INSTITUTO MUNICIPAL DE INVESTIGACION Y PLANEACION
Benjamín Franklin 4185 y Estocolmo. Circuito Pronaf. Cd. Juárez, Chih. Tels. 13-65-20 13-65-30 13-65-46 13-64-96

Tech Memo

DATE: December 15, 1999.

TO: Carl Snow, Project Director / TNRCC
Jim Yarbrough / EPA
Jack Jones / TxDOT
Zack Graham / TTI
Luis Raul Cordova/SEMARNAP

FROM: Nicolas Lopez-Duarte,
Salvador Gonzalez-Ayala

SUBJ: Task 5:
On-road mobile source emissions modeling.

PROJECT: **Estudio Integral de Transporte (III)/ Multimodal Transportation Study:** Development of Travel Demand and Mobile Source Emissions Models for base year 1996, Juarez. (Contract No. 9880055000)

SERIAL: EITIII-05

Overview

Under the current project five specific tasks have been outlined for development:

1. Trip generation model application
2. Trip distribution model application
3. Mode split model application
4. Traffic assignment application
5. On-road mobile source emissions modeling

Having completed the travel demand modeling part of the project (tasks 1 through 4), the present Tech Memo summarizes the work performed to accomplish the last task item: On-road mobile source emissions modeling for Juarez.

Background

Over the last years the TNRCC and EPA have developed a software known as MOBILE5Juarez to determine emissions from mobile sources, using emission factors specific of the Ciudad Juarez climatic conditions and its motorized-vehicle operating characteristics. This model is a modified version of MOBILE5a developed by EPA for use in US cities.

To estimate the amount of emissions from the motorized-vehicle fleet circulating in the Juarez roadway system, several factors specific to the city need to be accounted for, such as:

- Fuel volatility (RVP)
- Ambient temperature
- Vehicle operating mode
- Vehicle kilometers of travel (VKT) by vehicle type
- Exhaust and evaporative emission rates
- Control technology distribution
- Tampering rates
- Mileage accumulation rates
- Registration distribution

In 1996, the consulting firm Radian International LLC under contract with TNRCC was given the responsibility to develop MOBILE5Juarez and also to provide an initial estimation of the previously outlined emission factors. Part of the final recommendations of that project though was to continue the research in order to improve some of the input parameters, one of these being the VKT (or VMT for mile units) for the 8 vehicle types since the study was based on light-duty trucks and cars.

In this regard the Mutlimodal Transportation Study for Ciudad Juarez has now improved traffic information and vehicle characterization for the city, and thus can now establish better estimates of mobile source emissions.

Input for MOBILE5Juarez

Grid structure

In order to disaggregate the emissions levels at the study basin, a grid structure was created over the Juarez urban area, with each component cell measuring 2-miles by side. As a result, a grid of 36 cells was placed over the Juarez roadway network as depicted in Figure 1. For each cell, emissions factors for carbon-monoxide (CO), total volatile organic compounds (VOC), and nitrogen-oxide (NOx) were determined.

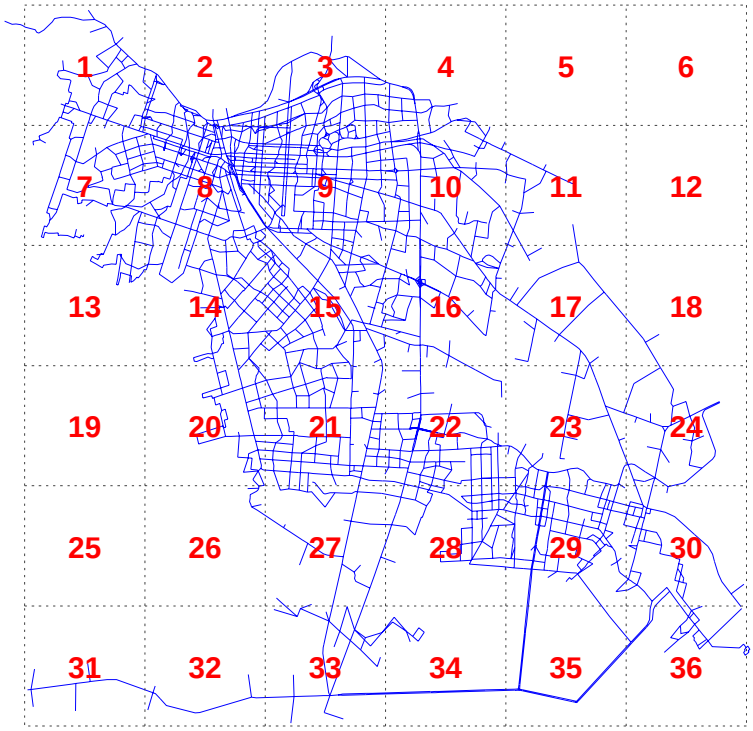

Figure 1. Grid structure for mobile source emissions modeling of Juarez.

Since the emissions were estimated only for traffic flows taking place in Juarez, cells 1, 2, 3, 4, 11, 17, and 18 do not account for emissions generated in the El Paso and Sunland Park areas on the north side of the US-Mexico border; similarly cells 5, 6, and 12 were expected to yield zero-emissions under the current exercise. Emissions from the El Paso modeling effort can eventually be added to these cells for a complete regional estimation.

Improved VKT and network speeds

As previously stated, improved traffic information has now been obtained from the travel demand modeling portion of the current project, as 24-hour totals. The current state-of-practice though suggests the estimation of emissions on 1-hour periods, so the daily data needs to be further disaggregated to this level. The usual periods to be evaluated are the following:

1) AM peak
2) Midday
3) PM peak
4) Night

Now, the Juarez hourly traffic distribution is slightly different from that typically observed in most US cities, where distinct spikes mark well known peaks (AM and PM peaks). The Juarez distribution portrays more of a gradual build-up of traffic throughout the day with a single but usually wide summit. This behavior is depicted in Figure 2 from 1996 counts at important arterials in Juarez. The pattern has been consistently observed in Juarez streets at least over the past five years.

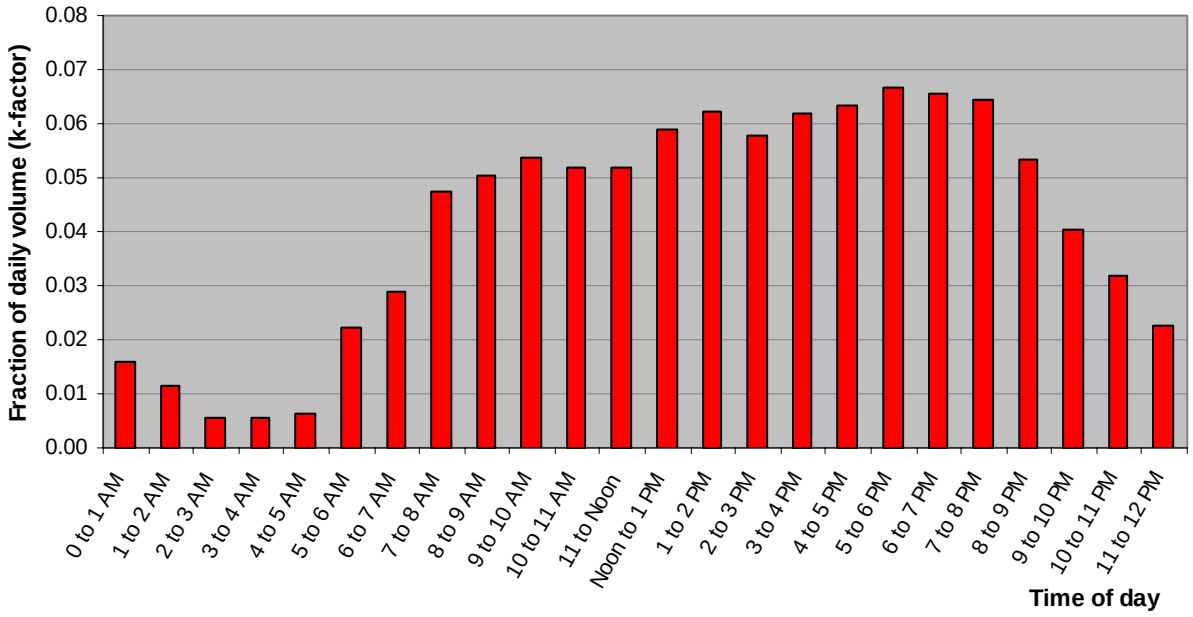

Figure 2. Typical hourly distribution of traffic for major arterials in Juarez.

The practical implication of this among other considerations is that no clear peaks are regularly defined aside from the PM peak, and even in this case, it is difficult to consistently assign a 1-hour peak period to a specific time of the day. Nevertheless, the four 1-hour periods were selected based on a most frequent occurrence criteria, for the following times: 8-9AM (AM), 1-2PM (MIDDAY), 5-6PM (PM) and 10-11PM (Night).

To disaggregate the 24-hour totals into the 1-hour periods, hourly factors (k-factors) were obtained for the entire study area. For traffic volumes these k-factors were directly averaged from hourly distribution plots such as the one shown in Figure 2; here the 1-hour volume is divided by the total 24-hour volume. For postprocessed speeds, k-factors were estimated through the following steps:

a) An area wide 24-hr speed was obtained as a weighted average based on link VKT, as depicted by Equation 1. Under the current exercise this speed is 37.75 kph.

$$\text{24-hr average speed} = \frac{\sum(\text{Link VKT})*(\text{link Speed})}{\sum(\text{Link VKT})} \qquad \textbf{(Eq. 1)}$$

b) From the speed-delay evaluation, city wide average speeds were obtained for the four specified 1-hour periods. These speeds are 35, 32, 30, and 48 kph respectively for AM peak, Midday, PM peak, and Night periods.

c) The speed k-factor was obtained dividing the 1-hour speed by the 24-hour speed.

The resulting k-factors for traffic volume and speed are shown in Table 1.

Table 1. Proportion factors (k-factors) for daily to hourly conversions.

	k-factors	
	traffic volume	average speed
AM peak	0.050	0.927
Midday	0.062	0.848
PM peak	0.067	0.795
Night	0.032	1.272

Having obtained the day-to-hour k-factors, the next step was to go through a similar exercise but now for each of the cells in the grid. Thus, daily VKT was obtained for each cell, and converted to hourly VKT according to the traffic volume k-factors. The daily VKT by cell was also used to develop 24-hr speeds by cell through the use of Equation 1; then these 24-hr speeds were used to obtain 1-hr speeds through the use of the speed k-factors. In summary, Table 2 presents the resulting VKT and average speeds for each of the cells of the grid.

Table 2. VKT and average speeds by cell by period.

CELL	VKT					Average Speed [kph]				
	24-hour	1-hour				24-hour	1-hour			
		AM peak	Midday	PM peak	Night		AM peak	Midday	PM peak	Night
1	98,418	4,921	6,102	6,594	3,149	43.28	40.12	36.70	34.41	51.04
2	255,573	12,779	15,846	17,123	8,178	43.83	40.63	37.17	34.84	51.68
3	320,146	16,007	19,849	21,450	10,245	45.73	42.39	38.78	36.35	53.92
4	84,020	4,201	5,209	5,629	2,689	41.66	38.62	35.33	33.12	49.12
5	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
7	108,088	5,404	6,701	7,242	3,459	32.12	29.77	27.23	25.53	37.87
8	614,416	30,721	38,094	41,166	19,661	28.22	26.16	23.93	22.44	33.28
9	396,846	19,842	24,604	26,589	12,699	32.37	30.01	27.45	25.74	38.17
10	384,628	19,231	23,847	25,770	12,308	31.84	29.52	27.00	25.31	37.55
11	43,362	2,168	2,688	2,905	1,388	39.00	36.16	33.07	31.01	45.99
12	-	-	-	-	-	-	-	-	-	-
13	4,609	230	286	309	147	32.16	29.82	27.27	25.57	37.93
14	122,064	6,103	7,568	8,178	3,906	34.09	31.61	28.91	27.11	40.20
15	585,469	29,273	36,299	39,226	18,735	36.77	34.08	31.18	29.23	43.35
16	430,824	21,541	26,711	28,865	13,786	32.98	30.58	27.97	26.22	38.89
17	186,524	9,326	11,565	12,497	5,969	46.68	43.27	39.58	37.11	55.04
18	187	9	12	13	6	51.04	47.31	43.28	40.57	60.18
19	-	-	-	-	-	-	-	-	-	-
20	90,190	4,510	5,592	6,043	2,886	37.14	34.42	31.49	29.52	43.79
21	414,956	20,748	25,727	27,802	13,279	38.02	35.25	32.24	30.23	44.83
22	325,049	16,252	20,153	21,778	10,402	35.12	32.56	29.79	27.92	41.42
23	334,062	16,703	20,712	22,382	10,690	48.85	45.28	41.42	38.84	57.60
24	160,652	8,033	9,960	10,764	5,141	39.32	36.45	33.35	31.26	46.37
25	-	-	-	-	-	-	-	-	-	-
26	3,135	157	194	210	100	35.06	32.50	29.73	27.87	41.34
27	94,962	4,748	5,888	6,362	3,039	48.50	44.96	41.12	38.55	57.18
28	137,707	6,885	8,538	9,226	4,407	32.73	30.34	27.75	26.02	38.59
29	218,743	10,937	13,562	14,656	7,000	36.01	33.38	30.54	28.63	42.46
30	149,526	7,476	9,271	10,018	4,785	44.09	40.87	37.39	35.05	51.98
31	11,357	568	704	761	363	57.81	53.59	49.02	45.96	68.17
32	15,463	773	959	1,036	495	57.91	53.68	49.11	46.04	68.28
33	74,446	3,722	4,616	4,988	2,382	56.44	52.32	47.86	44.87	66.56
34	12,963	648	804	869	415	48.38	44.85	41.03	38.46	57.05
35	9,172	459	569	615	294	46.53	43.14	39.46	36.99	54.87
36	21,622	1,081	1,341	1,449	692	40.23	37.29	34.11	31.98	47.43

Vehicle type distribution

A city wide vehicle type distribution was also obtained in 1996 as part of the field data gathering efforts of the Multimodal Transportation Study. This is reproduced in Table 3, according to the EPA's classification. This distribution is assumed to remain constant through all of the cells in the grid.

Table 3. Vehicle distribution.

Vehicle type	EPA code	%
Light-Duty Gas Vehicles	LDGV	82.2%
Light-Duty Gas Trucks (1)	LDGT1	3.6%
Light-Duty Gas Trucks (2)	LDGT2	1.5%
Heavy-Duty Gas Vehicles	HDGV	2.0%
Light-Duty Diesel Vehicles	LDDV	0.2%
Light-Duty Diesel Trucks	LDDT	3.9%
Heavy-Duty Diesel Vehicles	HDDV	6.0%
Motorcycles	MC	0.6%

It is important to underline that the Juarez vehicle fleet has a small proportion of light-duty trucks fueled with LPG. These were assumed to have similar emissions to that of gasoline vehicles and thus were included in the LDGT1 and LGDT2 groups.

Travel Length Frequency Distributions

Travel length frequency distributions (TLFDs) were obtained for each cell and for each of the four periods of the day, re-arranging those previously developed at the trip distribution step of the travel demand model. Figure 3 shows an example for the PM peak, under an average cell speed of 30kph. The specific format shown here complies with MOBILE5Juarez input requirements

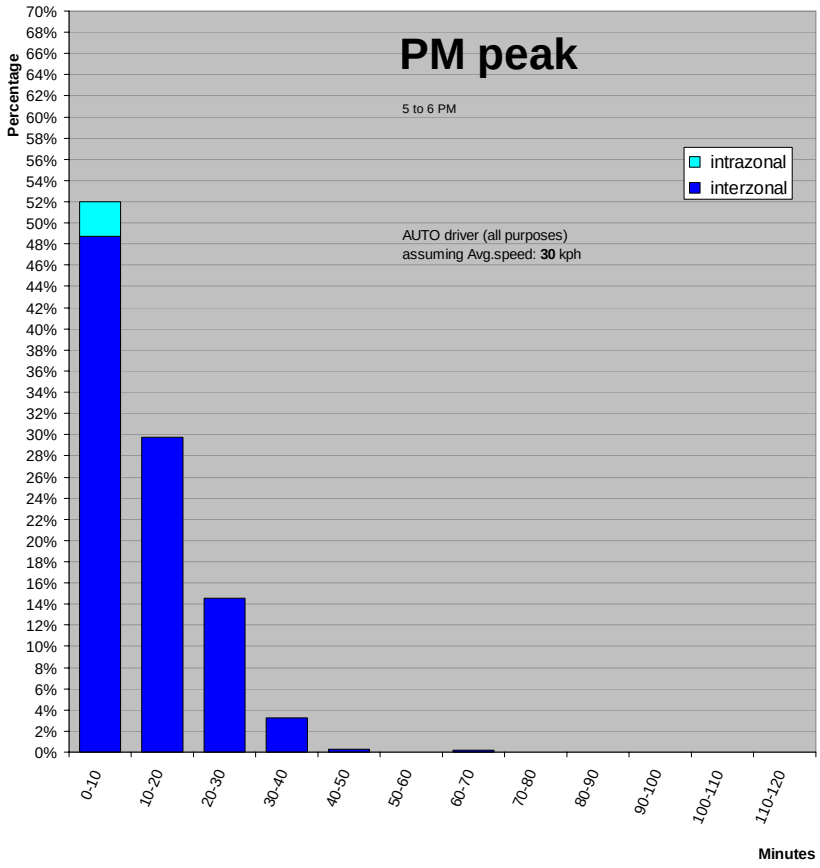

Figure 3. Example of TLFD for use with MOBILE5Juarez.

Other data

Data not specifically described here was obtained from the original MOBILE5Juarez run. Such information is currently unavailable from other sources, or has not been updated since 1996.

Output from MOBILE5Juarez

As output, MOBILE5Juarez yields emission rates for CO, total VOCs, and NOx, which under the present exercise were obtained for every cell of the grid, and for each of the four 1-hr periods. The emission rates are expressed in grams per kilometer (grams per vehicle-kilometer-of-travel).

The rates obtained from the MOBILE5Juarez run were then multiplied by each cell's hourly VKT to obtain an estimate of cell's emissions at specific time periods. Table 4 summarizes emissions by cell by time period for base year 1996.

Table 4. Mobile source emissions concentration by cell by 1-hr time period (MOBILE5Juarez).

CELL	CO [kg]				VOC [kg]				NOx [kg]			
	AM Peak	Midday	PM Peak	Night	AM Peak	Midday	PM Peak	Night	AM Peak	Midday	PM Peak	Night
1	192	259	299	91	24	32	36	13	14	18	19	9
2	493	664	768	235	63	82	93	33	37	45	49	24
3	595	801	926	283	77	100	114	41	46	57	62	30
4	170	229	264	81	21	28	32	11	12	15	16	8
5	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-
7	275	371	428	134	32	42	48	17	16	20	21	10
8	1,758	2,369	2,740	855	198	261	296	104	90	113	124	56
9	1,006	1,353	1,559	487	117	154	175	62	57	72	78	36
10	990	1,329	1,533	480	115	151	171	61	56	70	76	35
11	93	125	144	45	11	15	17	6	6	8	8	4
12	-	-	-	-	-	-	-	-	-	-	-	-
13	12	16	18	6	1	2	2	1	1	1	1	0
14	295	397	459	143	35	46	52	18	18	22	24	11
15	1,326	1,776	2,056	636	160	210	238	84	84	105	114	54
16	1,073	1,445	1,664	519	126	166	187	66	62	78	85	40
17	340	458	529	162	44	58	65	23	27	33	36	18
18	0	0	0	0	0	0	0	0	0	0	0	0
19	-	-	-	-	-	-	-	-	-	-	-	-
20	203	271	314	97	24	32	36	13	13	16	18	8
21	911	1,225	1,413	437	111	146	165	59	60	74	81	39
22	766	1,028	1,186	369	91	120	136	48	47	58	64	30
23	583	787	909	279	77	100	114	41	48	60	64	32
24	342	461	530	164	42	55	63	22	23	29	31	15
25	-	-	-	-	-	-	-	-	-	-	-	-
26	7	10	11	4	1	1	1	0	0	1	1	0
27	167	225	260	80	22	29	33	12	14	17	18	9
28	346	465	536	167	40	53	60	21	20	25	27	13
29	504	677	780	243	60	80	90	32	32	39	43	20
30	287	387	447	137	36	48	54	19	21	27	29	14
31	17	23	26	8	2	3	3	1	2	2	2	1
32	23	31	36	11	3	4	5	2	2	3	3	2
33	113	153	177	56	16	20	23	9	11	13	14	7
34	23	31	36	11	3	4	4	2	2	2	2	1
35	17	23	26	8	2	3	3	1	1	2	2	1
36	45	61	70	22	6	7	8	3	3	4	4	2

Schematic representations of these concentrations for the heaviest and lightest 1-hr periods are depicted in Figures 4 and 5 for CO, Figures 6 and 7 for VOCs, and Figures 8 and 9 for NOx.

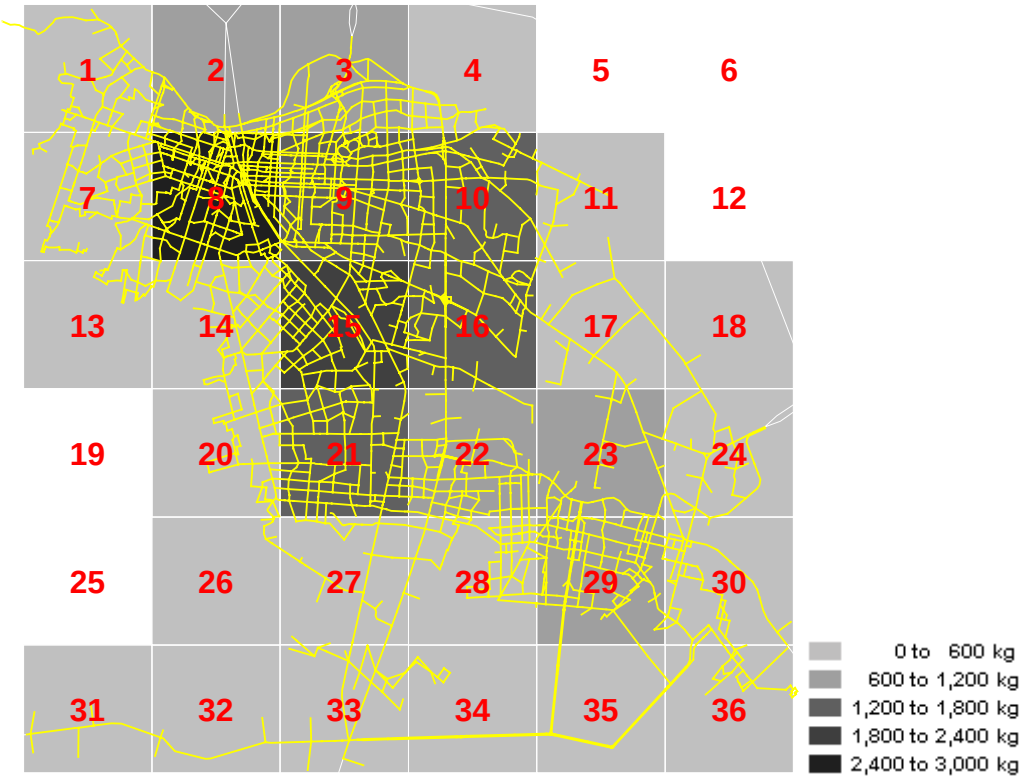

Figure 4. CO concentration at PM peak (1-hour).

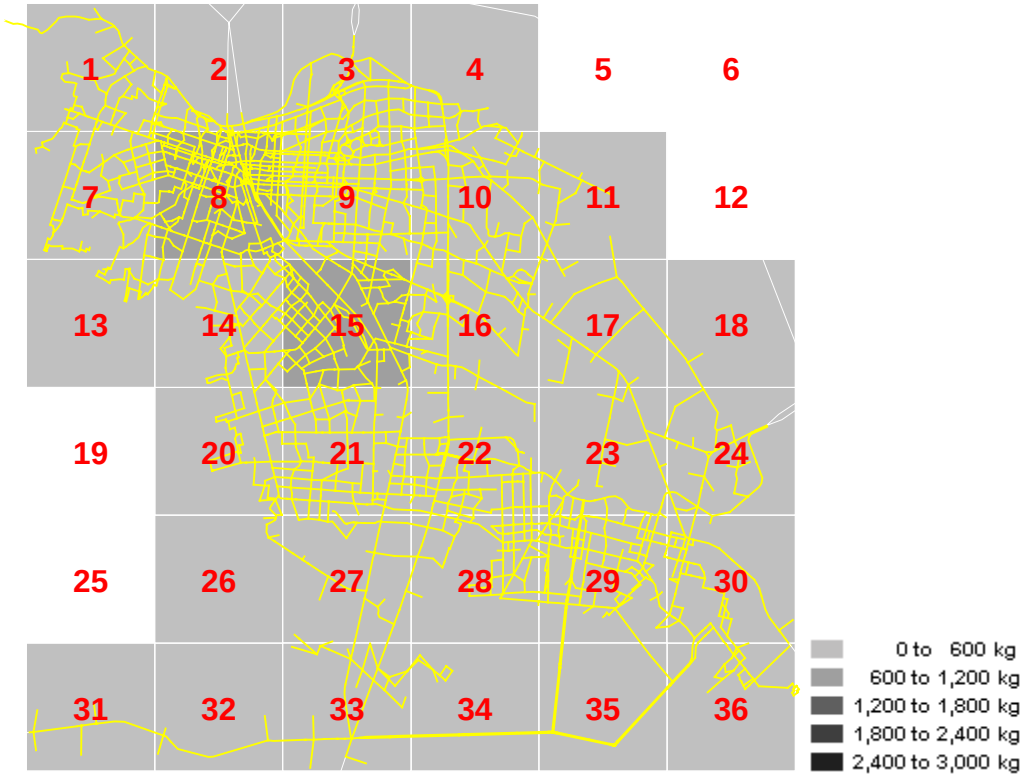

Figure 5. CO concentration at Night (1-hour).

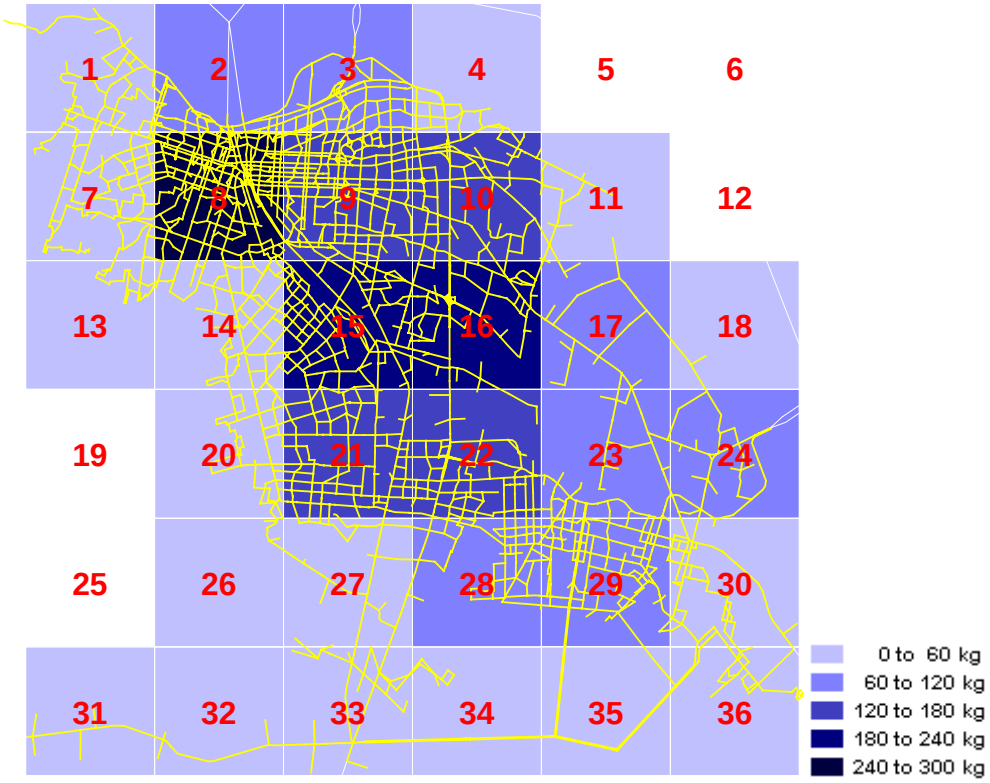

Figure 6. VOC concentration at PM peak (1-hour).

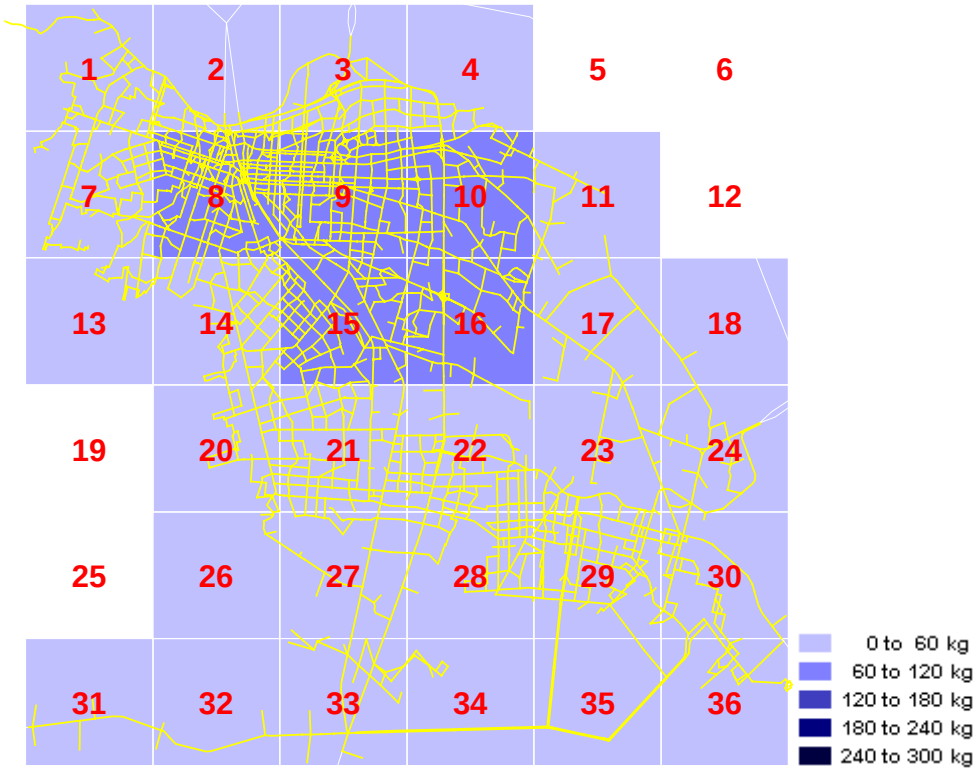

Figure 7. VOC concentration at Night (1-hour).

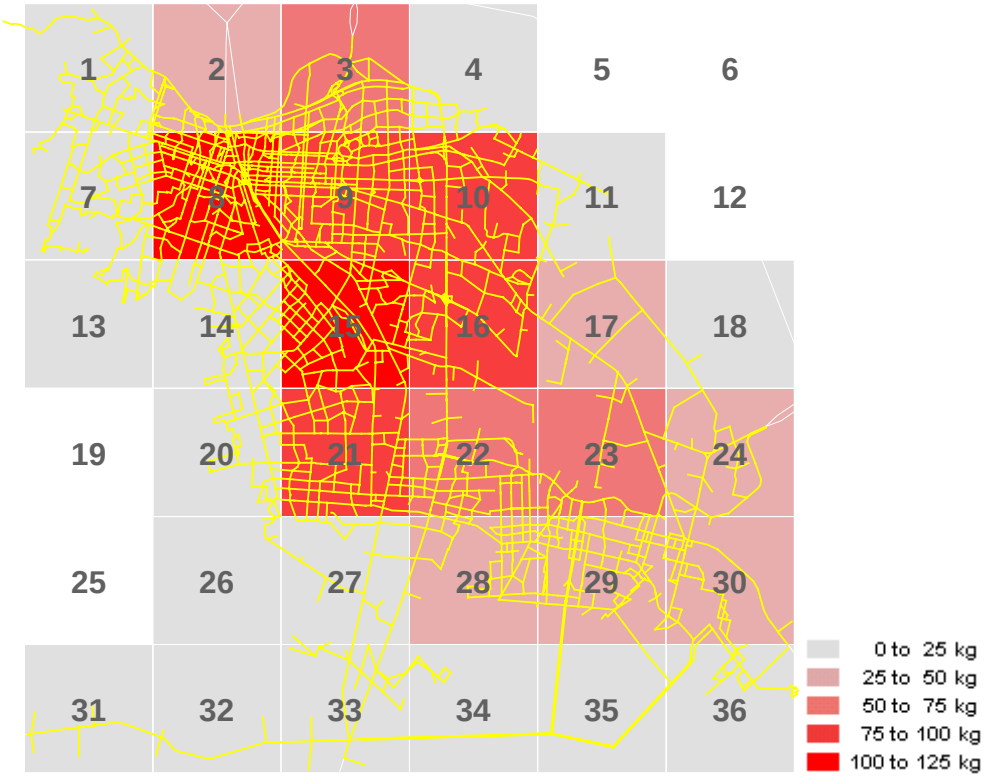

Figure 8. NOx concentration at PM peak (1-hour).

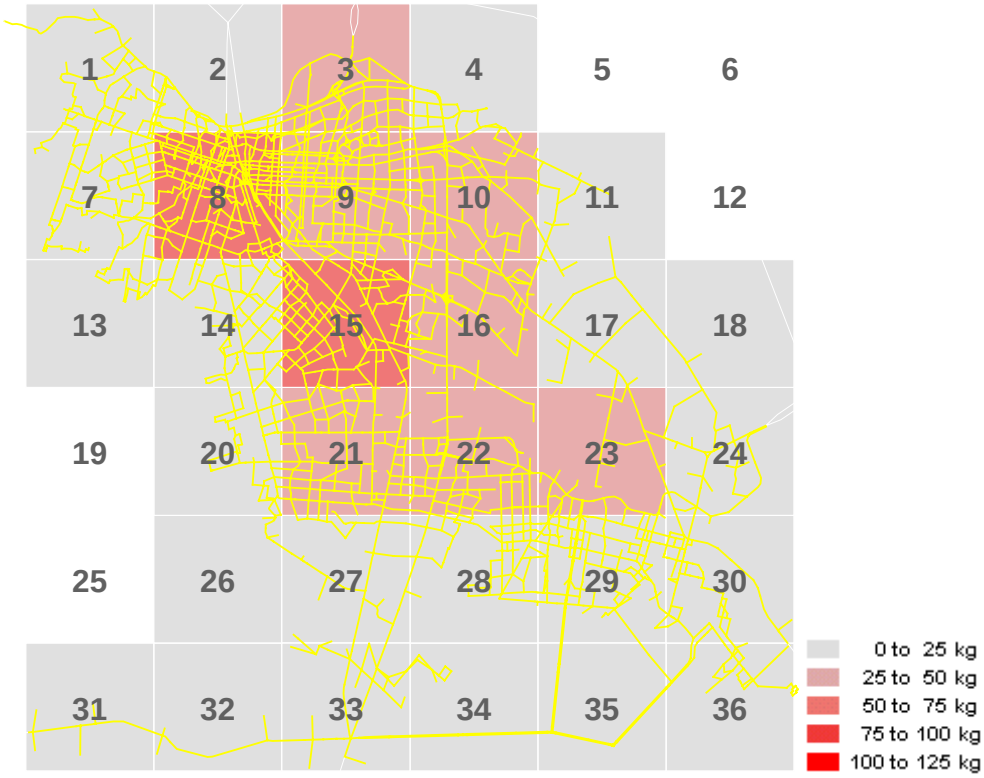

Figure 9. NOx concentration at Night (1-hour).