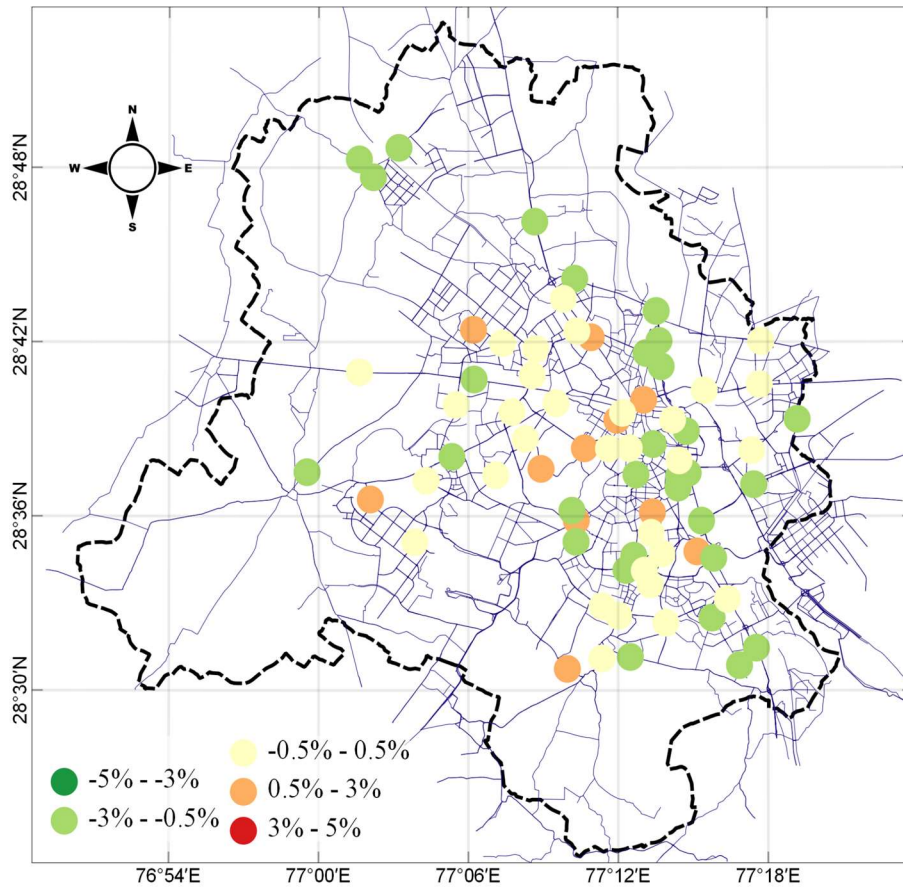


Figure S3. Map showing the percentage difference ($100\% * [\text{Estimated} - \text{Observed}] / \text{Observed}$) between estimated and observed traffic at the 72 locations.

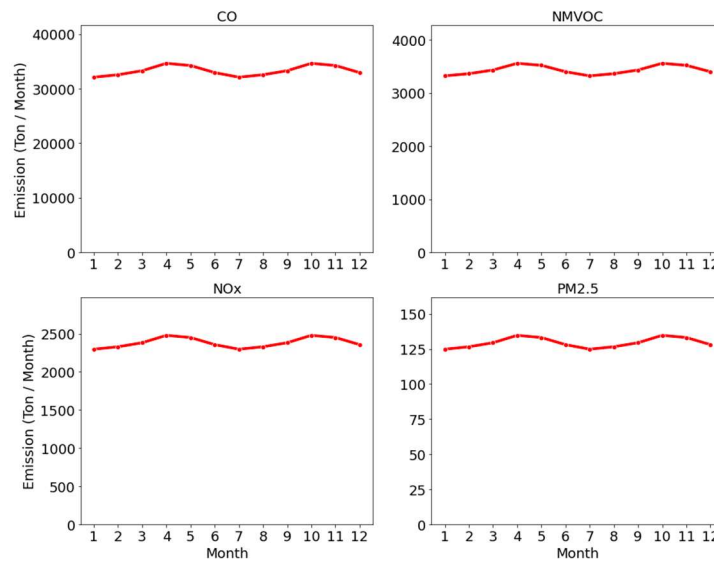


Figure S4. Monthly emission variation in EDGAR emission over Delhi for CO, NMVOC, NO_x and PM_{2.5}

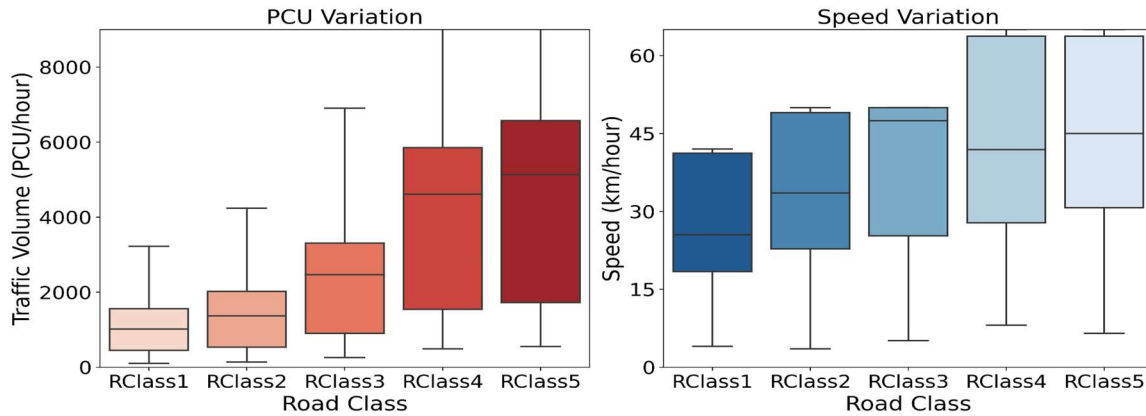


Figure S5. Boxplot for the PCU and speed variation across all road classes.

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