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Centre interuniversitaire de recherche sur les réseaux d'entreprise, la logistique et le transport

Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation

COMPUTATION OF MOBILE EMISSIONS ON A FINE GRID. THE OTTAWA-GATINEAU REGION

Final Report

Environment Canada

Ottawa | Transports Québec | Ontario | OC Transpo | STO Société de transport de l'Outaouais

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The Ministry of Transportation of Ontario supplied us with hourly counts which are useful to estimate the temporal traffic distribution.

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1. INTRODUCTION

The goal of this project is to adapt the GRID model, originally developed for the Montreal region, for the Ottawa-Gatineau region.

GRID was developed, upon request from Environment Canada, by the Centre of Research on Transportation of the University of Montreal in 2004. It has been updated for the Montreal region in 2009.

GRID computes emissions of the most important atmospheric pollutants generated by mobile sources and displays them on a fine resolution grid. The user only has to supply the meteorological information for the hour of evaluation. GRID uses two intermediate software tools: Emme calculates vehicle flows on the road network, and MOBILE6.2C calculates the emissions rates generated by these vehicles. For detailed information on GRID see [CRT05].

GRID was adapted in two major ways: data specific to the Ottawa-Gatineau region was introduced, and the computation process was modified.

Since the adapted software is meant to make estimates for every hour of the day, for every day of the year, for years ranging from 2005 to 2031, a few analyses and methods have been implemented in order to supplement the lack of information available for certain periods.

This report was written as a stand alone document, making it independent from the report issued for the Montreal project. It is organized as follows. Section 2 describes GRID; it details information specific to the Ottawa-Gatineau region. Section 3 lists all the input data required for the computation of emissions, covering both emission rates as well as traffic flow estimations. Section 4 describes the computation procedure in detail. Results are presented at Section 5. A brief conclusion is given at the end of the document.

2. DESCRIPTION OF GRID

GRID is an application integrating a computation process and a user interface. The computation procedure calls upon many programs and vast data sets. The user's interface allows for choosing input and launching computations. This section provides a general description of GRID.

2.1. Basic Characteristics

Table 2.1 lists emission types and pollutants calculated by the model in the Ottawa-Gatineau case.

GRID evaluates emission rates for the 28 vehicle types defined in MOBILE6.2C (for details on MOBILE6.2C see [EPA02] or [EC05]). These rates are then aggregated for the vehicle types defined in the Ottawa-Gatineau model (TRANS): cars, commercial vehicles and buses. A complete description on the model TRANS is given on [MRC08].

Emission rates are evaluated for 14 speeds: 2.5 miles/hour, and for all multiples of 5 miles / hour up to 65 miles / hour. Emission rates for intermediate speeds are derived by linear interpolation.

The TRANS model types of roads are classified in highways or arterial roads in order to map them to types used by MOBILE6.2C.

Emission rates are calculated on an hourly basis. Results are provided on an hourly basis also. Vehicular flows are however calculated according to the transportation model period definition. In the Ottawa-Gatineau model two main peak hour periods are defined: AM (from 6:30 to 9:00) and PM (from 15:30 to 18:30). In these cases the traffic assignment is carried out for the entire period and the flows are factored thereafter. For the rest of the day, the off peak periods, hourly or by half an hour data are available.

The year range over which emissions may be calculated depends on the scope of data available for the transportation model. The Ottawa-Gatineau TRANS model covers 2005 to 2031 inclusively.

Even though transportation demand is based on typical autumn days data only, GRID allows for estimating emissions for all the months of the year and for weekend days. These estimations are made possible in part by the application of distribution factors derived from traffic counts.

2.2. Graphical User's Interface

The user's interface allows for selection of input parameters and for the launching of the calculation process. It is easy to use and only requires basic knowledge of meteorology.

It was developed in Java on a Windows platform. Figure 2.1 features the main window. A full description of the interface GRID is given in [CIR10].

POLLUTANT	EMISSION		VEHICLE	ROAD	SPEEDS
HC (VOC)	RUNNING		ALL VEHICLES	FREEWAY and ARTERIAL 1	14
	START		LD + MC	ALL ROAD 2	1 *
	HOTSOAK		G + MC	ALL ROAD	1
	RUNLOSS		G - MC	FREEWAY and ARTERIAL	14
	CRANKCASE		G + MC	ALL ROAD	1
CO	RUNNING		ALL VEHICLES	FREEWAY and ARTERIAL	14
	START		LD + MC	ALL ROAD	1
NOX	RUNNING		ALL VEHICLES	FREEWAY and ARTERIAL	14
	START		LD + MC	ALL ROAD	1
CO2	RUNNING		ALL VEHICLES	FREEWAY or ARTERIAL 3	1
SO2	RUNNING		ALL VEHICLES	FREEWAY or ARTERIAL	14
NH3	RUNNING		ALL VEHICLES	FREEWAY or ARTERIAL	1
		PM			
SO4	RUNNING	2.5 10	ALL VEHICLES	FREEWAY or ARTERIAL	14
OCARBON	RUNNING	2.5 10	ALL VEHICLES	FREEWAY or ARTERIAL	1
ECARBON	RUNNING	2.5 10	ALL VEHICLES	FREEWAY or ARTERIAL	1
GASPM	RUNNING	2.5 10	ALL VEHICLES	FREEWAY or ARTERIAL	1
LEAD	RUNNING	2.5 10	ALL VEHICLES	FREEWAY or ARTERIAL	1
BRAKE WEAR	BRAKE WEAR	2.5 10	1 VEHICLE	ALL ROAD	1
TIRE WEAR	TIRE WEAR	2.5 10	ALL VEHICLES	ALL ROAD	1

1 FREEWAY and ARTERIAL. Rates are different.
2 ALLROAD. MOBILE62 provides only one rate.
3 FREEWAY or ARTERIAL. Rates are identical.
* 1 speed. The rate does not change with speed.

Table 2.1 Emissions Calculated by GRID

Among the parameters that may be set using the interface are the date and time of evaluation, weather conditions, fuel characteristics, oxygenated fuels (if required), and the grid layout. Most of these parameters have default values that may be adjusted.

The rest of the data required by the computation process is available to the program and the user does not have to be concerned with them.

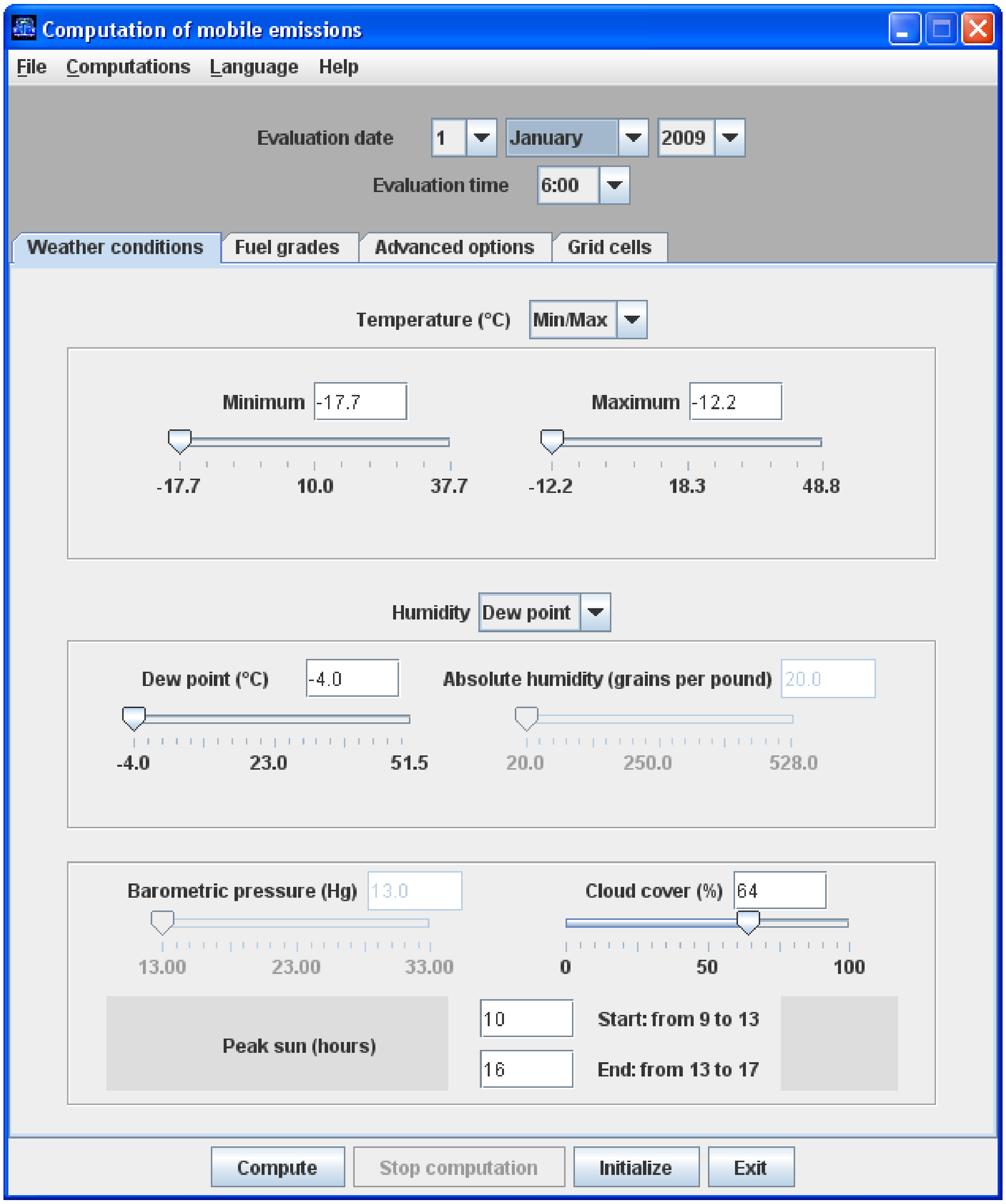

Figure 2.1 GRID Graphical User's Interface

3. INPUT DATA

Inputs are grouped according to the computation step where they are used.

3.1. Input Data Required for "Obtaining Emission Rates"

Input data in this phase consists mainly of the parameters required by MOBILE6.2C. Some of these parameters are set from the user's interface while others are found in specifically named and formatted data files. For more information about MOBILE6.2C please refer to [EPA02], [EC05] or [CRT05].

The following data are specified using GRID:

- Temperature. The temperature may be set in either of two modes: hourly, or as daily minimum and maximum. Minimum and maximum monthly default values for the Ottawa-Gatineau region are available.

  Source:
  http://climate.weatheroffice.gc.ca/climate_normals/results_f.html?StnId=4337

  Data: Daily Maximum (°C) and Daily Minimum (°C).

- Humidity. May be set in absolute (single value), relative (24 hourly values), or dew point modes (from which a single absolute value is derived). Default hourly values for relative humidity are available.

  Source:
  http://climate.weatheroffice.gc.ca/climate_normals/results_f.html?StnId=4337

  Data: Average Relative Humidity - 0600LST (%) and Average Relative Humidity - 1500LST (%). These values are bound to 6:00 and 15:00 respectively; values for interleaving hours are interpolated.

- Barometric pressure. Must be set when the relative humidity mode is chosen. No value by default is used.

- Cloud coverage. Default values are supplied with GRID.

  Source:
  http://climate.weatheroffice.gc.ca/climate_normals/results_f.html?StnId=4337

  Data: Cloud Amount (hours with):

- Peak sun. MOBILE6.2C default values are proposed.

- Reid Vapor Pressure. Default values for the Ottawa-Gatineau region are supplied.

Source: Brett Taylor, Environment Canada.

- Gasoline sulfur content. Default values for the Ottawa-Gatineau region are supplied.

  Source: Brett Taylor, Environment Canada.

- Diesel sulfur content. Default values for the Ottawa-Gatineau region are supplied.

  Source: Brett Taylor, Environment Canada.

- Oxygenated fuels. If used in the region, this must be specified. No default values are available. It is supposed that usage of oxygenated fuels in the Ottawa-Gatineau region is negligible.

- Size and offset of grid cells. This information is not required by MOBILE6.2C. It is used at the end of the computation procedure, when emissions are aggregated in the grid cell.

The following data are supplied with GRID and must be available at all time.

- Altitude. Set to “Low” for the Ottawa-Gatineau region.

- Sunrise and sunset times. This information takes into account the new summer advanced hour which was adopted in 2007.

  Source: http://ptaff.ca/soleil/

- Vehicle equivalence table. These tables allow for aggregating the 28 vehicle classes known to MOBILE6.2C to the 3 types used in the TRANS model. Three tables are included: one for vehicles with both fuel types together, one for diesel fuel type only, and one for the gasoline fuel type only.

  Source: Brett Taylor, Environment Canada.

For the rest of data in this section default MOBILE6.2C values are used by lack of region-specific data. They are generally American values.

- Distribution of Vehicle Registrations.

- Diesel Sales Fractions.

- Annual Mileage Accumulation Rates.

- Natural Gas Vehicles Fraction.

- Starts per day.

- Start Distribution.
- Soak Distribution.
- Hotsoak Distribution.
- Diurnal Soak Activity.
- Weekday and Weekend Trip Length Distribution.
- MPG Estimates.

3.2. Input Data Required for "Obtaining Flows and Estimating Pollution"

The data required for this step are essentially those required by the TRANS model.

The base characteristics of the TRANS model are the following:

- Three modes: car, commercial (truck), and transit.
- Two peak periods: AM (from 6:30 to 9:00) and PM (from 15:30 to 18:30).
- Five types of transit vehicles: 4 types of buses and train.
- Five types of roads: highway, major arterial, minor arterial, collector, and local street.

The City of Ottawa and the Ministry of Transportation of Quebec have supplied us all their available information. Ottawa supplied us the following data on TRANS:

- Road network for years 2005 and 2031.
- Transit network for years 2005 and 2031, AM and PM.
- Volume-delay functions and the traffic assignment macro.
- Demand matrices for 2005 and 2031, AM and PM periods, for cars (auto driver and external travels), and commercial vehicles (trucks).

The Ministry of Transportation of Quebec has supplied us with:

- 2005 hourly demand matrices for auto driver.
- Schedules and additional information concerning transit for a 2009 weekday.

The following sub-sections describe the data used; those that we have received, and those that we have generated.

3.2.1. The Road Network

The Ottawa "Transportation Master Plan", dated November 2008, sets three phases for the changes that are planned on the road network: from 2009 to 2015, from 2016 to 2022, and from 2023 to 2031. These dates are estimates made for budget planning purposes. All modifications and improvements planned in the three phases are included in the 2031 road network. The City of Ottawa is currently working on the establishment of an intermediate 2021 road network. Therefore, for years 2005 to 2030, the 2005 network is used. The 2031 network road is used only for 2031 computations.

Table 3.1 shows road network dimensions for years 2005 and 2031. For compatibility purposes with MOBILE6.2C and GRID, links in TRANS are classified as "Highways" or "Arterial" as shown in table 3.2. Figure 3.1 illustrates the Ottawa-Gatineau road network for 2005 modeled in TRANS. Figure 3.2 represents the same network, zoomed and with a geographical map as background. The differences between the 2005 and the 2031 networks are highlighted in Figure 3.3.

	2005	**2031**
Centroids	599	601
Regular nodes	7,984	8,197
Links	22,834	23,680
Turns	1,021	1,021

Table 3.1 Road Network Dimensions

TRANS	**GRID / MOBILE6.2C**
Highway	Highway
Major arterial	Arterial
Minor arterial	Arterial
Collector	Arterial
Local street	Arterial

Table 3.2 Road Type Equivalence

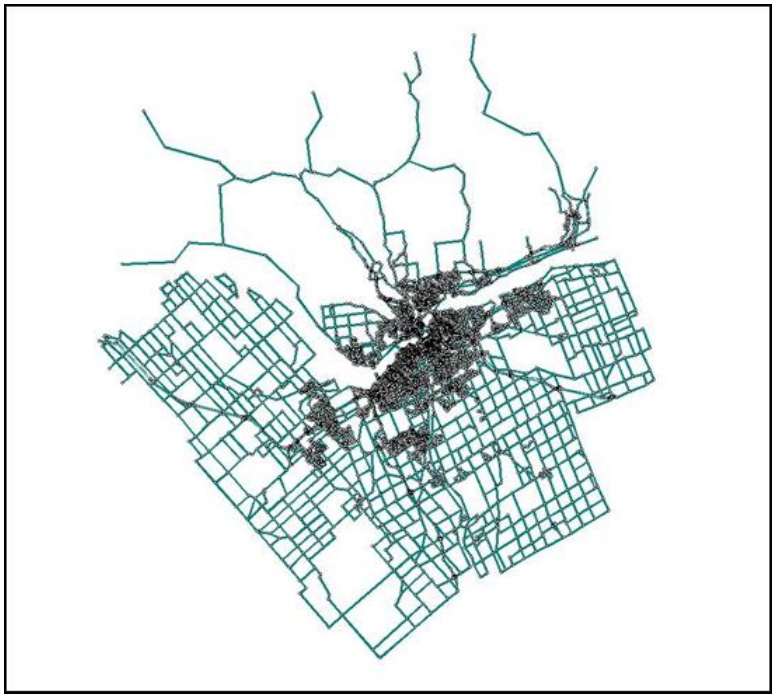

Figure 3.1 Ottawa-Gatineau Road Network 2005

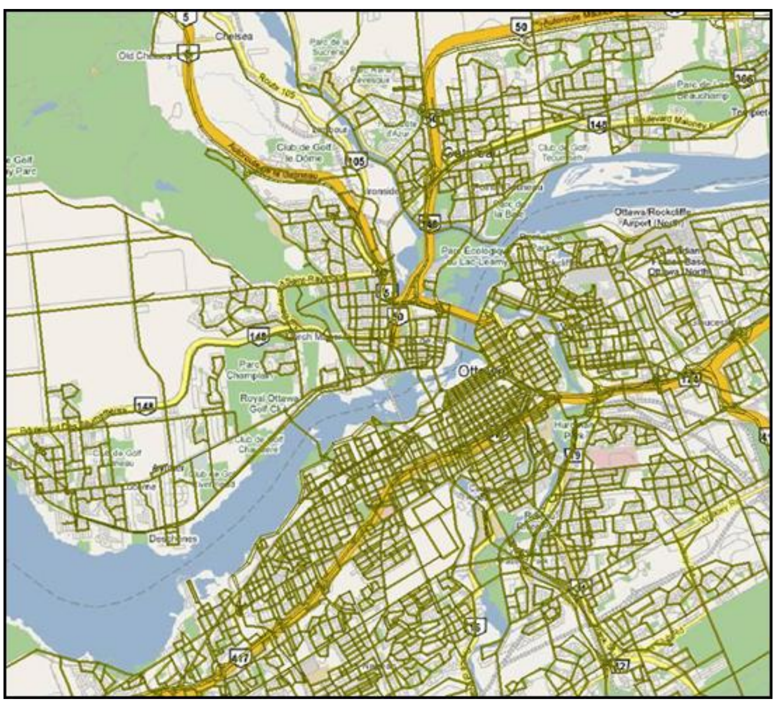

Figure 3.2 Ottawa-Gatineau Road Network 2005; Zoomed

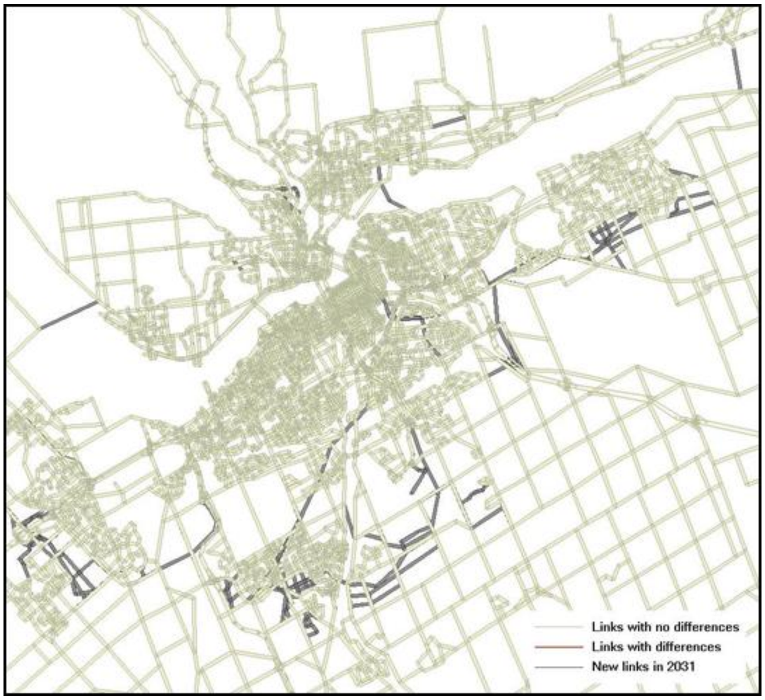

Figure 3.3 New Links from 2005 to 2031

3.2.2. The Transit Network

As previously mentioned, the City of Ottawa has provided us with the AM and PM transit networks for the years 2005 and 2031. These TRANS networks are coded in the Emme format and are described using, for each line, the itinerary, the transport company, the vehicle used, the headway, the average speed and the length of the route, among other data. Figures 3.4 and 3.5 show the number of lines on the network for the AM period, years 2005 and 2031, respectively. It may be observed that many lines crossing Ottawa downtown in the east-west direction disappeared for 2031, thus reflecting, we guess, the programmed transition to the light rail train (LTR). Table 3.3 shows the number of lines in use in each period.

The goal of this project is to compute pollutant emissions not only for the peak hour periods but for all hours of the day. MTQ has provided us with two sets of data describing the transit network in Ottawa-Gatineau. The first one describes the lines deserved by the *Société de transports de l'Outaouais* (STO), and the second one describes the lines deserved by OC Transpo. This data corresponds to the 24 hours of a day in 2009. Information contained in these files is coded using the following fields:

- STO: Number of the route, origin, destination, time of departure from origin, time of arrival at destination, direction, duration, and distance travelled. This is supplied for every transit line.

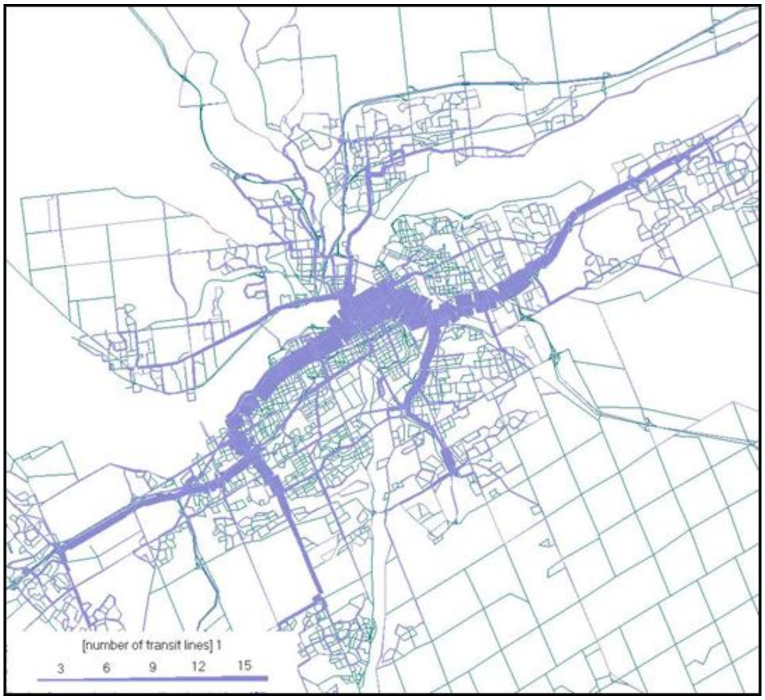

Figure 3.4 Transit Network – 2005

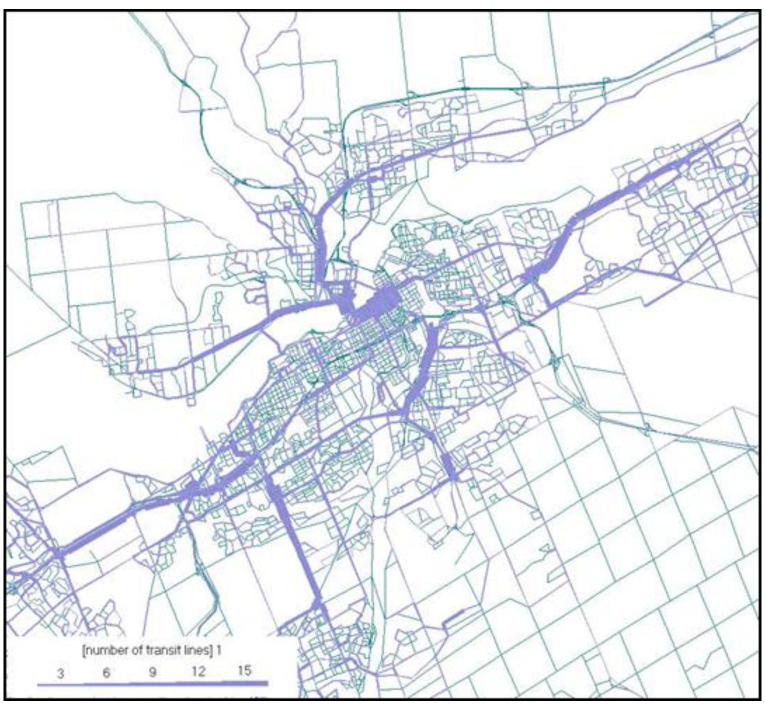

Figure 3.5 Transit Network – 2031

- OC Transpo: Run number, time of passage at most important stops, connection with other lines, length of the route, and direction. This is supplied for every line (express, peak hour and regular).

	2005 Total (OC Transpo / STO)	**2031** Total (OC Transpo / STO)
AM	303 (226 / 77)	358 (279 / 79)
PM	289 (211 / 78)	330 (251 / 79)

Table 3.3 Number of Transit Lines

This data has been processed to build Emme-format files for each hour of the day containing the description of the transit lines.

The most important problem that we have encountered was to establish the correspondence between the regular OCT lines received to their corresponding lines in the TRANS model. Some of the regular lines received are described using many different itineraries depending on the hour of departure. Line 5, for example, may take 7 different itineraries in the schedule descriptions, but in the TRANS (Emme) model, only 2 are coded. Extensive efforts were deployed in order to establish, as well as possible, the correspondence between the files. A few bus routes have been added. This was the first step. The second step was to extract the line's headways for all the off peak hours. In order to assign a run to a specific hour of the day an average criterion was used, whereby the average between the run start-time and the run end-time were used to yield the average time of the run. For each off peak hour and for each transit line, the information retained from this process was the headway, the average speed (of all the buses inside the hour), as well as the itinerary.

For weekend days, Saturdays and Sundays being considered separately, the frequency of each line was obtained directly from each transport company's web sites. The average speed for a line at a given hour was set to the maximum speed recorded in the same hour during a week day. The information corresponding to the weekday peak hour periods was also compiled. Table 3.4 lists the numbers of lines assigned to each hour and period of each day type, merging information from MTQ and the web sites. It may be observed that AM and PM periods lines represent 88% and 87% of all lines in 2005. This is due to changes to the transit network since 2005; some 2005 lines could not be found anymore.

As was the case for the road network, the transit network in 2031, AM and PM periods, includes all improvements planned by the government from year 2009 to 2031. GRID uses this data only for the year 2031. The 2005 AM and PM transit networks supplied by the City of Ottawa are used for years 2005 to 2008 inclusively, periods AM and PM. For the off peak hours all the years, and for the weekend days all the years, and for years 2009 to 2030 AM and PM periods, GRID uses the transit information generated by our team (updated 2009).

Hour	Weekday	Saturday	Sunday
0:00 – 1:00	61	57	21
1:00 – 2:00	13	14	6
2:00 – 3:00	8	6	6
3:00 – 4:00	2	3	2
4:00 – 5:00	12	2	2
5:00 – 6:00	50	16	4
6:00 – 6:30	130	20	8
6:30 – 9:00	**268**	**109**	**73**
9:00 – 10:00	165	122	105
10:00 – 11:00	140	125	111
11:00 – 12:00	138	125	114
12:00 – 13:00	138	125	114
13:00 – 14:00	138	125	114
14:00 – 15:00	148	125	113
15:00 – 15:30	162	115	97
15:30 – 18:30	**252**	**125**	**114**
18:30 – 19:00	146	100	73
19:00 – 20:00	124	113	100
20:00 – 21:00	122	107	95
21:00 – 22:00	122	105	91
22:00 – 23:00	108	100	85
23:00 – 24:00	88	91	68

Table 3.4 Transit Lines in 2009

3.2.3. Volume-Delay Functions and the Assignment Macro

The TRANS model volume-delay functions have been used as is. There are 90 BPR (Bureau of Public Roads) functions based on the former TRANS model. They have been improved in 2008 by using new link classifications and by updating the capacity of road segments. For more information, refer to [MRC08].

The assignment procedure is very simple. It may be summarized as follows:

- Compute the number of buses on each link (in car equivalents) using their respective line itineraries and headways.
- Buses as fixed flows on the links.
- Multi-class traffic assignment of cars and trucks (commercial vehicles). This takes into account the peak hour scale factor.

3.2.4. The Demand

The City of Ottawa supplied us with the demand AM and PM matrices for auto and commercial vehicles for the years 2005 and 2031. The auto demand that we have received is divided in two: auto driver and external (where external includes travel made to, from, and between outer zones). External demand has been aggregated to the auto demand. Figures 3.6 to 3.8 show the geographic distribution of the demand aggregated by origin and destination. Table 3.5 summarizes travel totals.

Please note that even if the auto and external demand is aggregated, both are treated differently at the time of the traffic assignment. The reason is that in the assignment procedure the “scaling coefficient” (defined for the peak hour periods) is only applied to the auto driver demand.

Please note also that the commercial demand for the PM period is significantly less (near 50%) than for the AM period. This differs of the behavior showed by the counts. The distribution shown in figures A.5 and A.11 presents more regularity between the volumes on these two periods, we know however that the counting stations are located on important roads (see figure A.1) and on highways 416 and 417.

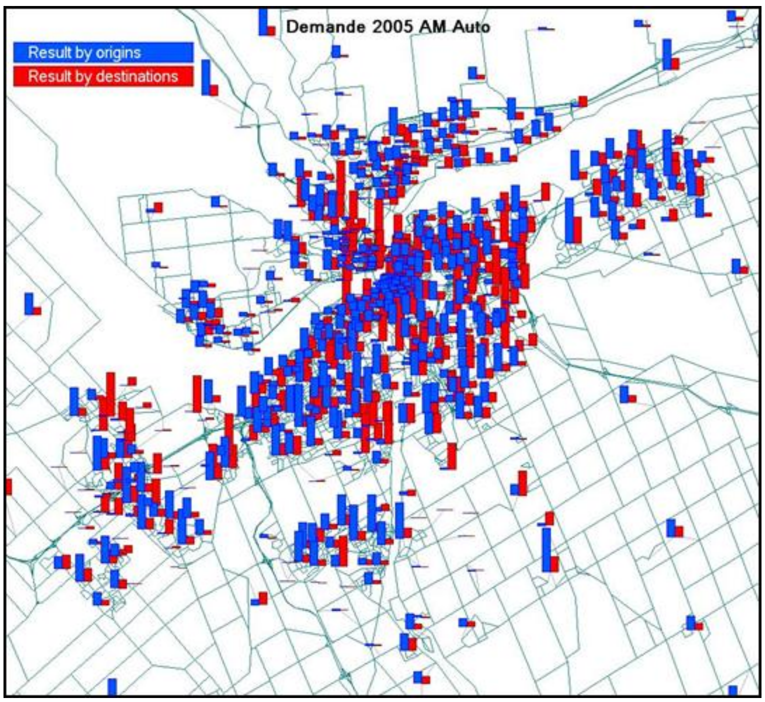

Figure 3.6 2005 AM Auto Demand. Aggregated by Origin-Destination

While analyzing the demand, we have noticed that 2031 forecasts for external and commercial travels represent a 30% increase relative to 2005.

AM and PM demand forecasts for intermediate years were generated by linear interpolation. Table 3.6 details total demand for years 2005 through 2031. These values are shown graphically in figures 3.9 and 3.10.

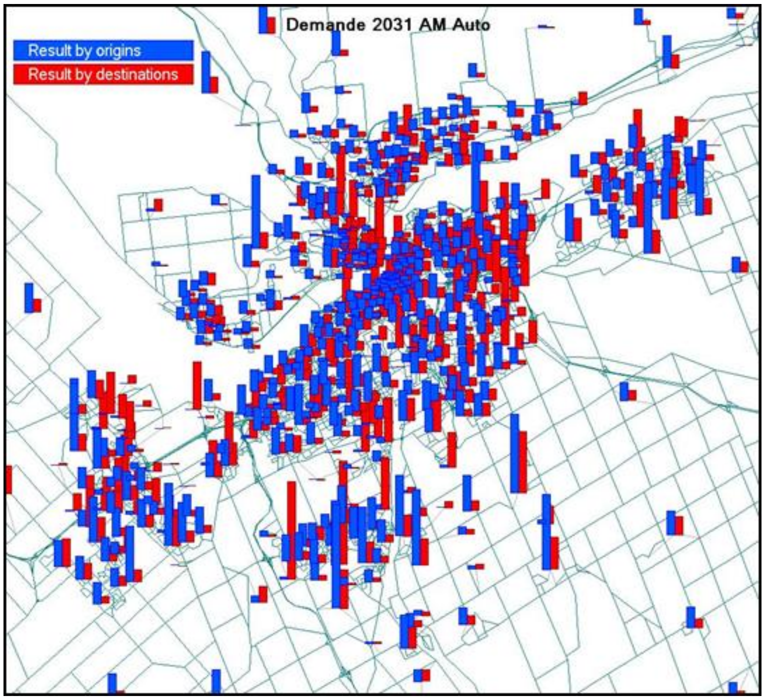

Figure 3.7 2031 AM Auto Demand. Aggregated by Origin-Destination

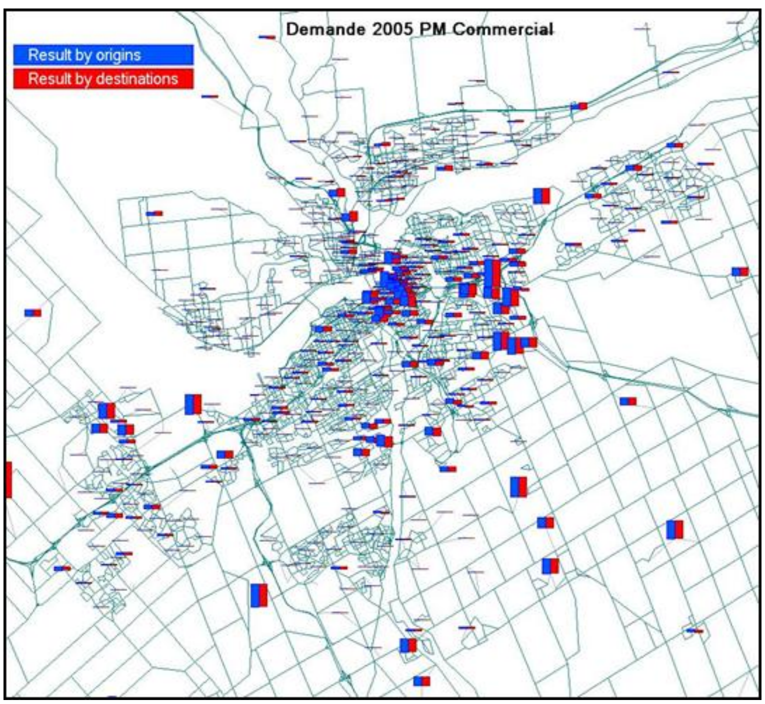

Figure 3.8 2005 PM Commercial Demand. Aggregated by Origin-Destination

	Auto		Commercial	
	AM	PM	AM	PM
2005	316,338	448,488	11,637	6,098
2031	399,207	552,726	15,128	7,927

Table 3.5 Total Travel Demand

	Auto		Commercial	
	AM	PM	AM	PM
2005	316 338	448 488	11 637	6 098
2006	319 525	452 497	11 771	6 168
2007	322 712	456 506	11 905	6 238
2008	325 900	460 516	12 040	6 309
2009	329 087	464 525	12 174	6 379
2010	332 274	468 534	12 308	6 449
2011	335 462	472 543	12 442	6 520
2012	338 649	476 553	12 577	6 590
2013	341 836	480 562	12 711	6 661
2014	345 023	484 571	12 845	6 731
2015	348 211	488 580	12 980	6 801
2016	351 398	492 589	13 114	6 872
2017	354 585	496 598	13 248	6 942
2018	357 772	500 608	13 382	7 012
2019	360 959	504 617	13 517	7 083
2020	364 147	508 626	13 651	7 153
2021	367 334	512 635	13 785	7 223
2022	370 521	516 644	13 919	7 294
2023	373 709	520 653	14 054	7 364
2024	376 896	524 663	14 188	7 434
2025	380 083	528 672	14 322	7 505
2026	383 270	532 680	14 456	7 575
2027	386 458	536 690	14 591	7 646
2028	389 645	540 699	14 725	7 716
2029	392 832	544 708	14 859	7 786
2030	396 019	548 718	14 994	7 857
2031	399 207	552 726	15 128	7 927

Table 3.6 Demand Evolution

As for the off peak hours, we received demand information from MTQ. It consists of the auto driver travel demand that was extracted from the fall 2005 origin-destination survey applied on the Ottawa-Gatineau region. Even if restricted to auto driver travel only, it allows to make approximate estimations for these hours. Also, this demand can be updated as soon as more precise data becomes available. The distribution of this demand is shown in figure 3.11. Figure 3.12 shows the auto driver demand at 10:00.

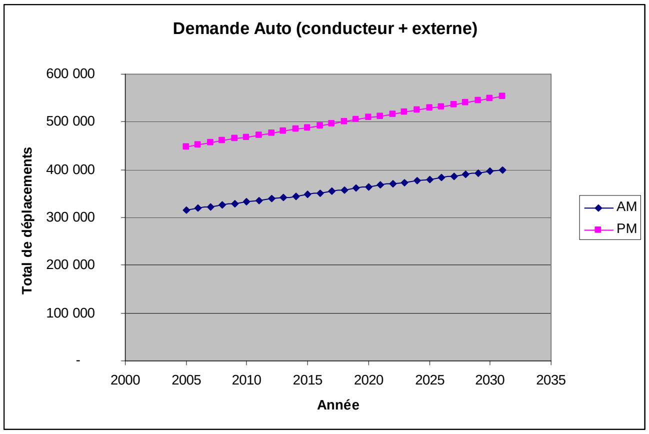

Figure 3.9 Total Demand Change – Auto Driver

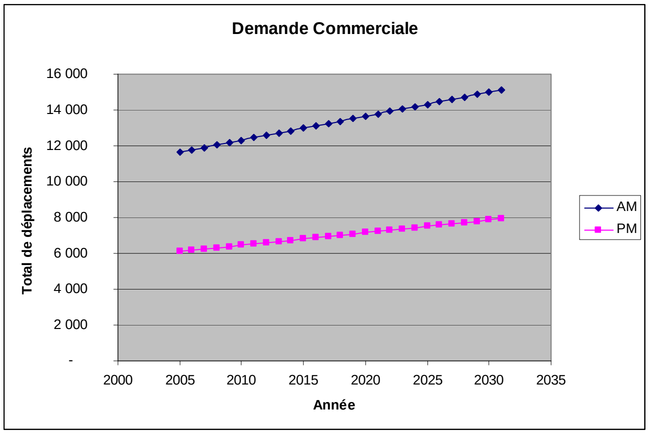

Figure 3.10 Total Demand Change – Commercial Vehicles

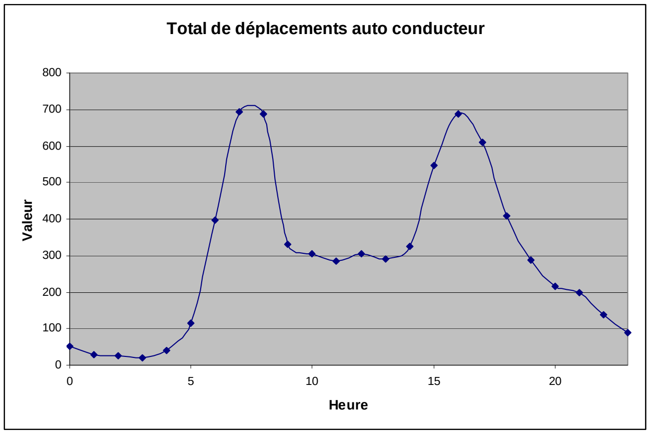

Figure 3.11 Distribution through the Day of the Total Auto Driver Demand for 2005

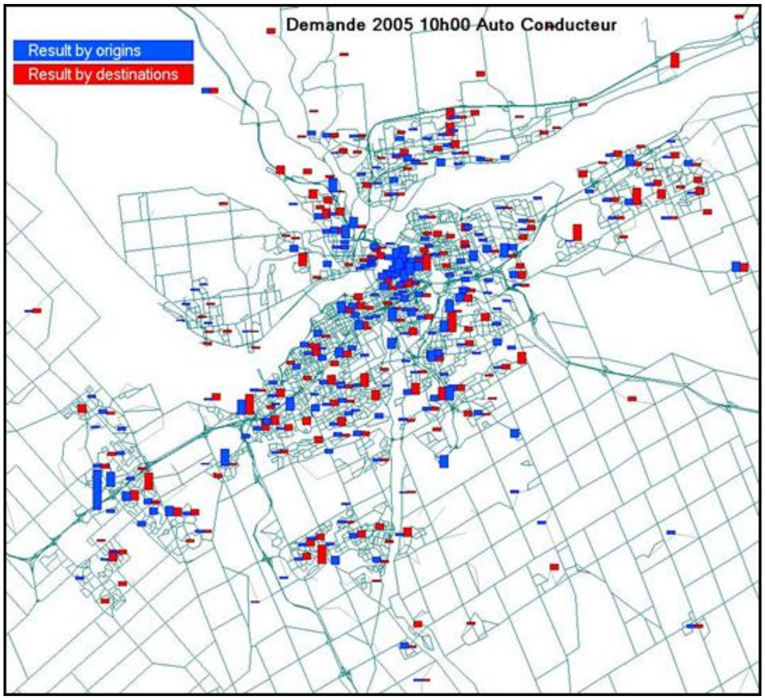

Figure 3.12 Auto Driver Demand for 10:00, 2005. Aggregated by Origin Destination

A few analyses were performed to find the best method to infer this demand over 2006 to 2031. We decided that for external travel the same factor as for the AM and PM periods, the 30% increase, would be applied. For all remaining zones, a global factor of 25% to 2031 is used. This factor was obtained by averaging all car demand growth factors from 2005 to 2031 for the AM and PM periods. These factors are used for the entire off peak hours. Table 3.7 lists the total auto driver demand for years 2005 and 2031, for the entire day. The AM and PM demand is included for reference purposes only.

The method used for commercial vehicles was different considering that we have no information concerning the off peak hours. For these hours, two distribution factors, obtained from MTO counts, were considered. These AM and PM factors are calculated as the ratio that each off peak hour represents relatively to the AM and PM values respectively. It must be noted that these factors are applied directly to the flows. The procedure is as follows: flows for AM and PM periods of the current year are calculated in advance; target hour specific factors are then applied to them and the average of these values is retained as the flow for this off peak hour. Table 3.8 lists the AM and PM factors for all hours. Figure 3.13 shows the traffic distribution from which these factors were obtained.

	Auto driver	
	2005	2031
0:00 à 1:00	9 183	11 486
1:00 à 2:00	3 436	4 300
2:00 à 3:00	2 714	3 394
3:00 à 4:00	1 207	1 509
4:00 à 5:00	3 750	4 697
5:00 à 6:00	14 784	18 508
6:00 à 6:30	23 896	29 905
AM	306 492	383 340
9:00 à 10:00	71 650	89 644
10:00 à 11:00	72 311	90 466
11:00 à 12:00	71 291	89 172
12:00 à 13:00	82 515	103 212
13:00 à 14:00	73 180	91 541
14:00 à 15:00	77 896	97 444
15:00 à 15:30	59 130	73 969
PM	451 994	565 345
18:30 à 19:00	47 773	59 766
19:00 à 20:00	90 515	113 217
20:00 à 21:00	66 487	83 158
21:00 à 22:00	55 847	69 856
22:00 à 23:00	32 964	41 227
23:00 à 24:00	18 604	23 276

Table 3.7 Auto Driver Demand Projection to 2031

Hour	AM Factor	PM Factor
0:00 - 1:00	0.0692	0.0542
1:00 - 2:00	0.0614	0.0481
2:00 - 3:00	0.0639	0.0500
3:00 - 4:00	0.0652	0.0510
4:00 - 5:00	0.0893	0.0699
5:00 - 6:00	0.1528	0.1196
6:00 - 6:30	0.1704	0.1335
AM		
9:00 - 10:00	0.4274	0.3347
10:00 - 11:00	0.3961	0.3102
11:00 - 12:00	0.4021	0.3149
12:00 - 13:00	0.3803	0.2978
13:00 - 14:00	0.3971	0.3110
14:00 - 15:00	0.4286	0.3356
15:00 - 15:30	0.2375	0.1860
PM		
18:30 - 19:00	0.1228	0.0962
19:00 - 20:00	0.1838	0.1439
20:00 - 21:00	0.1571	0.1230
21:00 - 22:00	0.1441	0.1129
22:00 - 23:00	0.1143	0.0895
23:00 - 24:00	0.0909	0.0712

Table 3.8 Commercial Off Peak Hour Factors

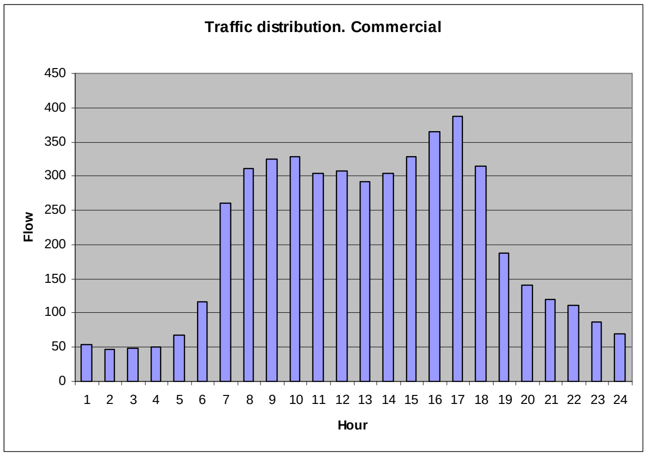

Figure 3.13 Hourly Distribution of Commercial Traffic

4. COMPUTATION PROCEDURE

The computation procedure consists of two steps: “Obtaining emission rates” and “Obtaining flows and estimating pollution”. Flow diagrams are provided in figures 4.1 to 4.3.

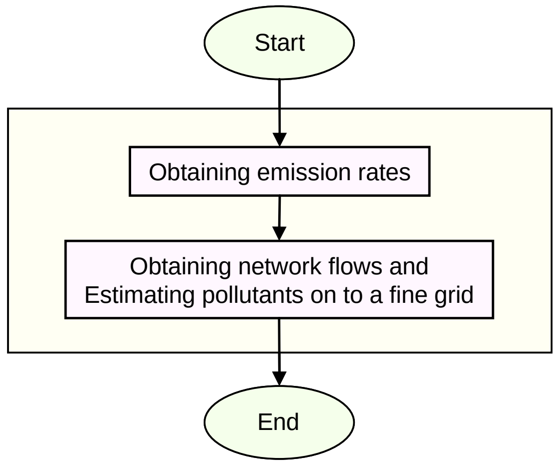

Figure 4.1 Computation Procedure

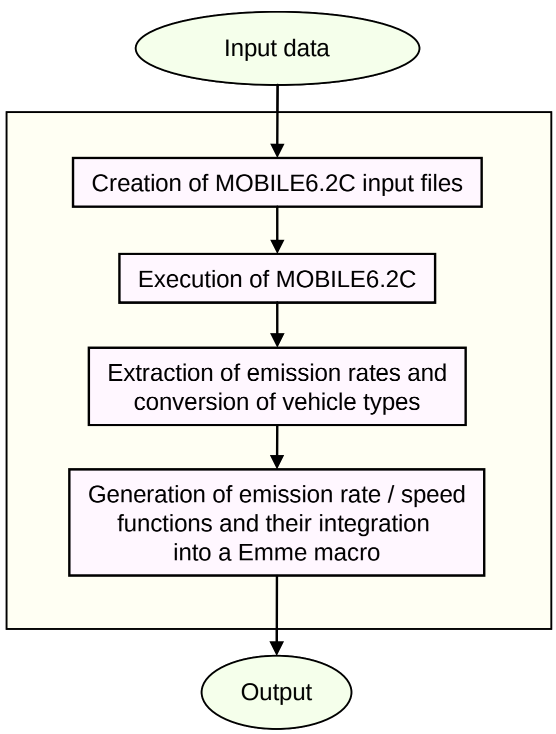

Figure 4.2 “Obtaining emission rates”

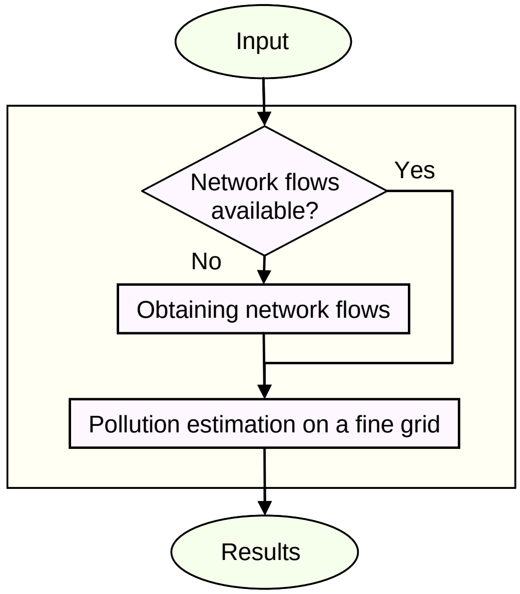

Figure 4.3 “Obtaining flows and estimating pollution”

The procedure is implemented using a combination of DOS and PERL programs and Emme macros. The procedure makes hourly evaluations, so when a day run is requested, 24 sub-calls are made.

4.1. “Obtaining Emission Rates”

This step is launched as soon as calculations are started from the user’s interface.

4.1.1. Creation of MOBILE6.2C Input Files

Input parameters selected from GRID (computation date and hour, temperature, fuel characteristics, etc.) as well as other data from external files (sunrise and sunset, fuel programs, etc.) are used to generate the input to MOBILE6.2C. Figure 4.4 shows the beginning of a MOBILE6.2C file.

Once MOBILE6.2C run calculates, for all 28 MOBILE6.2C vehicle types and for all pollutants, all emission types for a specified year, a single month (either for January or July), a single hour (for this project), a single type of road and a single particle size, and this for one or several speeds.

MOBILE6.2C can thus group emission evaluation, but some calls are required.

First, two runs are required to cover all possible emissions types: the two sizes of particles (10 and 2.5 microns), and the types of roads (arterial and freeway). The first call computes 10 micron-particle emissions and freeways, and the second computes 2.5 micron particles and arterial road.

```
MOBILE6 INPUT FILE :
POLLUTANTS          : HC CO NOX CO2
* Base de donnees Mobile6  PM size:25 heures:7,7 route:ARTERIAL annee:2010
DATABASE OUTPUT     :
WITH FIELDNAMES     :
EMISSIONS TABLE     : Bases\Hour7\M6Arterial25July.tb1
PARTICULATES        : SO4 GASPM OCARBON ECARBON BRAKE TIRE SO2 NH3
DATABASE EMISSIONS : 1222 2121 11
DATABASE HOURS      : 2 2

RUN DATA
EXPAND BUS EFS      :
EXPAND HDDV EFS     :
EXPAND HDGV EFS     :
EXPAND LDT EFS      :
EXPAND EXHAUST      :
EXPAND EVAPORATIVE :

MILE ACCUM RATES    : MileDat.def
VMT BY HOUR         : _hvmt.def
START DIST          :  startdis.txt
STARTS PER DAY      :  Stperday.d
WE DA TRI LEN DI    :  Mtripday.txt
WE EN TRI LEN DI    :  Mtripend.txt

SCENARIO REC        : Scenario no 1 - ARTERIAL   2.50 mi/h
CALENDAR YEAR       : 2010
EVALUATION MONTH    : 7
```

Figure 4.4 Sample of a MOBILE6.2C Input File

In addition, according to the month being computed, one or two MOBILE6.2C calls are required. When the month is neither January nor July, calculations are made for both months and values are interpolated linearly. Figure 4.5 shows the list of input files generated for an evaluation on April for example.

Each one of these evaluation contains 14 scenarios, one for each target speed (emissions may vary according to the speed).

```
M6Arterial25January.in
M6Arterial25July.in
M6Freeway10January.in
M6Freeway10July.in
```

Figure 4.5 List of MOBILE6.2C Input Files

4.1.2. MOBILE6.2C Execution

MOBILE6.2C is called.

4.1.3. Extraction of Emission Rates and Vehicle Type Conversion

Once MOBILE6.2C calls are terminated, emissions must be extracted from the output files. Three file types generated by MOBILE6.2C are used:

- txt: File containing emissions already aggregated over the 28 types of vehicles. Emissions to extract: Running, Crankcase and Running loss. These rates are required in grams / km.

- pm: File containing emissions for particulate matters for the 28 vehicle types. These emission rates are required in grams / km.

- tb1: Database-type file containing disaggregated emissions. Emissions to extract: Start and Hotsoak. These emissions are required in grams / start or in grams / end, respectively.

Figure 4.6 shows the files generated by MOBILE6.2C (month of April) and figure 4.7 shows partial content of the TXT file.

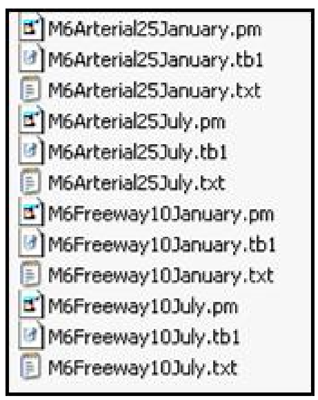

Figure 4.6 List of MOBILE6.2C Output Files

After extracting emission rates, aggregation on speed values must be carried out according to the transportation model vehicle types. In the case of TRANS, the rates of the 28 MOBILE6.2C types are re-distributed over the types auto, commercial and bus. This is made according to an equivalence table specific to the Ottawa-Gatineau region.

Note that to facilitate the transition from the Montreal GRID case to Ottawa-Gatineau, files are still coded with 4 vehicle classes, but one (the heavy truck) contains zero values only.

```
                Calendar Year:  2010
                        Month:  Jan.
                     Altitude:  Low
          Minimum Temperature:  34.0 (F)
          Maximum Temperature:  51.6 (F)
            Absolute Humidity:   28. grains/lb
             Nominal Fuel RVP:  14.7 psi
                Weathered RVP:  14.7 psi
          Fuel Sulfur Content:   25. ppm

          Exhaust I/M Program:  No
             Evap I/M Program:  No
                  ATP Program:  No
             Reformulated Gas:  No

       Vehicle Type:     LDGV     LDGT12    LDGT34     LDGT      HDGV
               GVWR:              <6000     >6000      (All)
                        ------   ------    ------    ------    ------
  VMT Distribution:     0.3541   0.3856    0.1315              0.0356
 Fuel Economy (mpg):      24.1     18.6      14.3      17.3       9.7
--------------------------------------------------------------------------
 Composite Emission Factors (g/mi):
     Composite VOC :     4.338     4.253     8.914     5.438     6.429
     Composite CO  :    38.42     40.88     72.32     48.87     50.32
     Composite NOX :     1.320     1.749     2.930     2.050     1.861
     Composite CO2 :   368.1     477.6     620.1     513.8     914.7
--------------------------------------------------------------------------
Exhaust emissions (g/mi):
      VOC    Start:     0.241    0.318     0.809     0.443
    VOC    Running:     1.181    1.585     3.869     2.165
  VOC Total Exhaust:    1.422    1.903     4.677     2.608     2.410
```

Figure 4.7 M6Arterial25January.txt – Partial Content

A file is generated for each emission type. Figure 4.8 lists all the files generated at this step of the computation process (for the month of January). Figure 4.9 shows a partial content of one of those files. The “RegularTruck” row corresponds to commercial vehicles, and the “HeavyTruck” row is empty.

- brake-10-July.txt
- brake-25-July.txt
- co2-July.txt
- co-running-ARTERIAL-July.txt
- co-running-FREEWAY-July.txt
- co-start-July.txt
- crankcase-July.txt
- ecarbon-10-July.txt
- ecarbon-25-July.txt
- gaspm-10-July.txt
- gaspm-25-July.txt
- nh3-July.txt
- nox-running-ARTERIAL-July.txt
- nox-running-FREEWAY-July.txt
- nox-start-July.txt
- ocarbon-10-July.txt
- ocarbon-25-July.txt
- running-loss-July.txt
- so2-July.txt
- so4-July.txt
- tire-10-July.txt
- tire-25-July.txt
- total-10-July.txt
- total-25-July.txt
- voc-diurnal-July.txt
- voc-hotsoak-July.txt
- voc-resting-July.txt
- voc-running-ARTERIAL-July.txt
- voc-running-FREEWAY-July.txt
- voc-start-July.txt

Figure 4.8 List of Emissions Files

```
CO        Running
Speed
    4.02      8.05    16.09    24.14    32.19    40.23    48.28    56.33    64.37    7
Car
  16.5235943428    9.1434398200    5.5236416565    4.4334923087    3.8914217006
RegularTruck
  10.7378042804    8.6220057436    5.7856342411    4.0929961271    3.0519646563
HeavyTruck
   0.0000000000    0.0000000000    0.0000000000    0.0000000000    0.0000000000
Bus
   7.3265580000    5.9808510000    4.1240610000    2.9758320000    2.2473990000
```

Figure 4.9 CO-running-ARTERIAL-July.txt Partial Content

4.1.4. Generation of Emission Rate / Speed Functions and Integration into an Emme Macro

As previously mentioned, in the case where the month of evaluation is neither January nor July, two sets of emission rates are generated (one for January and one for July).

Values for the evaluation month are interpolated linearly; this is made at the very beginning of this sub-step.

Thereafter emission rate / speed functions are generated from the 14 values of emission rates. These functions allow for determining emission rates at any intermediate speed by linear interpolation between the 14 values obtained from MOBILE6.2C. One such function is created in the Emme macro language for every vehicle type. When the rates do not depend on speed, the function returns a constant. Figure 4.10 shows the code of one such function.

```
Car
21.9039401437 + put(@spd)*0
+ (get(1).psum.-4.02) * -2.42795156
+ (get(1).psum.-8.05) * 1.83540377
+ (get(1).psum.-16.09) * 0.41419011
+ (get(1).psum.-24.14) * 0.08981044
+ (get(1).psum.-32.19) * 0.03985452
+ (get(1).psum.-40.23) * 0.02475140
+ (get(1).psum.-48.28) * 0.02356843
+ (get(1).psum.-56.33) * 0.03373188
+ (get(1).psum.-64.37) * 0.00061052
+ (get(1).psum.-72.42) * 0.00062166
+ (get(1).psum.-80.47) * 0.00036527
+ (get(1).psum.-88.51) * 0.01043346
+ (get(1).psum.-96.56) * 0.00020330
+ (get(1).psum.-104.61) * -0.04559321
RegularTruck
12.2544908875 + put(@spd)*0
+ (get(1).psum.-4.02) * -0.60014560
+ (get(1).psum.-8.05) * 0.19696408
+ (get(1).psum.-16.09) * 0.16316192
+ (get(1).psum.-24.14) * 0.09256486
+ (get(1).psum.-32.19) * 0.05497107
+ (get(1).psum.-40.23) * 0.03430707
+ (get(1).psum.-48.28) * 0.02267142
+ (get(1).psum.-56.33) * 0.01604867
+ (get(1).psum.-64.37) * 0.01295423
+ (get(1).psum.-72.42) * 0.01182761
+ (get(1).psum.-80.47) * 0.01281438
+ (get(1).psum.-88.51) * 0.01584391
+ (get(1).psum.-96.56) * 0.02225029
+ (get(1).psum.-104.61) * -0.05623391
HeavyTruck
0.0000000000 + put(@spd)*0
Bus
7.4560365000 + put(@spdb)*0
+ (get(4).psum.-4.02) * -0.33977792
+ (get(4).psum.-8.05) * 0.10474023
+ (get(4).psum.-16.09) * 0.08989340
+ (get(4).psum.-24.14) * 0.05303571
```

Figure 4.10 Emission Function for CO-running-ARTERIAL.txt Partial Content

At the end of this step, all emission rates / speed functions are inserted in a file. This is the Emme macro file that contains the command lines required for associating emission rate functions to vehicles moving on the network.

Another file is generated and contains the distribution factors by vehicle to apply according to the evaluation date and time. In the case of the following hours: 6:00, 15:00 and 18:00, two factor files are generated. One for the first and one for the second half-hours. This is due to the way the AM and PM peak hour spans are defined in the model. The content of one such file is shown in figure 4.11. Only the two first values are used; for cars and commercial vehicles.

```
19.974885
11.668095
11.668095
```

Figure 4.11 Factor File Content

4.2. "Obtaining Flows and Estimating Pollution"

The second step consists in calculating vehicle flows on the network, their speeds, and associating emission rates as obtained from the first part of the computation to the network flows. The emissions should be aggregated into the cells of a grid. This part of the computations is carried out by Emme macros; for more information on this software see [INR07].

For the Ottawa-Gatineau model, the following issues have to be considered:

- GRID was made to estimate pollutant emissions on an hourly basis. The TRANS model sets AM and PM periods from 6:30 to 9:00 and from 15:30 to 18:30, respectively. Flows for these periods must then be factorized to provide hourly figures. Also, since hours 6:00-7:00, 15:00-16:00, and 18:00-19:00 overlap two periods; two computations need to be done.

- In the case of the AM and PM peak periods the TRANS model uses demand matrices that span the entire time range. For off peak hours, matrices correspond to an hour or for a half-hour period. These two types of periods have to be processed differently.

- For off peak periods, demand matrices for commercial vehicles are not available and commercial flows are estimated from the AM and PM commercial flows.

- For the auto and commercial vehicles the weekend estimates are obtained using distribution factors. For buses, we rely on line-specific data for weekdays and weekends.

4.2.1. Obtaining Network Flows

If vehicle network flows are not available for all vehicle types, they have to be computed. A flow diagram of this process is shown in figure 4.12. Figure 4.13 provides the list of all the files that should exist to avoid going through this step, for an evaluation at 10:00 on a weekday.

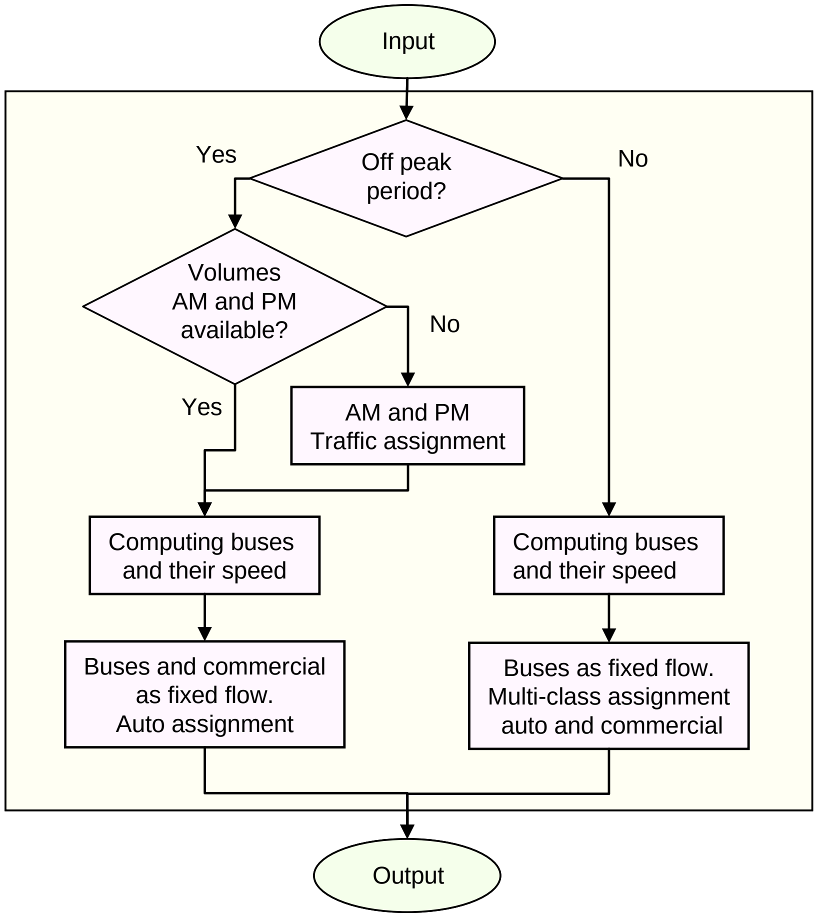

Figure 4.12 “Obtaining Network Flows” Process

Figure 4.13 Files Containing Volumes for 10:00

In this calculation sub-step, reference is always made to the “evaluation period”. This refers to the AM peak hour (6:30-9:00), the PM peak hour (15:30-18:30), or to the off peak hour or half-hour times (0:00-1:00, 1:00-2:00,… 6:00-6:30, 15:00-15:30,… etc.).

Flows are obtained as follows: buses are always estimated from line itineraries and headways. Their speeds are those reported from their respective transport companies (OC Transpo and STO). Autos are always estimated from a traffic assignment. As for commercial vehicles, it depends on the evaluation period. They are obtained from a multi-class assignment for the peak periods, or from an AM and PM flow factorization for the off peak periods. In this last case the AM and PM commercial flows must be available, if they are not, they must be computed following this same procedure.

The calculation starts by initializing the road and the transit networks for the current evaluation. Files required for this initialization for an AM period on a weekday evaluation are listed in figure 4.14.

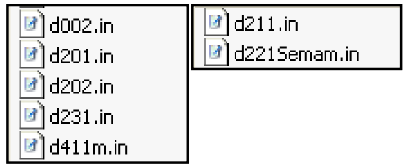

Figure 4.14 Files Required for the Network Initialization

Then, the number of buses on each link is calculated. Their speeds are estimated as the average speed of all buses passing on the links. Bus flows and their respective speeds are saved. Figure 4.15 offers a view of a file reading this information.

Depending of the evaluation period the procedure continues as follows:

- AM or PM peak periods. Auto and commercial travel demand matrices are read. Buses are considered as fixed flows on the links, and an auto commercial multi-class assignment is carried out.

- Off peak periods. The auto travel demand matrix is read. Commercial distribution factors and commercial flows (AM and PM) are read. Factorization is applied to obtain commercial volumes for the evaluation period. Bus and commercial flows are considered fixed. Traffic assignment for autos is executed.

Afterwards, car and commercial flows on links, for the evaluation period, are saved. Travel demand is aggregated by origin and destination and saved also. Please note that for off peak periods this aggregation is made only for autos since the commercial demand is not available. Figure 4.16 shows a section of these flows file.

inode	jnode	@buses	@spdb
193008	193004	49.9959	31.7011
193008	193010	47.9964	32.6344
193008	193011	17.0068	26.47
193009	193005	11	31.9173
193010	188021	32.0068	29.3897
193010	193008	40.9977	32.4037
193010	193012	23.9982	32.4714
193010	193014	17.9964	30.73
193011	193008	8.9982	28.5
193011	193014	17.0068	26.47
193012	188022	0	0
193012	193010	32.9977	32.1549
193012	193015	23.9982	32.4714
193013	193007	0	0
193013	193009	11	31.9173
193013	193016	14.0056	32.03
193014	1930	0	0
193014	193010	17.0068	26.47
193014	193011	8.9982	28.5
193014	193026	8.9982	32.96
193015	193012	32.9977	32.1549
193015	193018	23.9982	32.4714

Figure 4.15 Bus Flows and their Speeds

inode	jnode	@auto	@comm
110	11001	39.8641	.04669
110	13001	0	0
120	14006	9.46734	3.89661
120	15003	17.5305	0
131	13001	31.5361	9.74939
131	16001	62.6608	35.844
132	14001	49.18	6.17939
132	16003	125.807	21.9328
141	11001	57.1536	39.4619
141	17001	139.008	7.70766
142	15002	144.269	42.3427
142	18001	115.676	17.8142
151	15005	47.1836	0
151	18004	103.64	14.7139
152	15011	52.3676	0
152	18007	95.7333	18.0125
161	16016	69.9495	10.1553
161	16019	30.1101	3.47104
162	16006	67.3975	21.9177
162	16011	136.051	34.6266
163	16008	35.8371	17.8389
163	16012	145.661	39.5407
171	17002	84.7516	9.35217

Figure 4.16 Auto and Commercial Flows

When the evaluation hour is 6:00, 15:00 or 18:00, this sub-procedure is applied, once for the first half-hour, and once for the second half-hour. Figure 4.17 lists all the files generated for a weekday evaluation at 6:00.

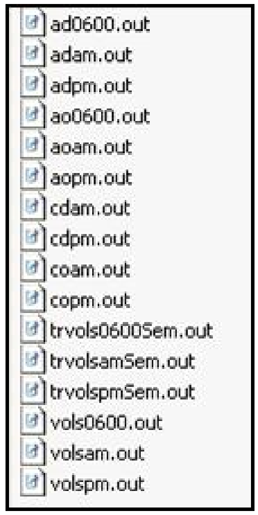

Figure 4.17 Files Generated for an Evaluation at 6:00

4.2.2. Pollution Estimation on a Fine Grid

The last step of the calculation procedure is the aggregation of the pollution estimations into the grid cells. The corresponding flow diagram is presented in figure 4.18.

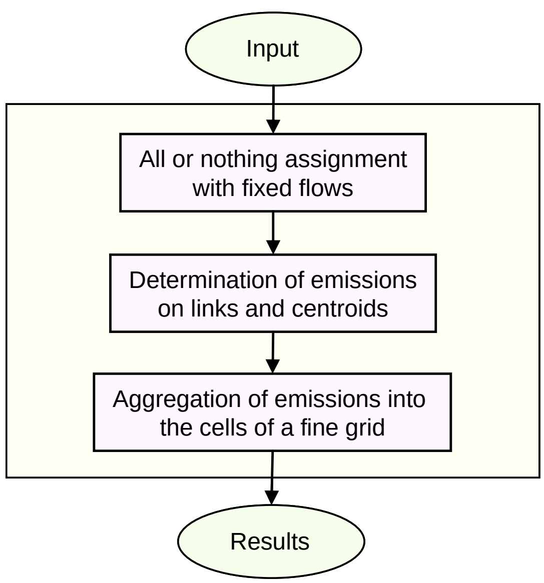

Figure 4.18 'Pollution Estimation on a Fine Grid'

The road network is initialized first.

Auto, commercial, and bus volumes are then read from the files. The origin-destination aggregated demand is also read.

Next, traffic distribution factors are applied to volumes and to auto and commercial demand in order to:

- Determine the hourly values inside the period (for AM and PM peak periods).
- Estimate the traffic for any month of the year.
- Estimate the traffic for weekend days.

In the case of buses there are no distribution factors. The distribution of flows inside a period (AM or PM) is assumed uniform. Flows are specific for weekdays, Saturdays and Sundays, but there is only one estimation for all the months of the year.

If the evaluation period is either 6:00, 15:00 or 18:00, two sets of volumes are read, factorized, and then added. The sets correspond to the evaluation periods 6:00-6:30 and AM; 15:00-15:30 and PM; and PM and 18:30-19:00, respectively.

Auto, commercial, and bus hourly flows are set as fixed on the links and a null-demand all-or-nothing assignment is made. Speeds are determined from the transit times on the road network.

At this moment, the macro associating emission rate / speed data to vehicles on the network is called. The speed just computed is used for the autos and commercial vehicles, whereas buses have speeds provided by their respective company data. The macro computes the total emissions for vehicles moving on the network and for parked vehicles. The total amount of each pollutant generated by all types of vehicles is associated to each link. The accumulated emissions generated when vehicles are parked are associated to centroids. Please note that emissions are also calculated for connectors that join centroids to real links in the road network.

The last part of the calculation process consists in aggregating link and node emissions into the cells of a fine grid covering the area. The aggregation is made using the GRTOOL utility. GRTOOL, “A link to grid interface”, first saves emissions on links and nodes in temporary files. Figure 4.19 shows the content of one such file. It lists emissions associated to links.

In a second step, GRTOOL processes saved data by aggregating emissions according to the size and location of the cells as specified using the GRID interface.

Since GRTOOL has limitations concerning the number of emissions to process in one run, 4 text files are generated, the three first being emissions produced by moving vehicles (on the links), and the last one being for parked vehicles (on the centroids). Figure 4.20 show the content of a results file, listing emissions associated to grid cells.

inode	jnode	xi	yi	xj	yj	tmp19	@co2	@nh3	@bw25	@bw10	@tw25	@tw10	@oca25
110	11001	367375	5031852	367258	5031629	.01	.0004	.09195	.00498	.01173	.00186	.00745	.00055
110	13001	367375	5031852	367566	5031818	.01	0	0	0	0	0	0	0
120	14006	366862	5031494	367098	5031527	.01	.00024	.0252	.00183	.00433	.001	.00402	.00453
120	15003	366862	5031494	366934	5031426	.01	.00007	.01618	.00087	.00206	.00033	.00131	.00009
131	13001	367717	5031785	367566	5031818	.01	.00042	.05034	.00345	.00814	.00178	.00713	.00708
131	16001	367717	5031785	367692	5031614	.01	.00233	.34281	.02162	.05098	.01016	.04064	.03061
132	14001	367550	5031670	367414	5031723	.01	.00041	.0684	.00412	.00973	.00183	.00732	.00434
132	16003	367550	5031670	367539	5031521	.01	.0019	.33243	.01967	.04639	.0085	.034	.01766
141	11001	367397	5031578	367258	5031629	.01	.00202	.27721	.01794	.04232	.0087	.03481	.02906
141	17001	367397	5031578	367386	5031424	.01	.00103	.2003	.01144	.02698	.00469	.01876	.00681
142	15002	367237	5031480	367180	5031387	.01	.00136	.16593	.0113	.02665	.00579	.02317	.02259
142	18001	367237	5031480	367222	5031320	.01	.00109	.1575	.00999	.02356	.00473	.01891	.01459
151	15005	367074	5031378	367019	5031288	.01	.0002	.04649	.00251	.00593	.00094	.00376	.00025
151	18004	367074	5031378	367063	5031220	.01	.00104	.16566	.01014	.02392	.00459	.01837	.01196
152	15011	366811	5031208	366709	5031095	.01	.00031	.07249	.00392	.00924	.00146	.00586	.00039
152	18007	366811	5031208	366943	5031144	.01	.0016	.28393	.01671	.03941	.00716	.02866	.01424
161	16016	368134	5031605	368040	5031605	.01	.00041	.0655	.004	.00943	.0018	.00722	.00463
161	16019	368134	5031605	368075	5031346	.01	.00043	.06942	.00423	.00998	.00191	.00762	.00485
162	16006	367863	5031519	367732	5031550	.01	.00148	.25164	.01503	.03545	.00658	.02632	.01467
162	16011	367863	5031519	367793	5031452	.01	.00145	.22231	.01377	.03248	.00633	.02532	.01755
163	16008	367685	5031453	367580	5031451	.01	.00043	.04288	.00321	.00758	.0018	.00722	.00856

Figure 4.19 Intermediate Results File Content

# Created by GRLINK (2.5)								
xg=15000	yg=15000	@co2	@nh3	@bw25	@bw10	@tw25	@tw10	@oca25
180000.000	5070000.000	0.077	8.518	0.606	1.428	0.324	1.297	1.503
195000.000	5055000.000	0.110	12.099	0.860	2.029	0.460	1.842	2.134
195000.000	5070000.000	0.025	2.810	0.200	0.471	0.107	0.428	0.496
210000.000	5055000.000	0.135	14.909	1.060	2.500	0.567	2.269	2.630
225000.000	4935000.000	0.086	16.634	0.951	2.244	0.391	1.563	0.615
225000.000	5055000.000	0.135	14.909	1.060	2.500	0.567	2.269	2.630
240000.000	4935000.000	0.124	23.956	1.370	3.232	0.563	2.251	0.886
240000.000	5040000.000	0.100	11.061	0.786	1.855	0.421	1.684	1.951
240000.000	5055000.000	0.035	3.848	0.274	0.645	0.146	0.586	0.679
255000.000	4935000.000	0.060	11.536	0.660	1.556	0.271	1.084	0.427
255000.000	4950000.000	0.064	12.420	0.710	1.676	0.292	1.167	0.459
255000.000	5025000.000	0.004	0.736	0.042	0.098	0.017	0.067	0.023
255000.000	5040000.000	0.135	14.909	1.060	2.500	0.567	2.269	2.630
270000.000	4950000.000	0.124	23.957	1.370	3.232	0.563	2.251	0.886
270000.000	5025000.000	0.184	36.787	2.083	4.912	0.841	3.365	1.144
270000.000	5040000.000	0.135	14.909	1.060	2.500	0.567	2.269	2.630
285000.000	4950000.000	0.110	21.226	1.214	2.864	0.499	1.994	0.785

Figure 4.20 Contents of a Result File

The list of result files for an evaluation at 6:00 on a weekday is shown in figure 4.21. File are named “emmi<*Num*><*Hour*><*Day*>.out” where <*Num*> is a sequential number ranging from 1 to 4, <*Hour*> is the evaluation hour, and <*Day*> is either “Sem” (weekday), “Sam” (Saturday), or “Dim” (Sunday). Table 4.1 lists all pollutants, emission types and the names by which they are known in Emme as well as in the file where they are written.

emmi16Sem.out
emmi26Sem.out
emmi36Sem.out
emmi46Sem.out

Figure 4.21 List of Output Files for a weekday at 6:00

Network element	Pollutant	Emission	Emme Name	Units	File
Centroid	HC(VOC)	Start	hcst	Kilos	emmi4*.out
	CO	Start	cost	Kilos	emmi4*.out
	NOX	Start	noxst	Kilos	emmi4*.out
	HC (VOC)	Hotsoak	hchs	Grams	emmi4*.out
Link	HC (VOC)	Running	hcru	Kilos	emmi3*.out
	HC (VOC)	Runloss	hcrl	Kilos	emmi2*.out
	HC (VOC)	Crankcase	hcck	Grams	emmi2*.out
	CO	Running	coru	Kilos	emmi3*.out
	NOX	Running	noxru	Kilos	emmi3*.out
	CO2	Running	co2	Metric tons	emmi1*.out
	SO2	Running	so2	Grams	emmi2*.out
	NH3	Running	nh3	Grams	emmi1*.out
	BRAKEWEAR 2.5	Brakewear	bw25	Grams	emmi1*.out
	TIREWEAR 2.5	Tirewear	tw25	Grams	emmi1*.out
	SO4	Running	so4	Grams	emmi2*.out
	OCARBON 2.5	Running	oca25	Grams	emmi1*.out
	ECARBON 2.5	Running	eca25	Grams	emmi2*.out
	GASPM 2.5	Running	gas25	Grams	emmi3*.out
	PMTOT 2.5	Running	tot25	Grams	emmi3*.out
	BRAKEWEAR 10	Brakewear	bw10	Grams	emmi1*.out
	TIREWEAR 10	Tirewear	tw10	Grams	emmi1*.out
	OCARBON 10	Running	oca10	Grams	emmi2*.out
	ECARBON 10	Running	eca10	Grams	emmi2*.out
	GASPM 10	Running	gas10	Grams	emmi3*.out
	PMTOT 10	Running	tot10	Grams	emmi3*.out

Table 4.1 Emissions, Units and Output Files

It is also possible to see the results using the Emme GUI. This is made by using the “Grid values” worksheet. Aggregation in cells is made automatically and the user can define the size and position of the grid. Only one pollutant may be visualized at a time and values can be saved in a file.

5. RESULTS

The results were validated once the model has been entirely generated, i.e. all input data had been assembled, the computation procedure had been decided, and all programs had been coded and tested.

After validation, some emissions calculation for typical cases were carried out, while keeping a focused view in order to keep this document to a reasonable size. The Montreal project has served as a base for choosing the type of evaluation to conduct, and has offered a way to compare results between the two regions.

As mentioned in the previous section, there are two output formats: a text file, or a graphical image using Emme. Figure 4.19 offers a partial view on a results text file. Figures 5.1 to 5.8 offer a graphical view of various emissions on a 1 km grid. Computations were made at 6:00 AM, on a January 2010 weekday.

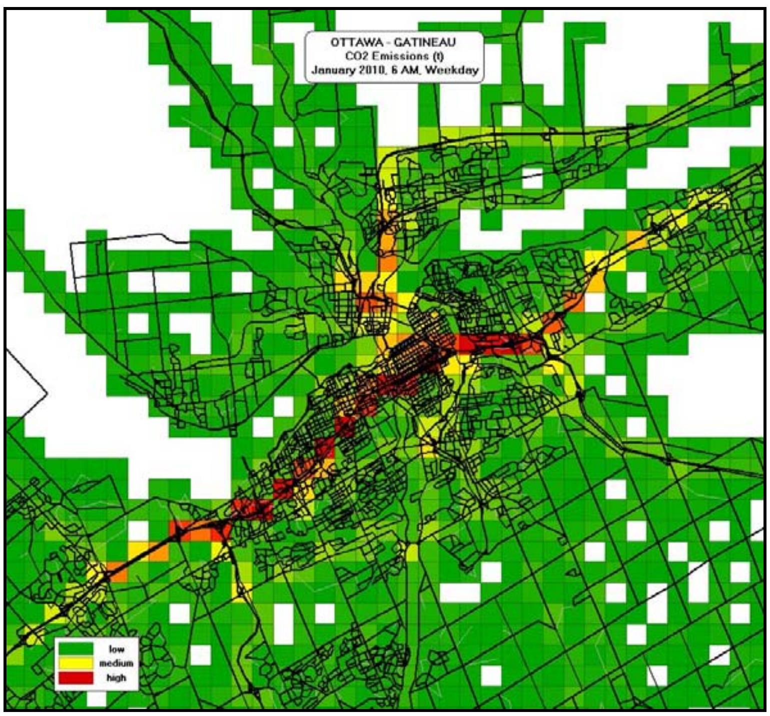

Figure 5.1 CO_2 Emissions

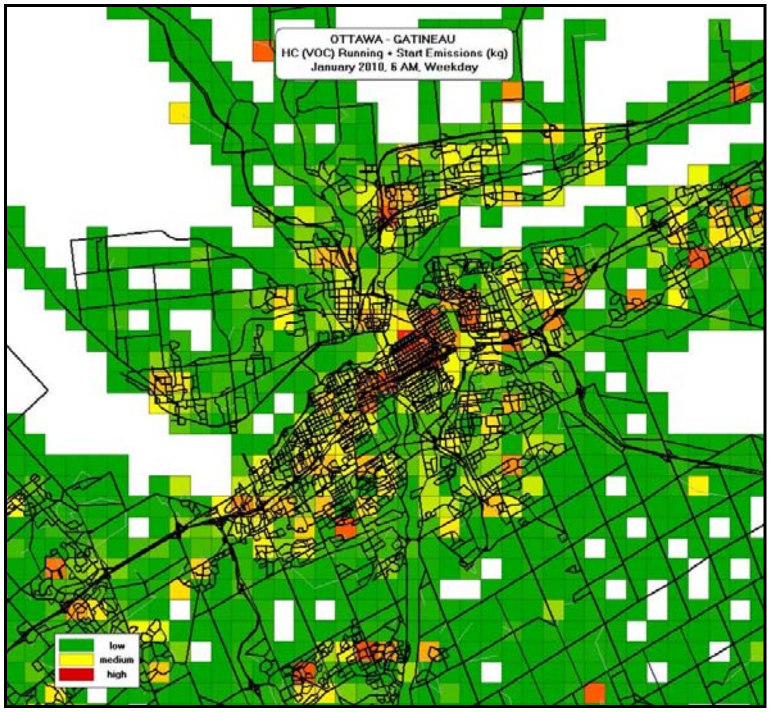

Figure 5.2 HC(VOC) (Running + Start) Emissions

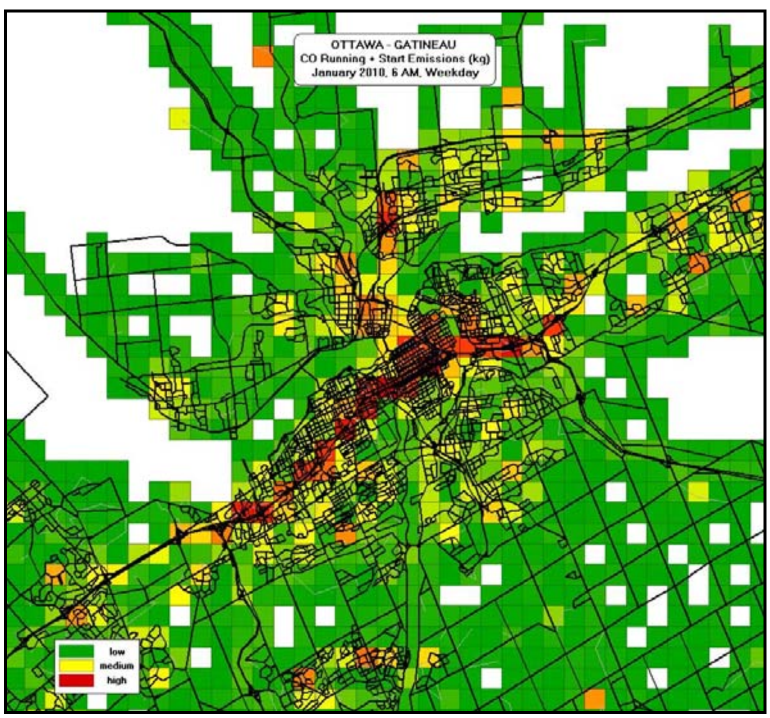

Figure 5.3 CO (Running + Start) Emissions

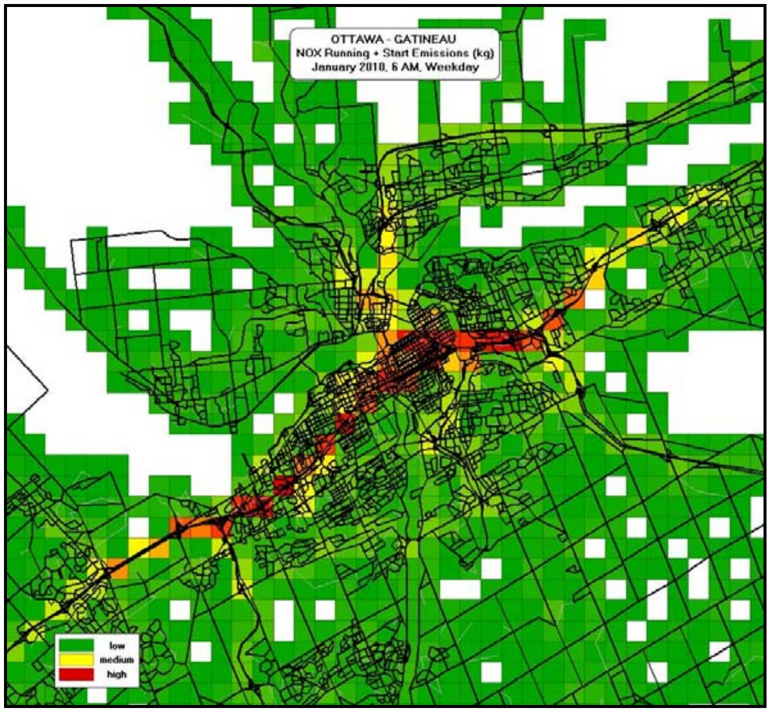

Figure 5.4 NO_X (Running + Start) Emissions

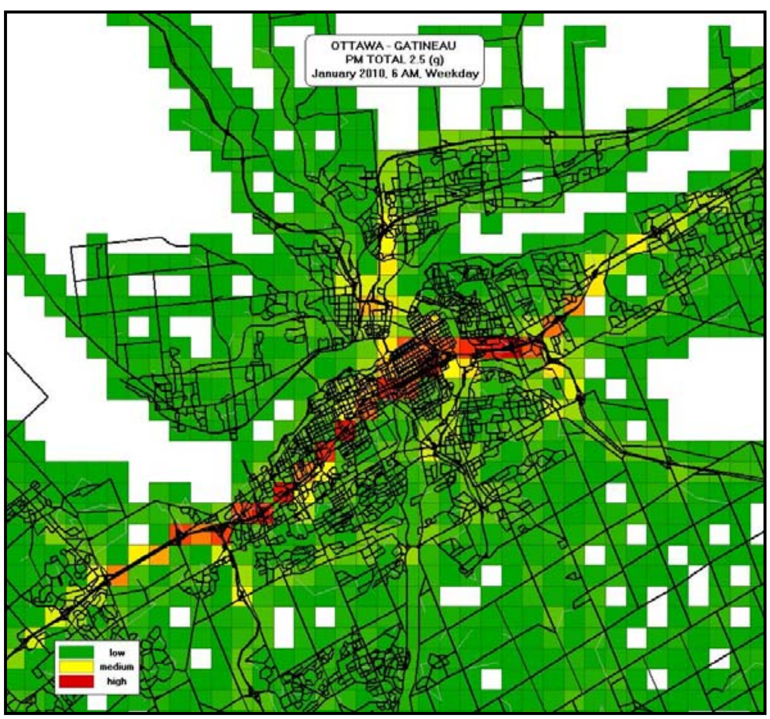

Figure 5.5 TOTAL PM 2.5 Emissions

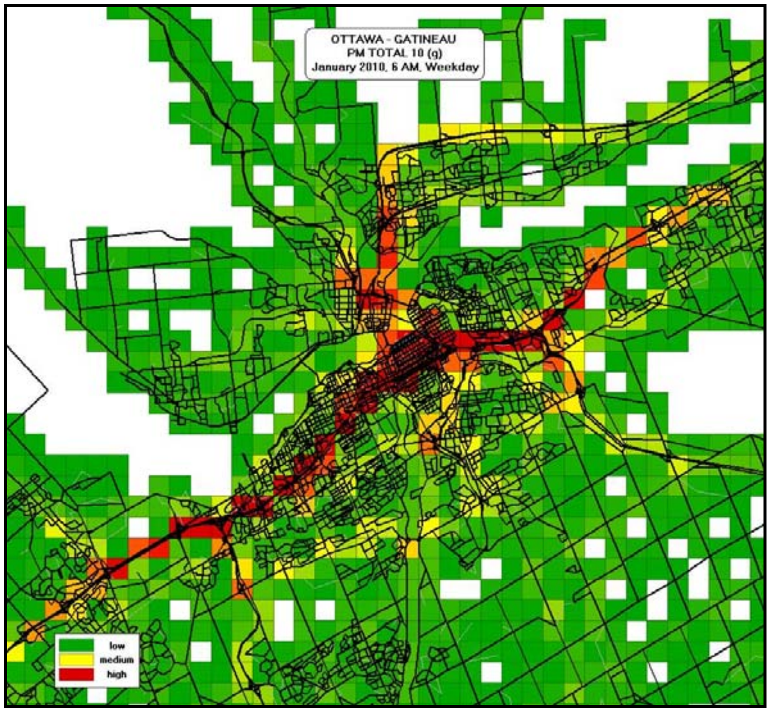

Figure 5.6 TOTAL PM 10 Emissions

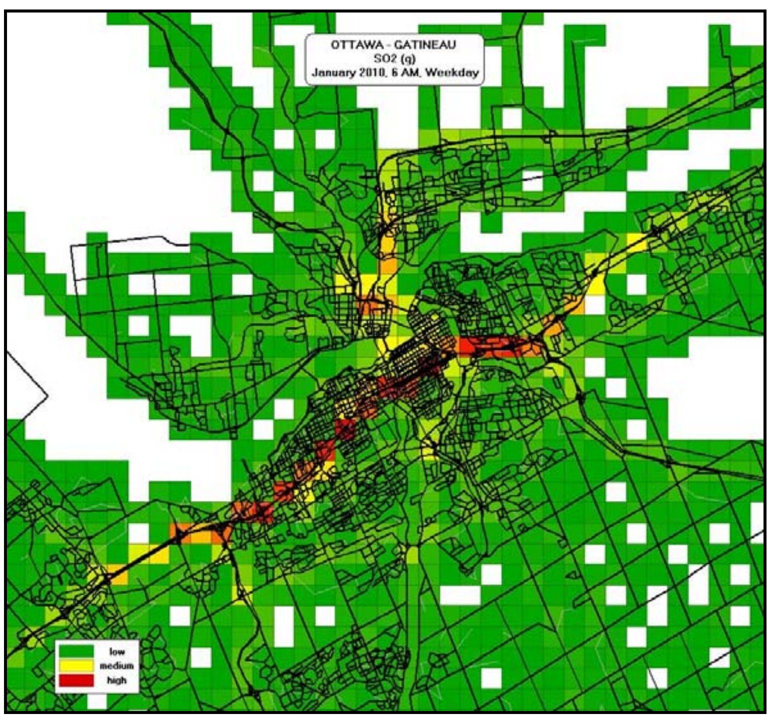

Figure 5.7 SO_2 Emissions

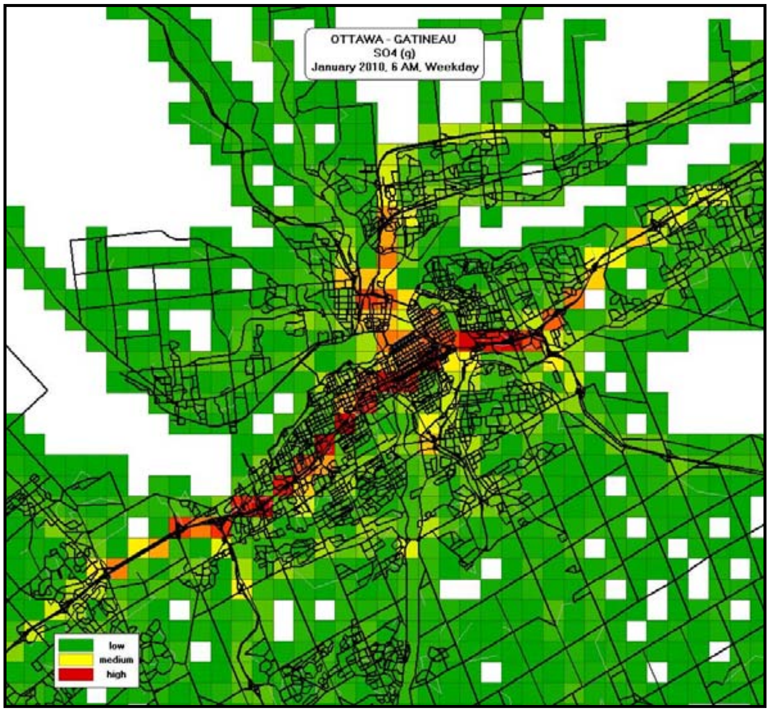

Figure 5.8 SO_4 Emissions

Figures 5.9 to 5.17 and 5.18 to 5.26 show the total of emissions on a typical winter weekday and on a typical summer weekday in 2010 respectively. Values taken by meteorological parameters are listed in table 5.1. Other parameters are GRID defaults.

Season	**Winter**	**Summer**
Month	January	July
Temp. Min.	-14.8	15.5
Temp. Max.	-6.1	26.4
Humidity	Relative by default	Relative by default
Barometric Pressure	29.62	29.53
Cloud Cover	64 %	56 %
Peak sun start	12:00	11:00
Peak sun end	13:00	14:00

Table 5.1 Meteorological Parameters for winter and summer 2010

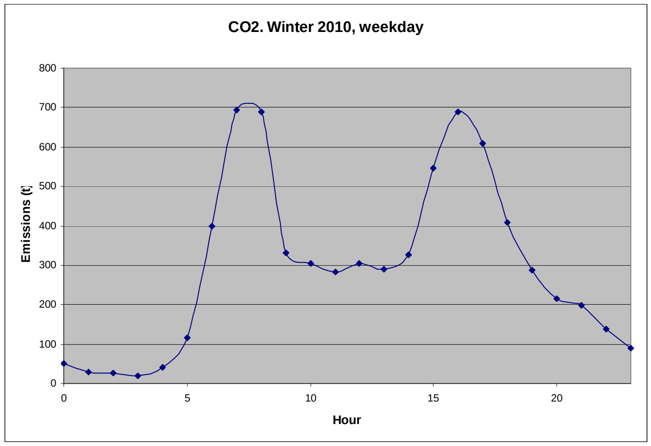

Figure 5.9 CO_2 Emissions. Winter 2010

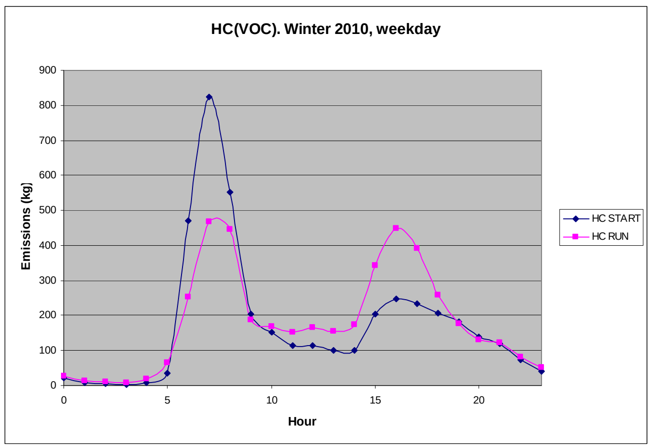

Figure 5.10 HC (VOC) Emissions. Winter 2010

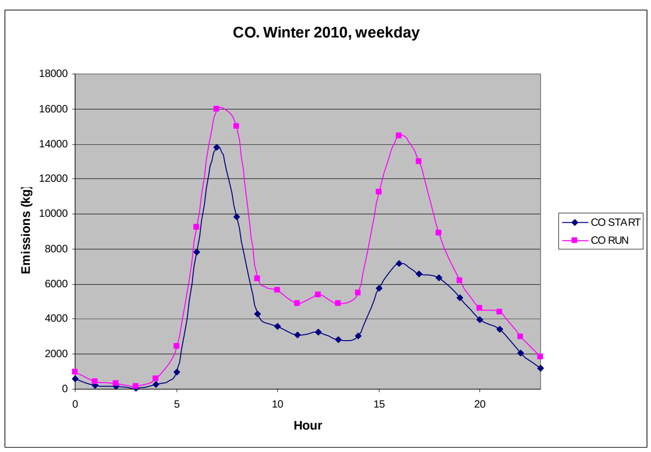

Figure 5.11 CO Emissions. Winter 2010

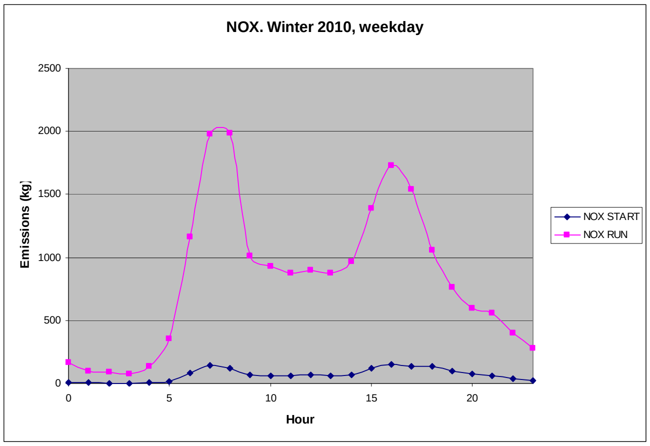

Figure 5.12 NO_X Emissions. Winter 2010

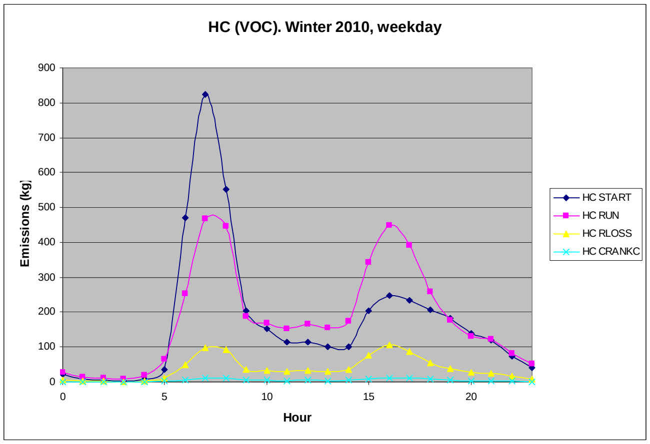

Figure 5.13 HC (VOC) Emissions. Winter 2010

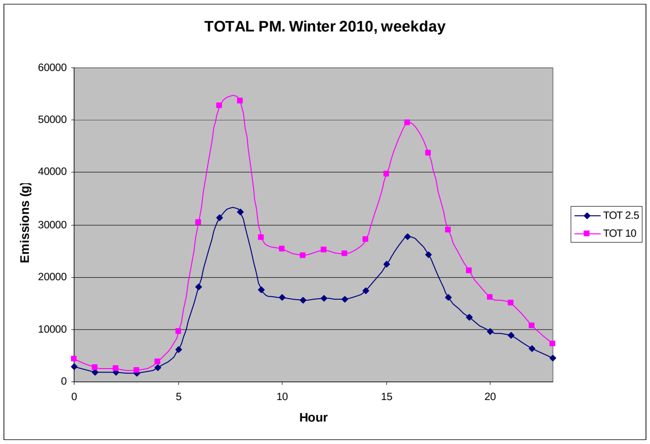

Figure 5.14 PM TOTAL Emissions. Winter 2010

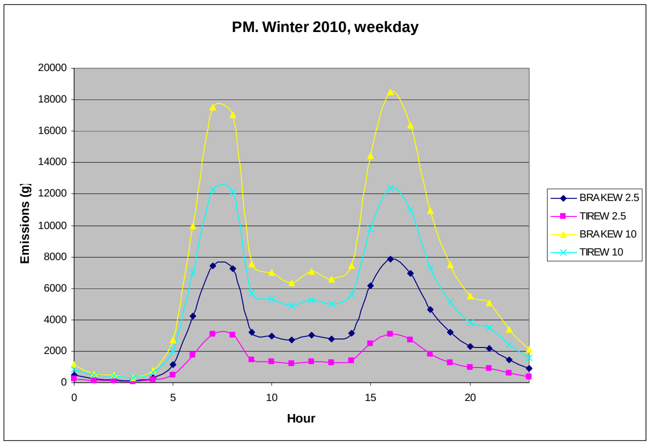

Figure 5.15 PM Brake and Tire Emissions. Winter 2010

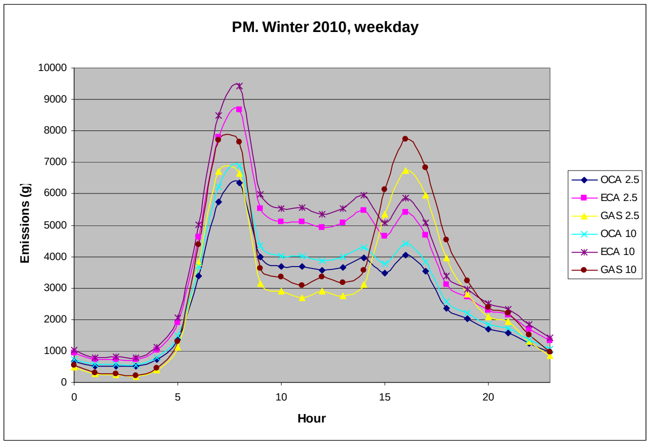

Figure 5.16 PM OCA, ECA and GAS Emissions. Winter 2010

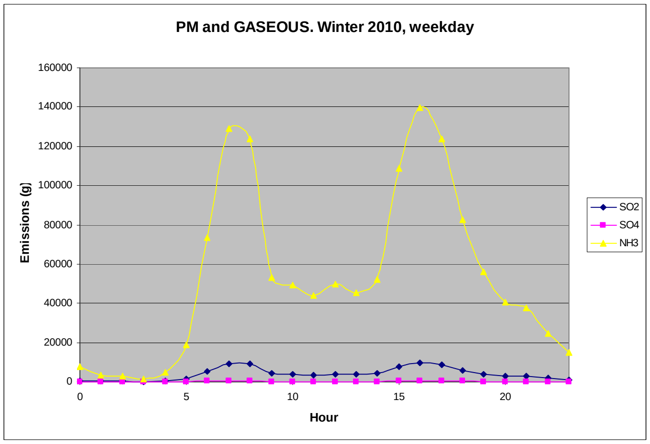

Figure 5.17 NH_3, SO_2 and SO_4 Emissions. Winter 2010

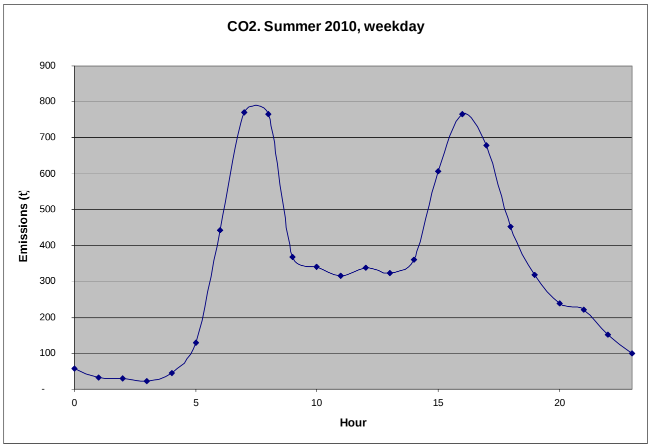

Figure 5.18 CO_2 Emissions. Summer 2010

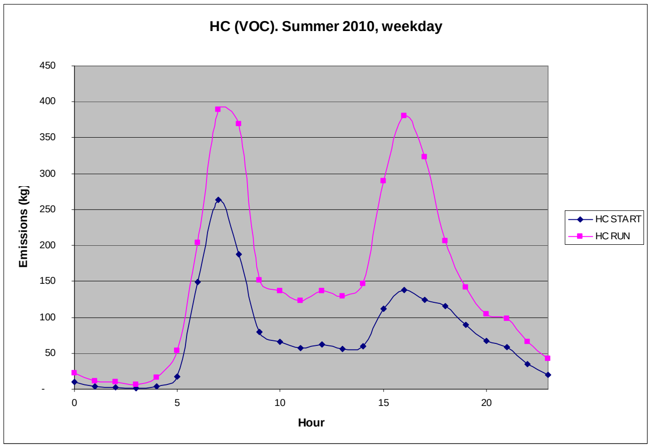

Figure 5.19 HC (VOC) Emissions. Summer 2010

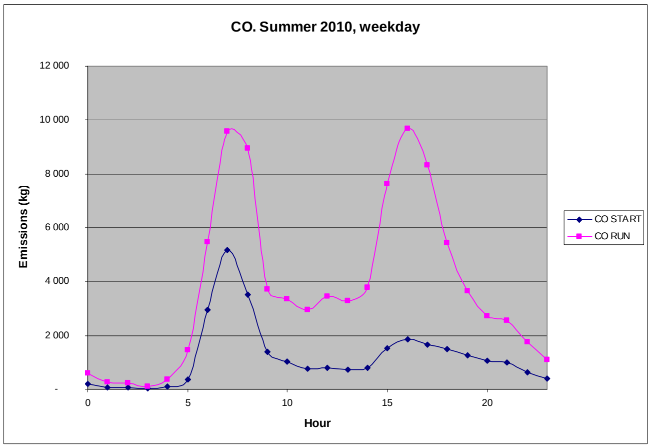

Figure 5.20 CO Emissions. Summer 2010

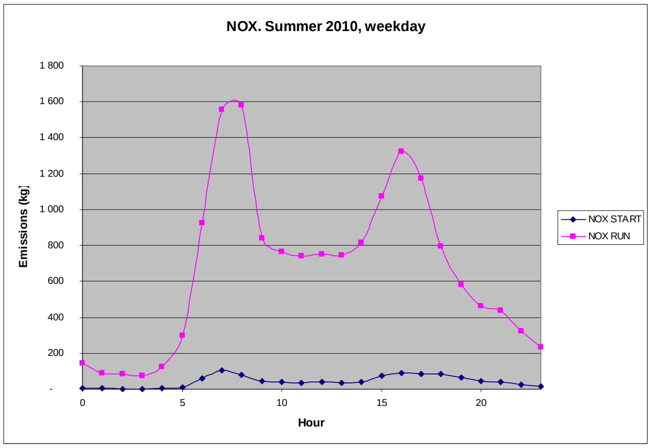

Figure 5.21 NO_X Emissions. Summer 2010

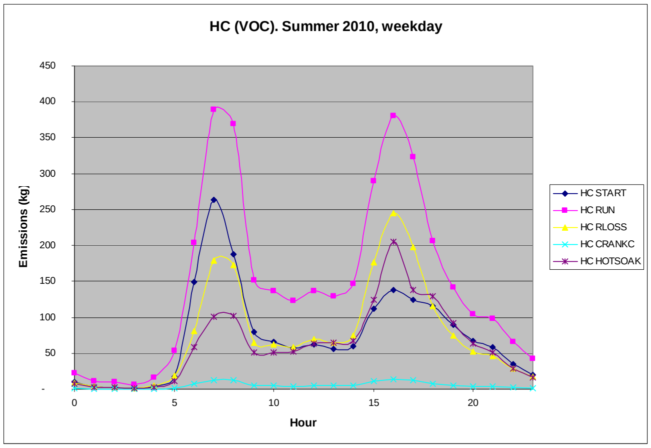

Figure 5.22 HC (VOC) Emissions. Summer 2010

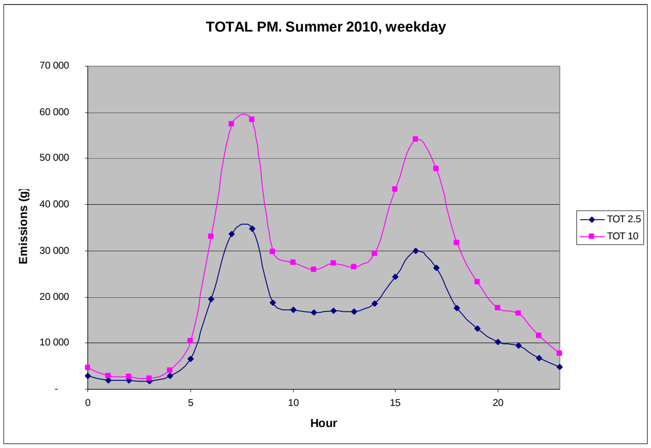

Figure 5.23 PM TOTAL Emissions. Summer 2010

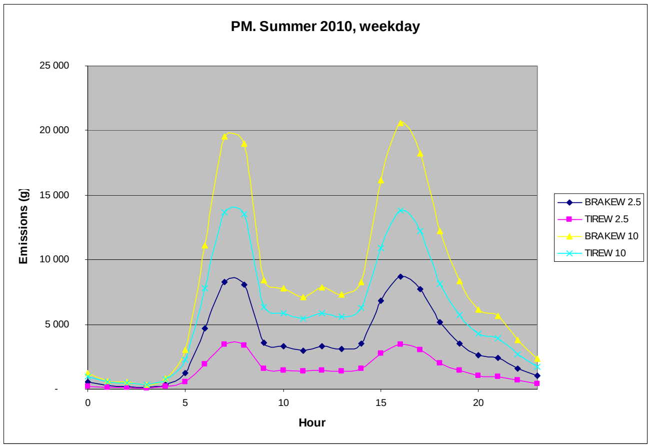

Figure 5.24 PM Brake and Tire Emissions. Summer 2010

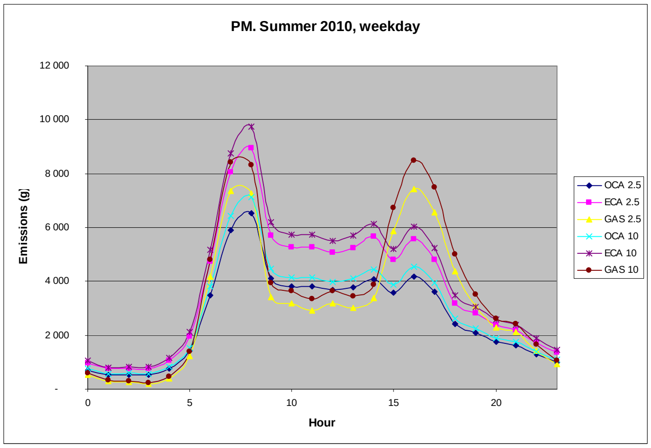

Figure 5.25 PM OCA, ECA and GAS Emissions. Summer 2010

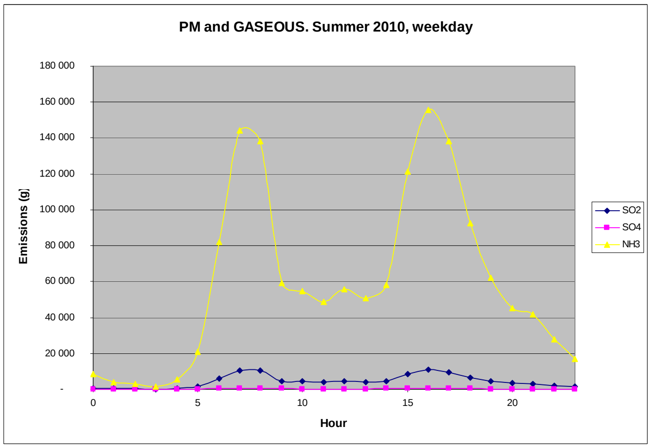

Figure 5.26 NH_3, SO_2, SO_4 Emissions. Summer 2010

Total emissions depend essentially on two values: emission rates (which vary according to weather conditions, fuel characteristics, etc.), and vehicle flows (which vary according to the hour, month and type of day). By keeping constant vehicle flows, the effect of the weather variable can be isolated. Likewise, by keeping weather variables constant, we can observe the effect of vehicle flows. Figures 5.27 to 5.32 and 5.33 to 5.38 respectively show variations arising from weather changes (by selecting January, April, and July) and keeping January flows, and variations of ±15% in vehicle flows using January weather conditions. This was calculated for a weekday in 2010. When two components are changed at the same time, total emissions throughout the day will depend on the interaction of the two parameter sets.

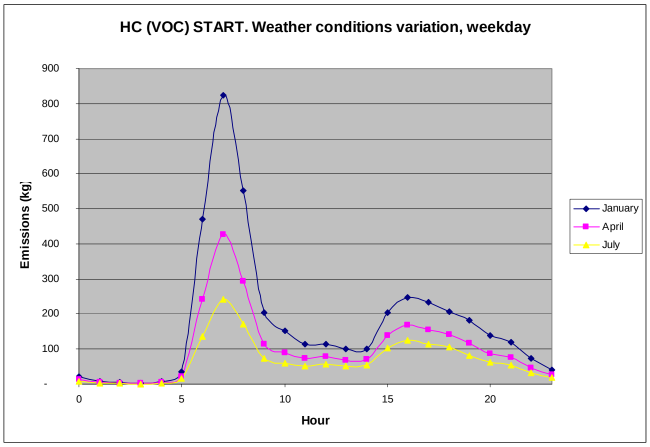

Figure 5.27 HC (VOC) Start Emissions. Variation According to External Conditions

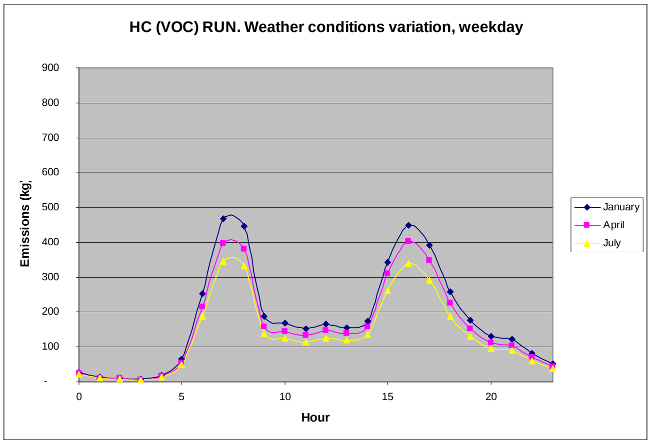

Figure 5.28 HC (VOC) Running Emissions. Variation According to External Conditions

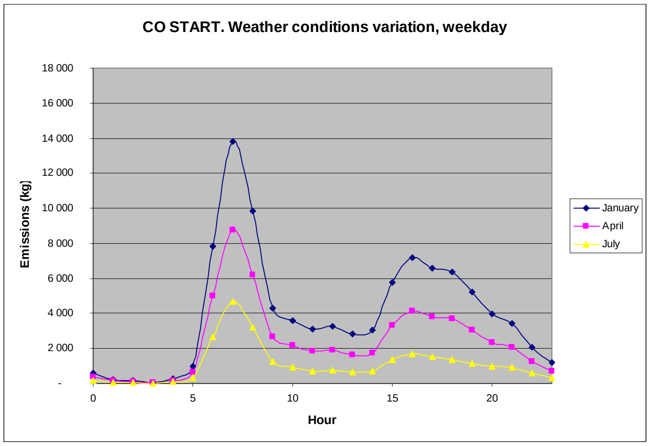

Figure 5.29 CO Start Emissions. Variation According to External Conditions

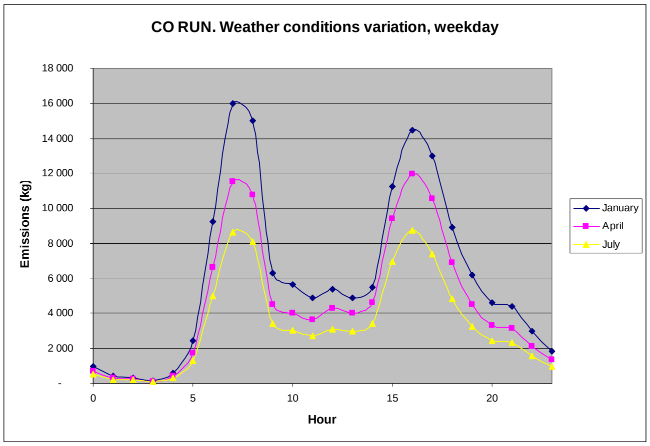

Figure 5.30 CO Running Emissions. Variation According to External Conditions

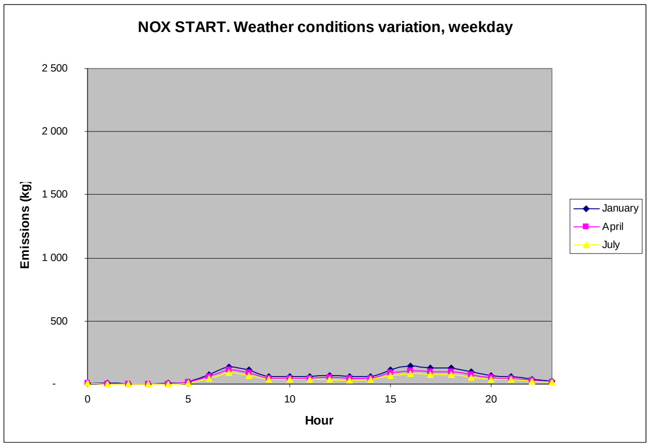

Figure 5.31 NO_X Start Emissions. Variation According to External Conditions

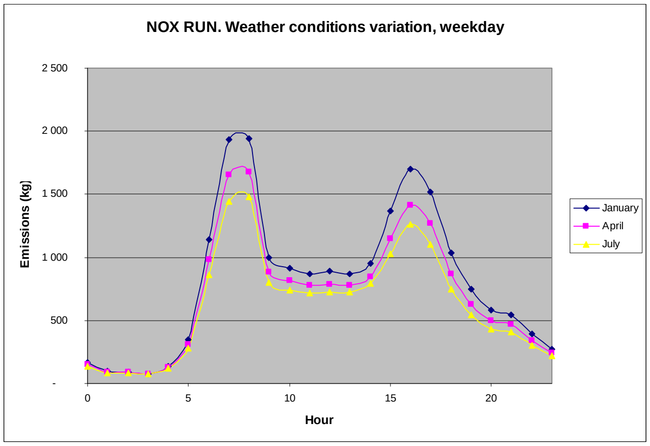

Figure 5.32 NO_X Running Emissions. Variation According to External Conditions

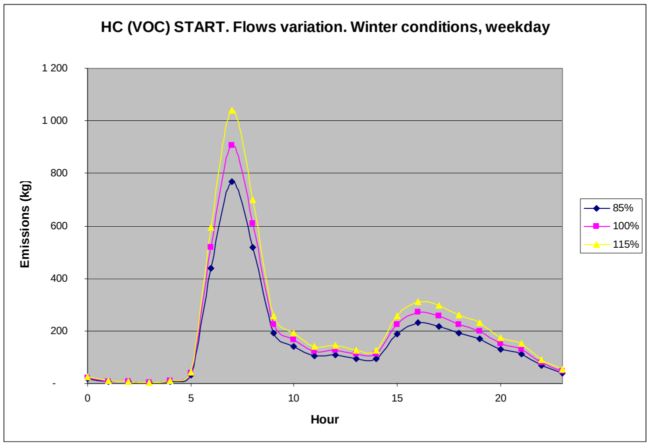

Figure 5.33 HC (VOC) Start Emissions. Variation Depending on Flows

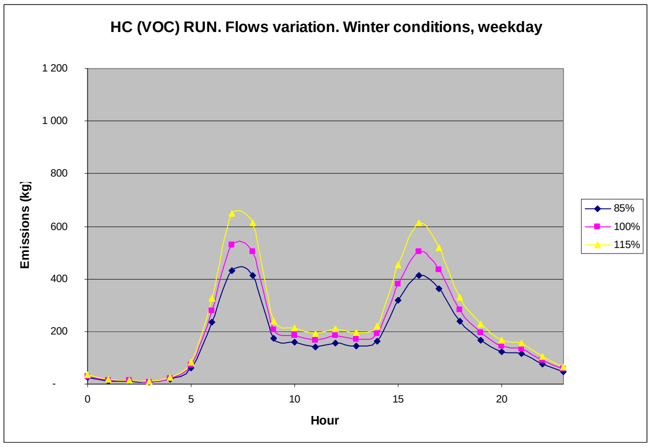

Figure 5.34 HC (VOC) Running Emissions. Variation Depending on Flows

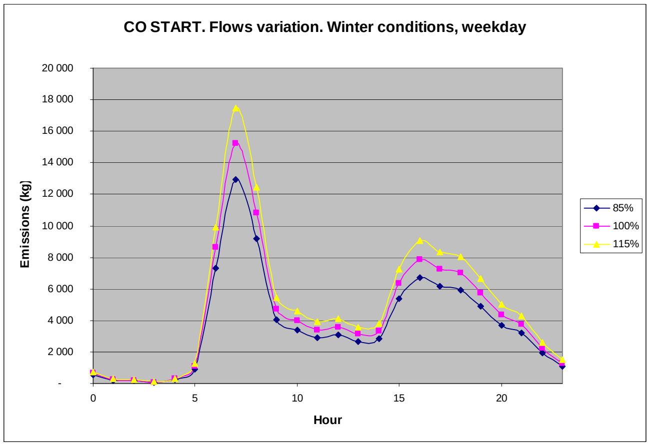

Figure 5.35 CO Start Emissions. Variation Depending on Flows

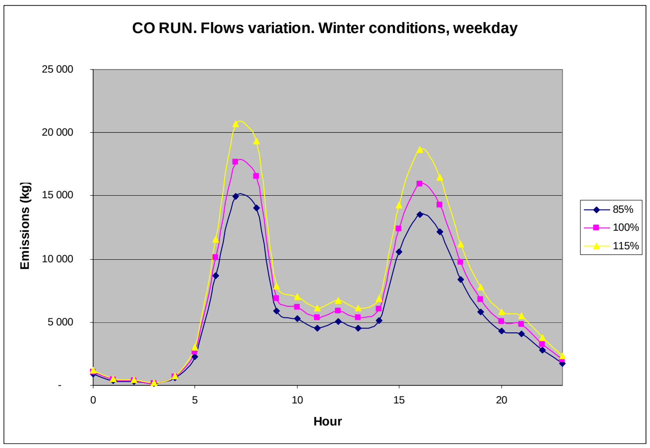

Figure 5.36 CO Running Emissions. Variation Depending on Flows

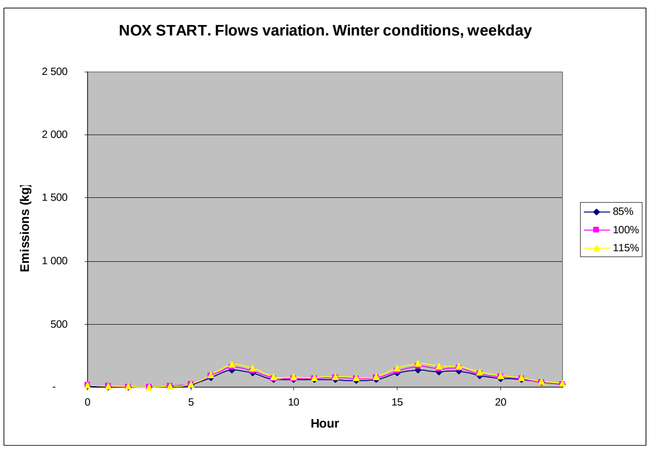

Figure 5.37 NO_X Start Emissions. Variation Depending on Flows

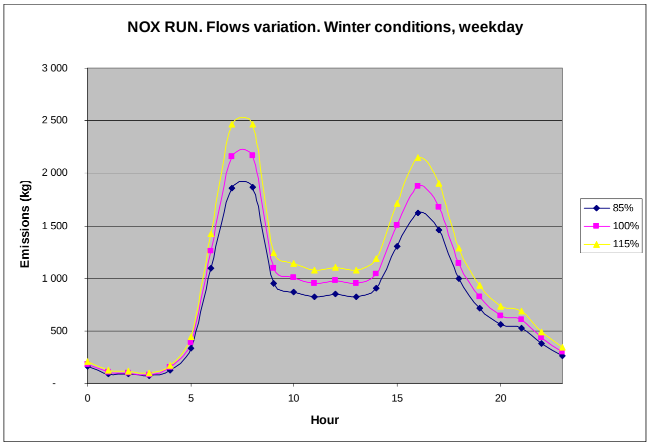

Figure 5.38 NO_X Running Emissions. Variation Depending on Flows

Figures 5.39 to 5.42; 5.44 to 5.45 and 5.47 to 5.49 show the variations of different emissions between years 2010 and 2030 on a summer weekday (with the parameters shown in table 5.1). Figures 5.43 and 5.46 show the variations in “CO Start” and “NO_X Start” (respectively) for the same years, on a summer weekday, at 7:00. It may be seen that CO Start incurs a large decrease between 2010 and 2015 whereas the decrease is less pronounced between 2020 and 2030. This entails higher “CO Start” emissions in 2030 relatively to 2020. In the case of “NO_X Start”, the decrease of emission rates is more uniform between 2010 and 2030, and this may be observed in the total emissions plot. Total emissions rates that change little depend mainly on flows.

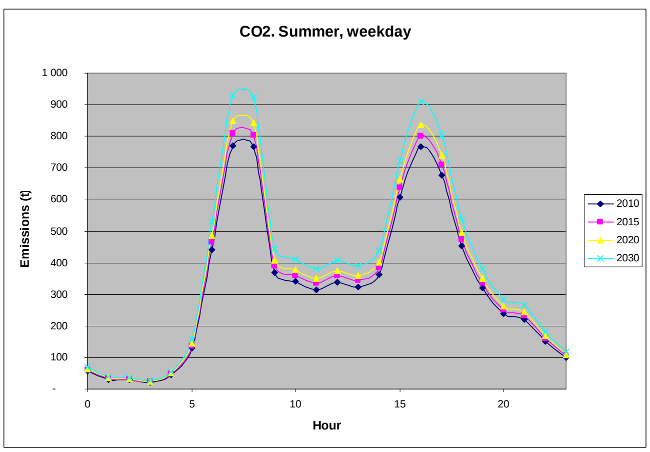

Figure 5.39 CO_2 Emissions. Summer 2010, 2015, 2020 and 2030

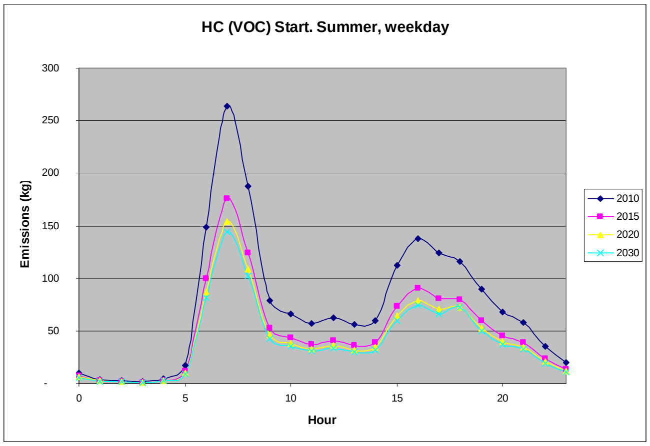

Figure 5.40 HC (VOC) Start Emissions. Summer 2010, 2015, 2020 and 2030

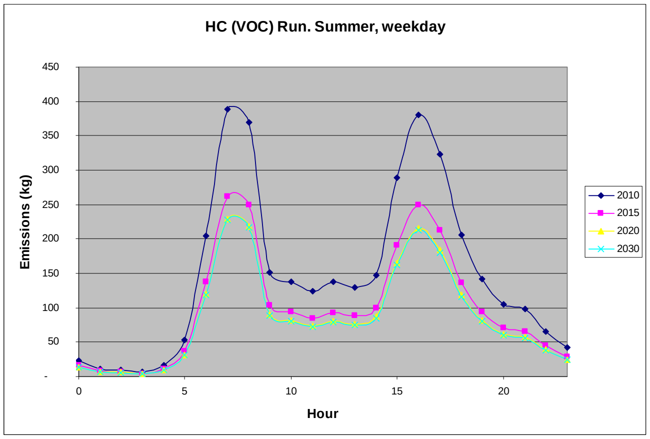

Figure 5.41 HC (VOC) Running Emissions. Summer 2010, 2015, 2020 and 2030

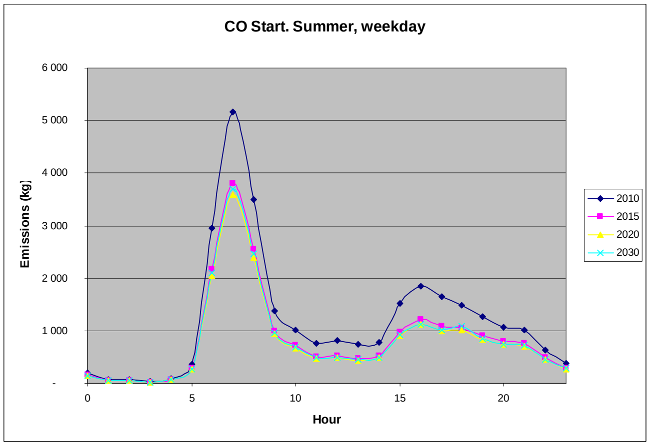

Figure 5.42 CO Start Emissions. Summer 2010, 2015, 2020 and 2030

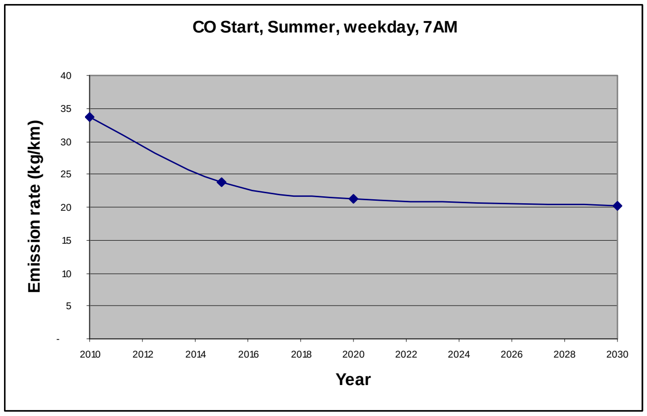

Figure 5.43 CO Start. Rates Variation. 7:00. Summer 2010, 2015, 2020 and 2030

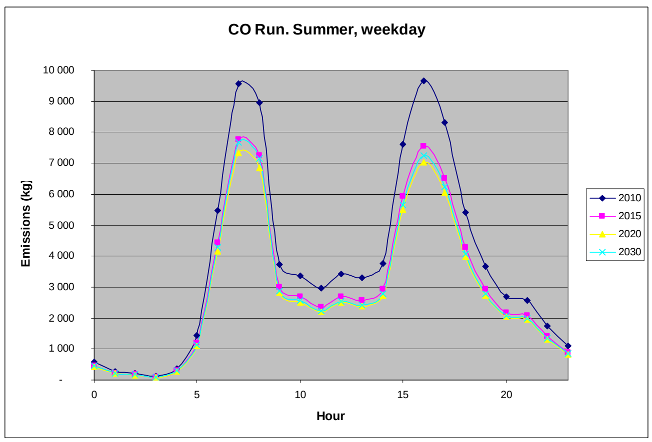

Figure 5.44 CO Running Emissions. Summer 2010, 2015, 2020 and 2030

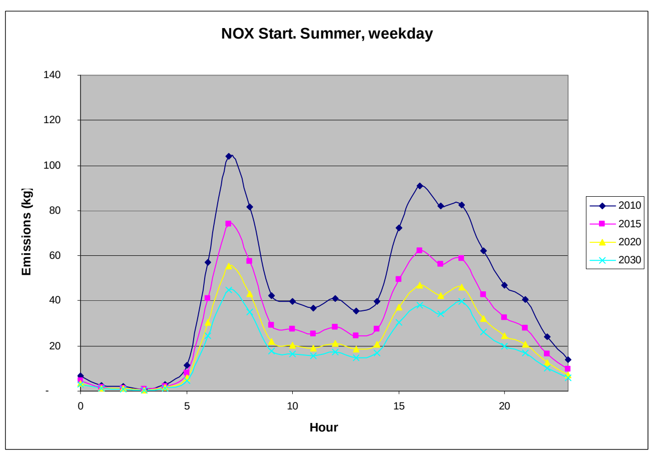

Figure 5.45 NO_X Start Emissions. Summer 2010, 2015, 2020 and 2030

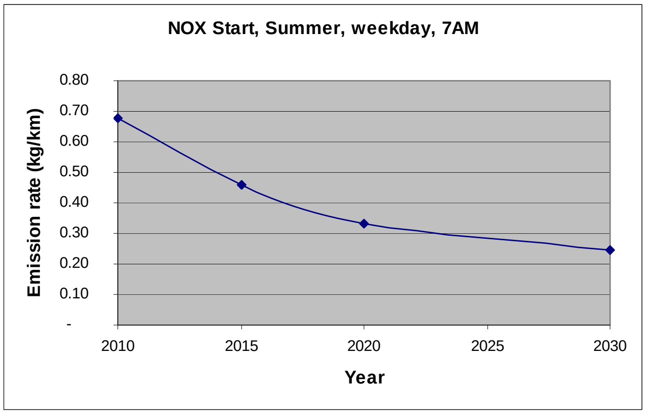

Figure 5.46 NO_X Start. Rates Variation. 7:00. Summer 2010, 2015, 2020 and 2030

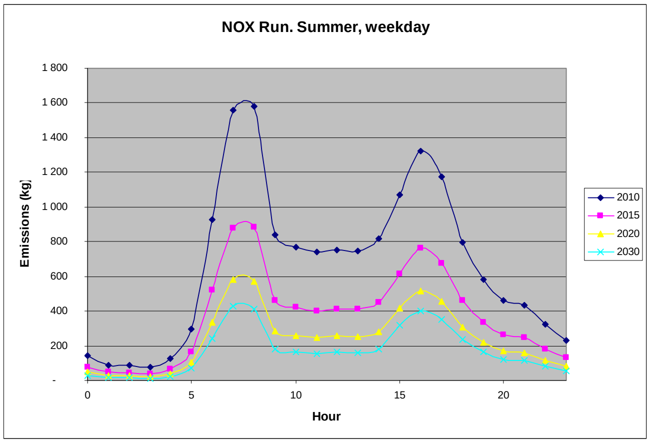

Figure 5.47 NO_X Running Emissions. Summer 2010, 2015, 2020 and 2030

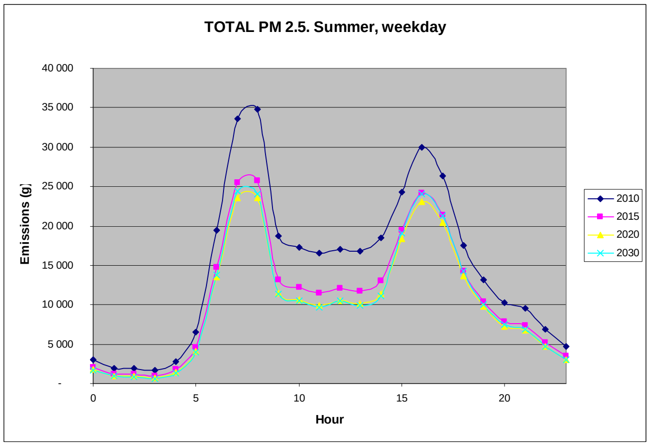

Figure 5.48 PM TOTAL 10 Emissions. Summer 2010, 2015, 2020 and 2030

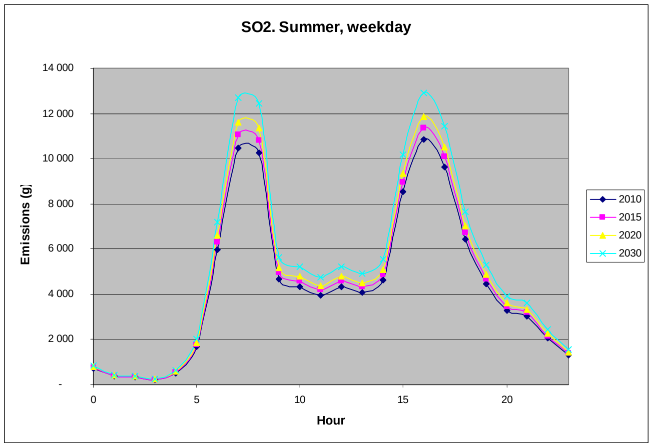

Figure 5.49 SO_2 Emissions. Summer 2010, 2015, 2020 and 2030

Figures 5.50 to 5.55 present variations of emissions according to the type of day (weekday, Saturday or Sunday) for a summer day in 2010. Weather parameters are those listed in 5.1; all others are default parameters. For the three vehicle types, flows are reduced on Saturdays and Sundays (see figure A.15), especially for commercial vehicles. Bus frequencies are also lower. During weekend days, no peak hour can be observed, but from the figures, one may observe that total weekend emissions follow the general weekday trend. This is due to the fact that weekend flows are estimated on the basis of weekday flows because information concerning weekend travel demand is lacking.

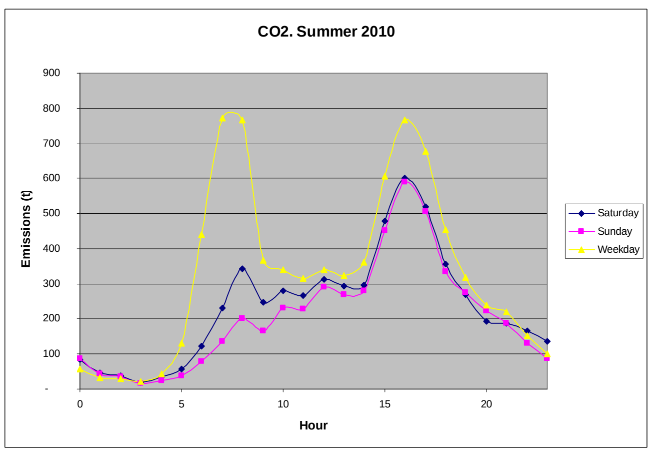

Figure 5.50 CO_2 Emissions. Summer 2010. Weekday, Saturday and Sunday

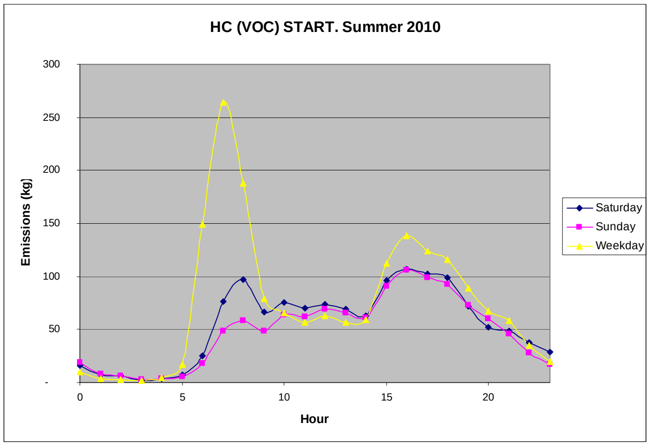

Figure 5.51 HC (VOC) Start Emissions. Summer 2010. Weekday, Saturday and Sunday

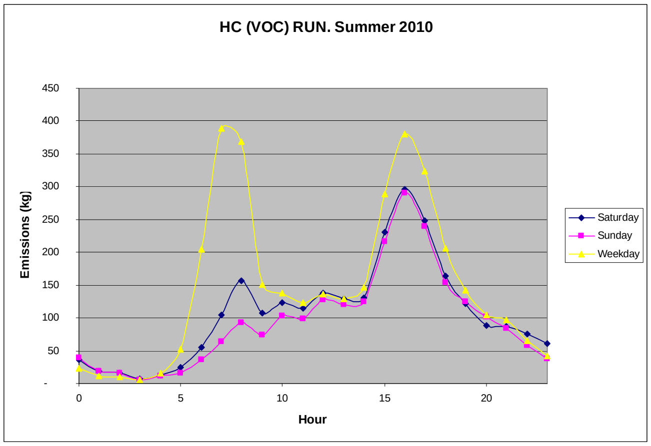

Figure 5.52 HC (VOC) Running Emissions. Summer 2010. Weekday, Saturday and Sunday

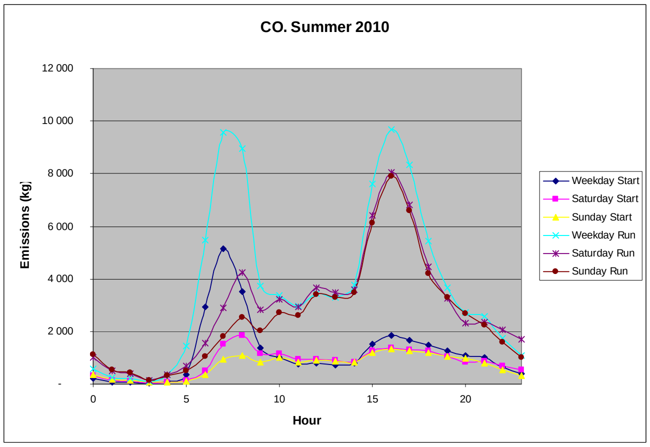

Figure 5.53 CO Emissions. Summer 2010. Weekday, Saturday and Sunday

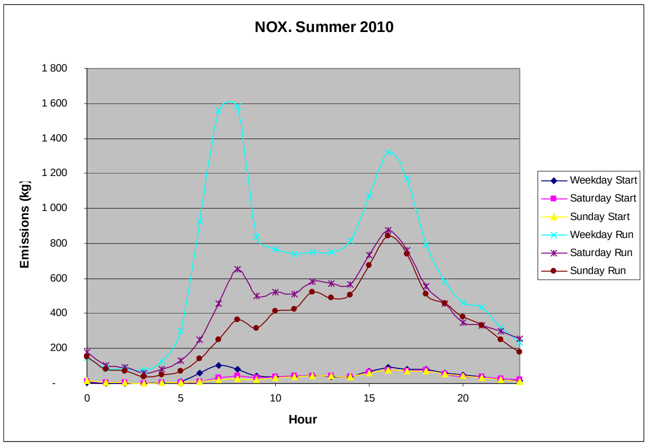

Figure 5.54 NO_X Emissions. Summer 2010. Weekday, Saturday and Sunday

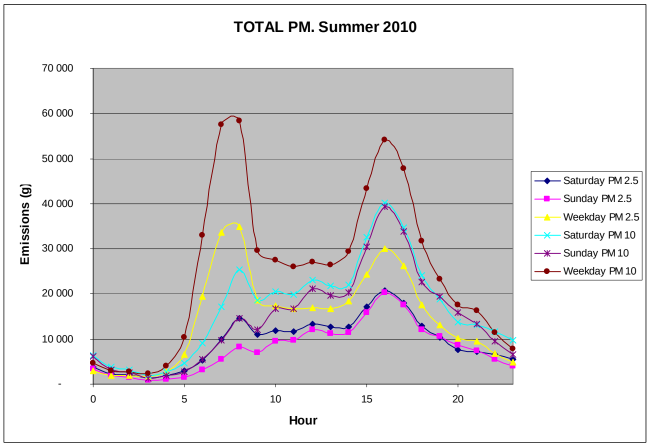

Figure 5.55 PM TOTAL Emissions. Summer 2010. Weekday, Saturday and Sunday

The last figures, 5.56 to 5.61, show the contribution of each fuel type, i.e. diesel and gasoline, to emissions.

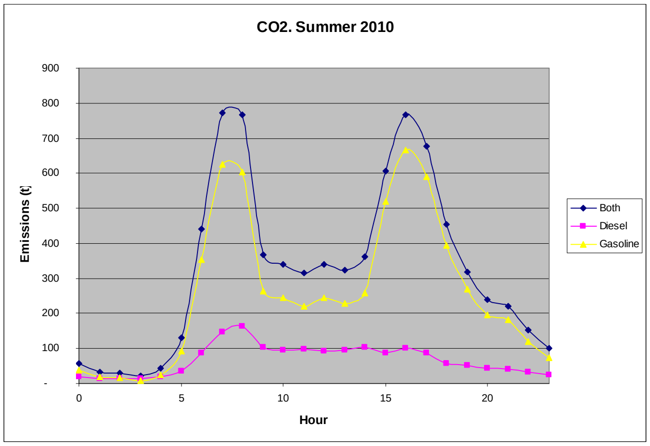

Figure 5.56 CO_2 Emissions. Summer 2010. Diesel, Gasoline, and Both

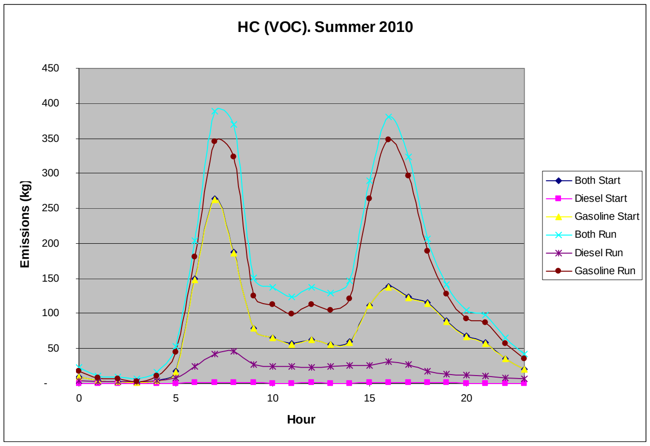

Figure 5.57 HC (VOC) Emissions. Summer 2010. Diesel, Gasoline, and Both

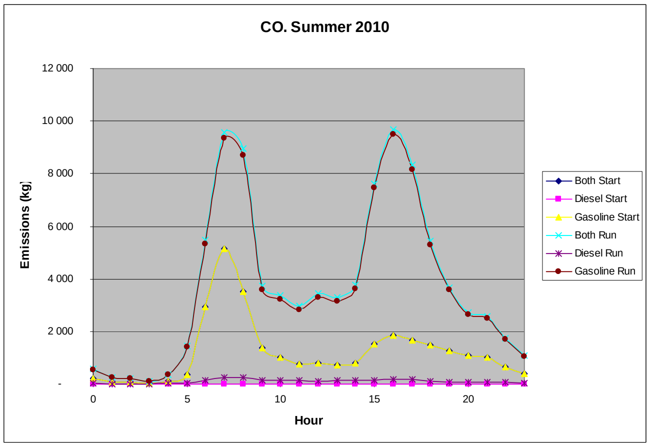

Figure 5.58 CO Emissions. Summer 2010. Diesel, Gasoline, and Both

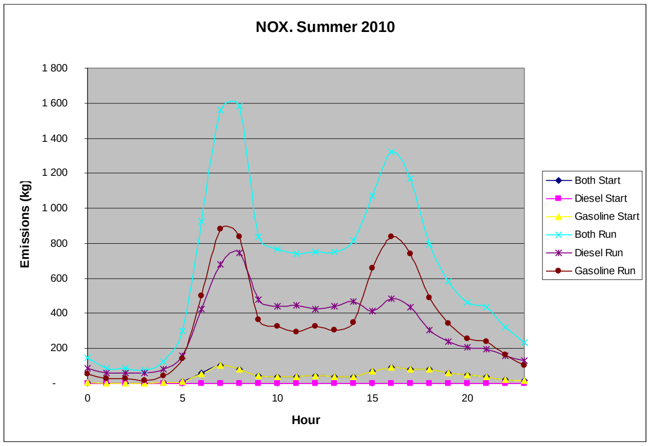

Figure 5.59 NO_X Emissions. Summer 2010. Diesel, Gasoline, and Both

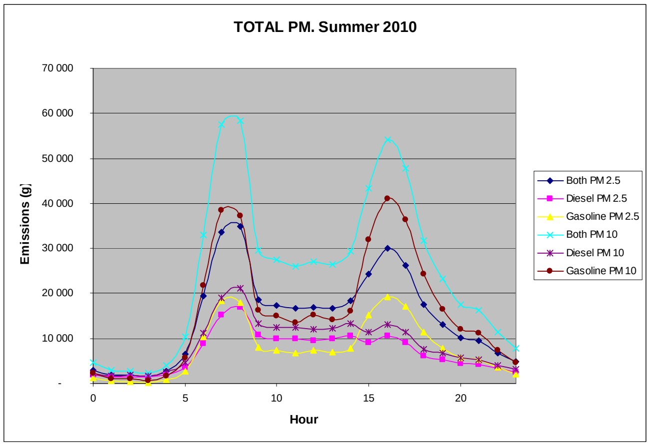

Figure 5.60 PM TOTAL Emissions. Summer 2010. Diesel, Gasoline, and Both

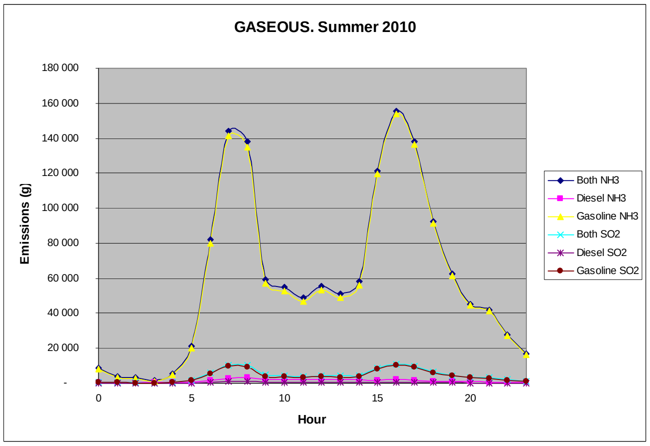

Figure 5.61 NH_3 and SO_2 Emissions. Summer 2010. Diesel, Gasoline, and Both

CONCLUSION

The goal of this project was to adapt the GRID model to the Ottawa-Gatineau region, and this was achieved successfully.

The adaptation of the user's interface did not pose any problem. A few programs have been modified and a few input parameters were set default values.

Data compilation for MOBILE6.2C input data did not involve any problem either. However, American default values are used in many places because corresponding data is not known for the Ottawa-Gatineau region.

There was a lack of information concerning travel demand for some evaluation periods, but this missing data were circumvented in the following ways:

- Car travel-demand for 2005 off peak hour periods was inferred from the origin-destination survey made in 2005. This demand has been extrapolated from 2006 to 2031 using projection factors.

- Commercial vehicles for AM and PM periods are factored to yield off peak hour flows. This was made for years 2005 to 2031. Factors used have been generated from traffic counts.

- Year 2009 transit schedules have been compiled for off peak hours on weekdays and for all weekend hours.

- Factors used for yearly flow variations were obtained from the AADT factor table.

- Factors used for weekly variations of traffic flows as well as inside the AM and PM periods were generated from traffic counts.

The development and the implementation of programs managing this large dataset was a success.

One hour[1] of real-time computation is required to evaluate an entire day's emissions.

The results obtained are very satisfactory.

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[1] On an Intel® Core™ 2 CPU, 2.13 GHz, 3.25 GB RAM.

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APPENDIX A. TRAFFIC DISTRIBUTION

The goal of the following analysis is to identify traffic patterns in order to allow GRID to compute pollutant emissions for the most of periods possible.

A.1 Vehicular Counts

The information presented below is grouped according our sources of information:

A.1.1 City of Ottawa

The City of Ottawa provided us with screen line road counts for Ottawa. Counts were taken on 161 stations, during the week, in the months of May and June 2005 and 2006. Figure A.1 shows the counts stations.

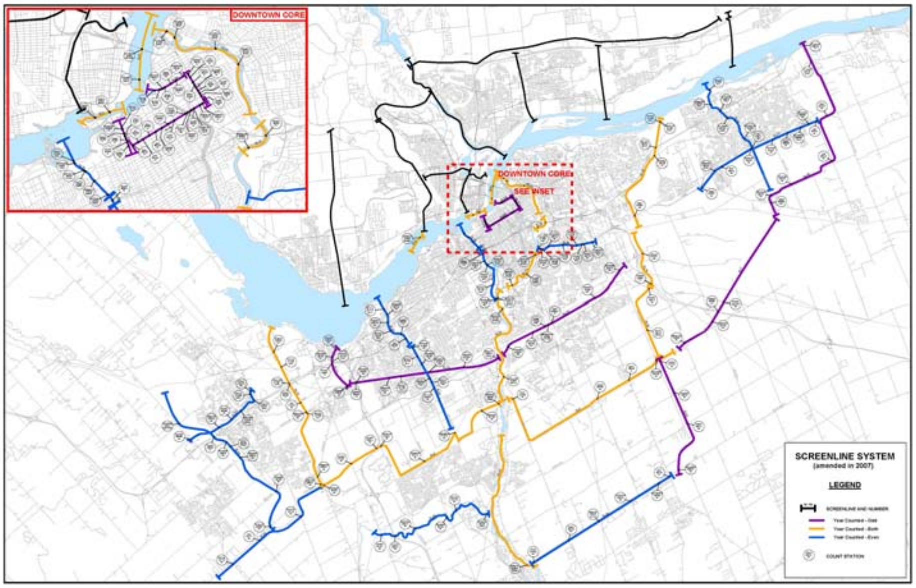

Figure A.1. "Screen Line" Counts

Counts are grouped by type of vehicles (passenger vehicle, taxi, light truck, heavy truck, bus, and bicycle). They go from 7:00 to 19:00 by intervals of 15 minutes. Figures A.2 and A.3 show distributions of traffic at one station.

The first issue with these counts is the time range. As may be seen from the graphics, the AM rush-hour is incomplete. In the TRANS model, the AM period goes from 6:30 until 9:00. Also, it should be noted that all these count stations are located in the region of Ottawa. These counts may however be used to identify hourly traffic distribution factors inside the PM peak hour by vehicle type.

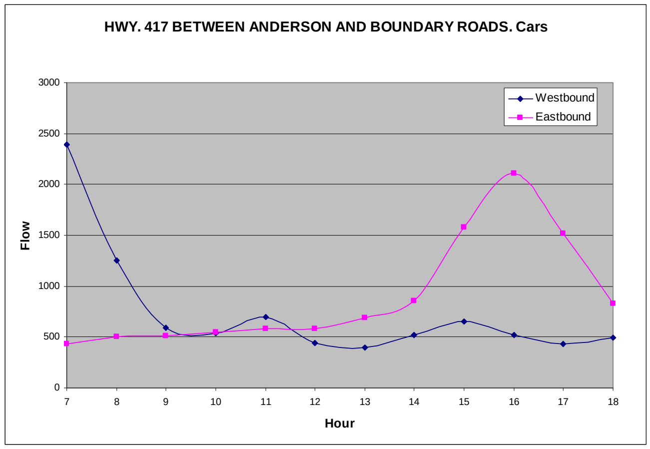

Figure A.2. Hourly Flow Distribution – Cars

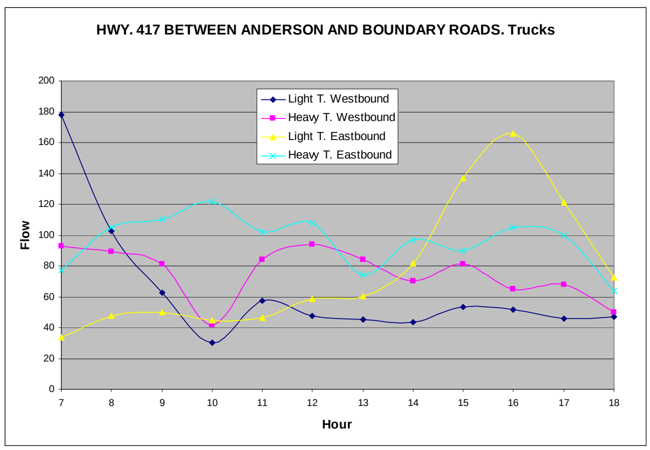

Figure A.3. Hourly Flow Distribution – Trucks

The distribution of traffic in the 7:00 to 17:00 period is shown in figures A.4 and A.5 for cars and trucks respectively.

Figure A.6 shows the hourly fractions obtained from these counts for cars and trucks in the PM peak hour. These fractions may help distribute the flows-by-period obtained from the TRANS model within hourly flows required for pollution estimation.

A comparison is made with the fractions calculated in the Montreal project. Figure A.7 compares the fractions for the two cities. In the case of Montreal, the truck fraction corresponds to heavy trucks. These Montreal fractions were gathered from counts taken over all months throughout 2000 and 2003.

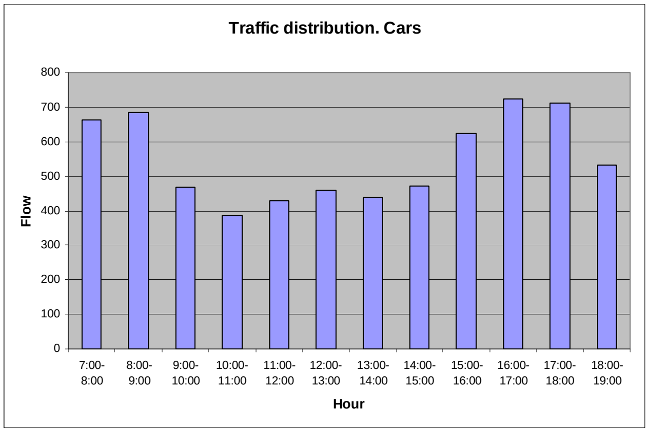

Figure A.4. Flow Distribution – 12 Hour – Cars

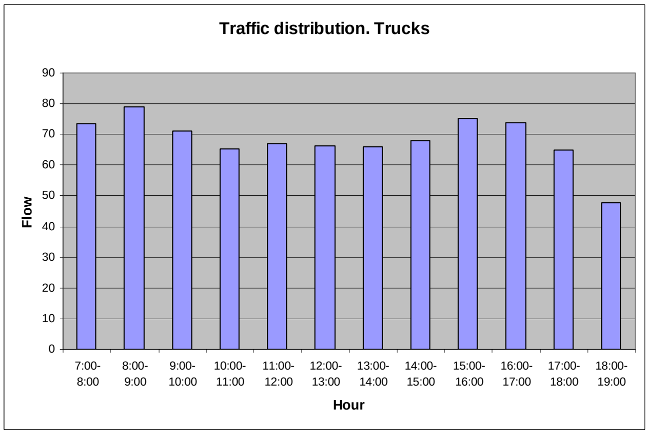

Figure A.5. Flow Distribution – 12 Hour – Trucks

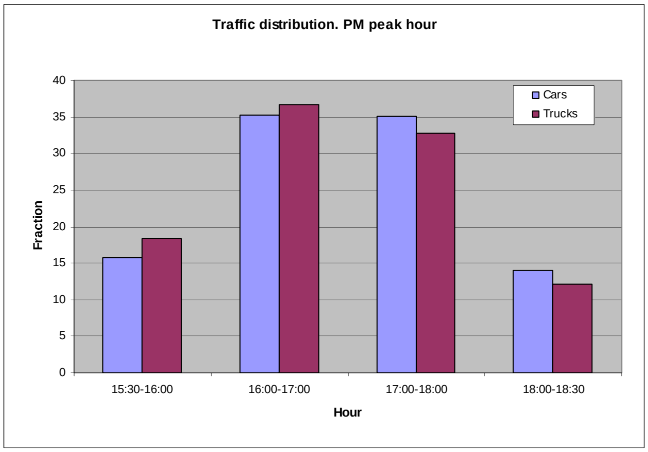

Figure A.6. PM Traffic Distribution – Cars and Trucks

The City of Ottawa also made available an AADT (Annual Average Daily Traffic) factors table. This table was generated during the '80 from counts taken over 20 intersections. See Table A.1. From this table we can identify weekly and yearly traffic patterns. It should be noted however that these counts are not disaggregated by vehicle classes. Figures A.8 and A.9 show the distributions. According to the AADT factors, monthly variations are not significant but the difference between a weekday and a weekend day is.

The weekly distribution in Ottawa differs slightly from its Montreal counterpart whereas for car (which comprise the body of vehicles on the road), these differences are less visible.

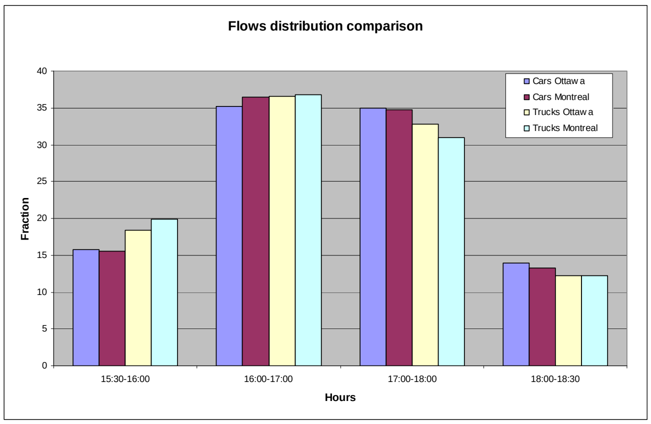

Figure A.7. Comparison of Ottawa - Montreal Fractions

	Monday	Tuesday	Wednesday	Thursday	Friday	Weekday	Saturday	Sunday
January	1.1	1.1	1.0	1.0	1.0	1.04	1.20	1.50
February	1.0	1.0	1.0	0.9	0.9	0.96	1.10	1.40
March	1.0	1.0	1.0	1.0	0.9	0.98	1.10	1.40
April	1.0	0.9	0.9	0.9	0.9	0.92	1.00	1.30
May	1.0	0.9	0.9	0.9	0.8	0.90	1.00	1.30
June	0.9	0.9	0.9	0.9	0.8	0.88	1.10	1.30
July	1.0	0.9	0.9	0.9	0.9	0.92	1.10	1.40
August	1.0	0.9	0.9	0.9	0.9	0.92	1.10	1.40
September	1.0	1.0	1.0	1.0	0.9	0.98	1.20	1.40
October	1.1	0.9	0.9	0.9	0.9	0.94	1.10	1.40
November	1.0	1.0	0.9	0.9	0.9	0.94	1.10	1.50
December	1.0	1.3	1.0	1.0	0.9	1.04	1.10	1.60

Table A.1. Ottawa AADT Factors

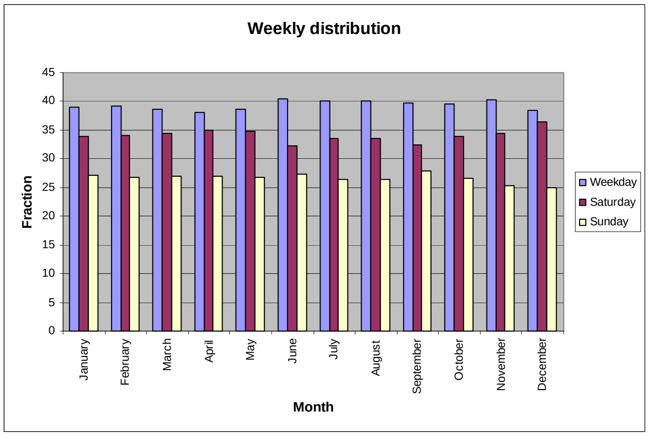

Figure A.8. Weekly Distribution of Vehicle Flows

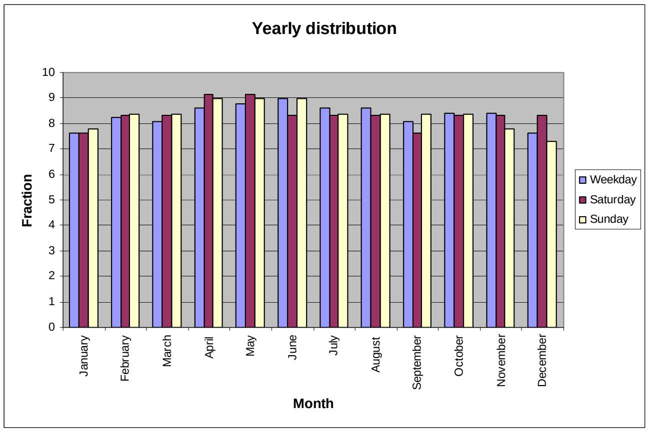

Figure A.9. Yearly Distribution of Vehicle Flows

A.1.2 Ministry of Transportation of Ontario

The Ministry of Transportation of Ontario (MTO) has provided us with a set of counts made at eight points on highways 416 and 417 in Ottawa. The counts were taken in 2006 in March, July, September and October. They are grouped according to the length of vehicles: 6.1 m, 12.8 m, and longer than 12.8 m. These are hourly counts taken over 3 week days (7 cases) or over 7 consecutive days (8 remaining cases). The counts stations are indicated in figure A.10.

The hourly traffic distribution obtained from the counts is presented graphically in figure A.11 and A.12. We have considered as cars all 6.1 m vehicles and as trucks all the rest. A slight peak at noon may be made out, as is the case in data from Ottawa (see figure A.4). Aside from this, distributions from Ottawa and Montreal are quite similar.

Figure A.10. Count Stations on Highways 416 and 417

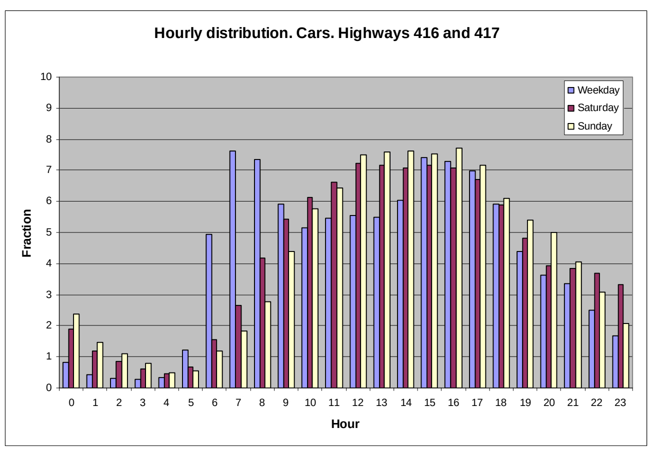

Figure A.11. Hourly Distribution – Cars

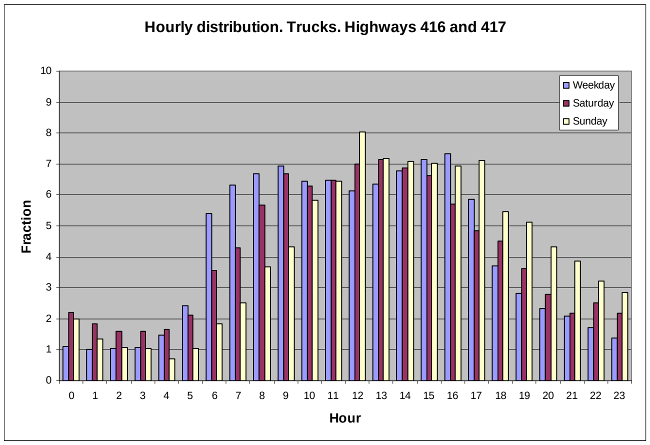

Figure A.12. Hourly Distribution – Trucks

Figures A.13 and A.14 show the distribution of flows within the AM and PM peak hours. In the case of the PM, data obtained from the City of Ottawa complement the highway counts.

As a last graph obtained with these counts, figure A.15 shows the weekly distribution of traffic. Fractions obtained from the Montreal project are included.

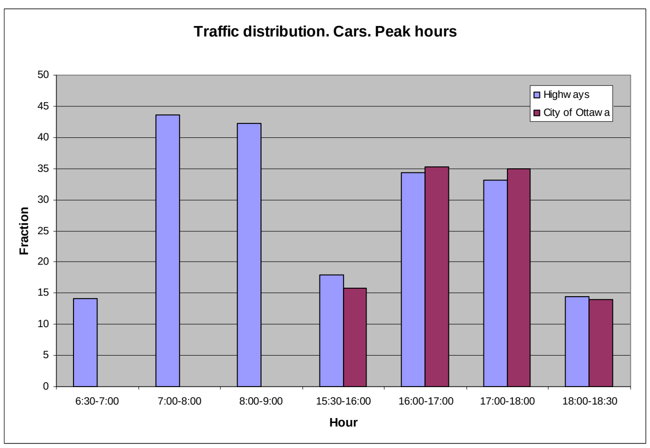

Figure A.13. Peak hour Distribution - Cars

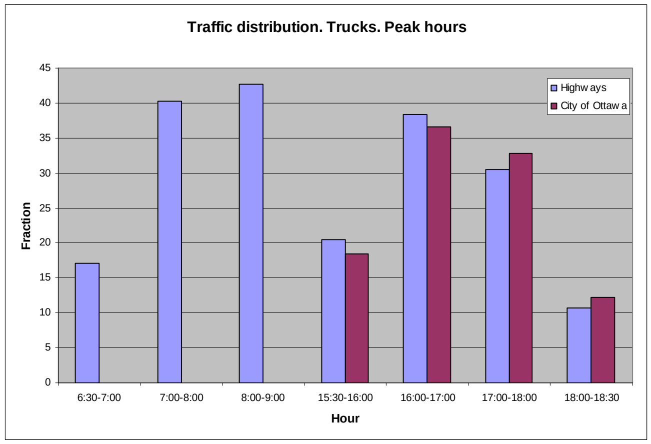

Figure A.14. Peak hour Distribution - Trucks

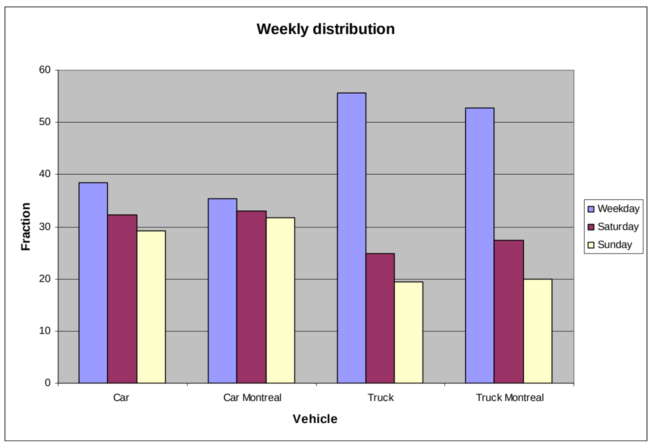

Figure A.15. Weekly Flow Distribution

A.1.3 Ministry of Transportation of Quebec

The Ministry of Transportation of Quebec (MTQ) has supplied us with four sets of counts. We review here only the two most interesting.

The first set consists of 15-minute interval counts for two periods of the day: 6:00 to 10:00 and 15:00 to 19:00. These counts are classified by vehicle types and have been taken in weekdays of October and November 2005. They have been sampled over 27 counts stations located on the Gatineau region, on five of the screen lines illustrated in figure A.16.

We have isolated the AM and PM hourly distributions from these counts. They are represented in figures A.17 and A.18 along with previously shown distributions.

The second set is made of unclassified hourly counts (in 15 min. intervals) for periods of 24 consecutive hours. The total daily count of cars, light trucks and heavy trucks / buses is supplied. However, these numbers do not allow us to split counts by vehicle types. The counts were taken on 78 points in the region of Aylmer, Gatineau, Hull, and Buckingham, on weekdays between April and August 2005. Figure A.19 shows the location of these count points. Figure A.20 illustrates the distribution of hourly traffic issued from these data. This distribution also includes values obtained from Ottawa highways in figure A.21.

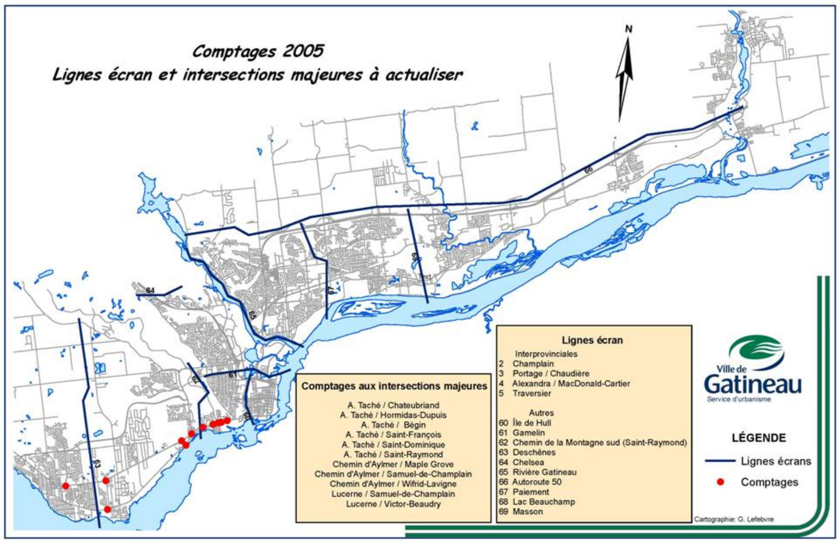

Figure A.16. Gatineau Screen Lines

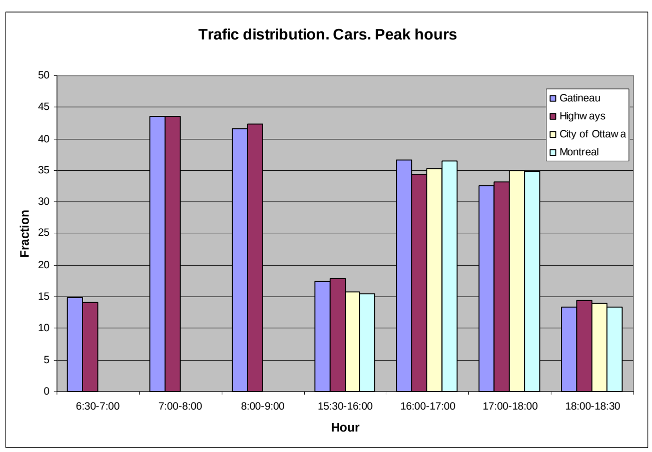

Figure A.17. Peak Hour Distribution – Cars

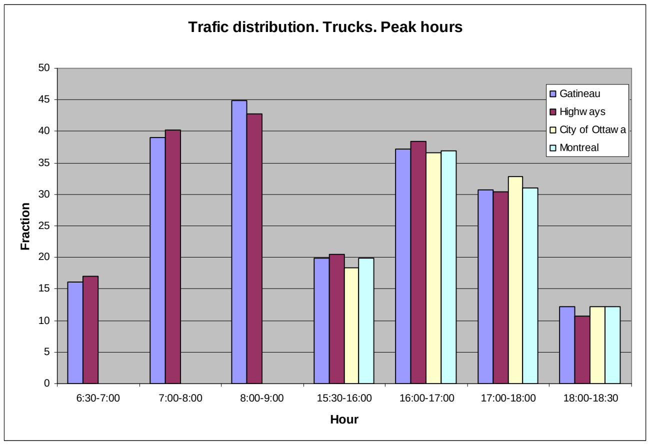

Figure A.18. Peak Hour Distribution – Trucks

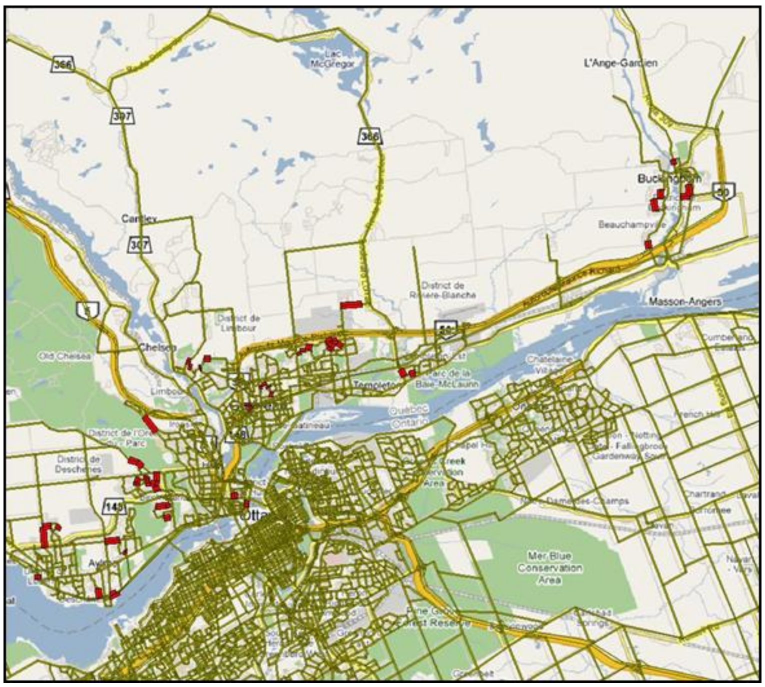

Figure A.19. Gatineau Count Stations

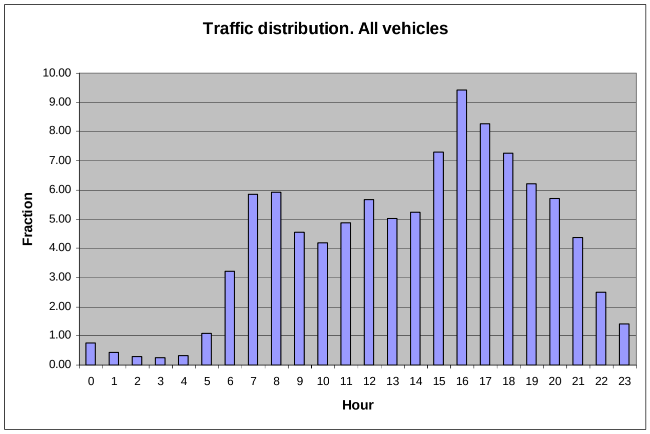

Figure A.20. Vehicle Distribution – Gatineau – Weekday

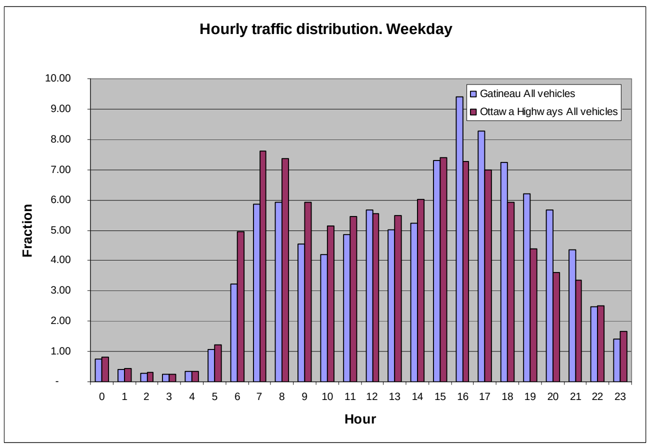

Figure A.21. Vehicle Distribution – Gatineau and Ottawa

Table A.2 provides a summary of the counts that have been supplied by the three sources (Ottawa, MTO, MTQ).

Supplier	Ottawa	MTO	MTQ	MTQ
Region	Screen lines Ottawa	Highways 416 and 417 in Ottawa	Screen lines Gatineau	Gatineau
Count points	161	8	27	78
Hours	7:00 to 19:00	24 hours	6:00 to 10:00 and 15:00 to 19:00	24 hours
Days	Weekdays	All	Weekdays	Weekdays
Months	May, June	March, July, September, October, November	October, November	April, May, June, July, August
Years	2005 2006	2006	2005	2005
Vehicle Types	Car, Light truck, Heavy truck, Bus	6.1m, 12.8m, >12.8m	Car, Light truck, Heavy truck, Bus	Aggregated

Table A.2. Counts Summary

A.2 Calculation of Distribution Factors

- **Annual Distribution**

The AADT table provided by the City of Ottawa is the only source of information concerning annual traffic distributions. In this table, there is no vehicular classification, so the same factor will be applied to all vehicles. Since this table dates back to the ’80 and it makes no difference among vehicle classes, it should be replaced with more recent data as soon as they become available.

Figure A.9 show the distribution of traffic. It may be observed that weekdays, Saturdays, and Sundays do not differ significantly. The average variation ratio between days is 3%, and the maximum, 7%, is measured in December. This suggests that a single day-independent distribution may be used. It is calculated as a weighted average over 5 weekdays, one Saturday, and one Sunday.

Table A.3 lists the distribution factors. Since the demand stands for travels made on September, October and November, we chose October as a reference month (100%).

	Distribution	Factor
January	7.63	90.99
February	8.27	98.51
March	8.15	97.08
April	8.73	104.07
May	8.87	105.69
June	8.89	105.98
July	8.52	101.56
August	8.52	101.56
September	8.05	95.90
October	8.39	100.00
November	8.31	99.05
December	7.66	91.33

Table A.3. Traffic Distribution -Annual

- ## Hourly Distribution

The travel demand we have is divided in peak hour and off peak hour periods. In the off peak hour periods, we have hourly matrices but for peak hours, matrices apply for the entire time range, i.e. 6:30 to 9:00 and 15:30 to 18:30. In view of generating hourly estimations, traffic must be distributed over hour separations within these periods. Also, figures A.8 to A.14, A.17 and A.18 indicate that hourly distributions for cars and trucks are different.

According to the count review presented previously, data from MTO or MTQ screen-line counts around Gatineau could be used to find the distribution inside peak hour periods. These two data sets cover both peak periods entirely.

From figure A.17 and A.18, it may be observed that fractions coming from the two sets are similar. It seems however that fractions obtained from MTO data are less precise since hourly volumes for the 6:00-6:30, 15:00-15:30 and 18:00-18:30 half hours are inferred by splitting the hour count in two. In the other set, volumes counts are grouped in 15 minute batches, and incur no precision loss. Also, these counts have been sampled during weekdays during the same months as the origin-destination survey (October and November 2005). This is why we have chosen this later data set to determine the hourly distribution of vehicle flows. Table A.4 lists hourly fractions according to vehicle types.

	Hour	Car	Truck
AM	**6:30-7:00**	14.91	16.16
	7:00-8:00	43.55	38.93
	8:00-9:00	41.54	44.91
PM	**15:30-16:00**	17.46	19.85
	16:00-17:00	36.58	37.27
	17:00-18:00	32.53	30.69
	18:00-18:30	13.42	12.19

Table A.4. Traffic Distribution – Hourly inside Peak Periods

- **Weekly Distribution**

We have two sources of information concerning weekly traffic distributions: AADT factors and counts supplied by MTO.

In the case of AADT factors, traffic distributions vary only slightly during the month. Variation coefficients associated are 5.2%, 5.5% and 6.2% for weekdays, Saturdays, and Sundays respectively. Then, it is possible to use a single value for each day type. However, fractions from these counts are less interesting because counts are not specific to vehicle types. Table A.5 shows these factors as well as factors obtained from MTO data, which are vehicle-type specific.

		Weekday	Saturday	Sunday
MTO	Car	0.39	0.33	0.29
	Truck	0.55	0.25	0.20
AADT	All	0.39	0.34	0.27

Table A.5. Traffic Distribution – Weekly

It may be seen that differences between vehicle types are significant. Type of vehicle specific figures can then be used. It should also be mentioned that fractions obtained from MTO are very close to those used in the Montreal model. Also, since MTO counts are hour based, we are able to obtain fractions for each hour of the day. This is useful because in off peak periods, we have an hourly travel demand.

Table A.6 lists the weekly – hourly fractions by vehicle of type. Although the values seem valid, it must not be forgotten that they are derived from a very little sample. Indeed, variation coefficients of these fractions range from 9% in case of cars on a Saturday up to 27% for trucks on Sundays. It would then be desirable to update them as soon as more precise data becomes available.

Hour	Car			Truck		
	Weekday	Saturday	Sunday	Weekday	Saturday	Sunday
0	0.20	0.37	0.42	0.39	0.36	0.24
1	0.18	0.39	0.43	0.42	0.36	0.22
2	0.18	0.38	0.44	0.45	0.37	0.18
3	0.20	0.38	0.42	0.49	0.33	0.18
4	0.32	0.34	0.34	0.58	0.31	0.11
5	0.55	0.26	0.20	0.63	0.27	0.10
6	0.68	0.19	0.13	0.71	0.20	0.08
7	0.67	0.20	0.13	0.70	0.21	0.09
8	0.57	0.27	0.16	0.64	0.24	0.12
9	0.43	0.33	0.24	0.59	0.27	0.13
10	0.35	0.35	0.30	0.57	0.25	0.18
11	0.33	0.35	0.31	0.55	0.25	0.20
12	0.32	0.35	0.33	0.51	0.26	0.23
13	0.31	0.35	0.34	0.52	0.27	0.21
14	0.34	0.34	0.33	0.55	0.25	0.20
15	0.37	0.32	0.31	0.57	0.23	0.20
16	0.37	0.32	0.31	0.59	0.20	0.20
17	0.38	0.32	0.30	0.57	0.20	0.23
18	0.38	0.32	0.30	0.50	0.25	0.25
19	0.36	0.32	0.33	0.46	0.25	0.29
20	0.35	0.30	0.35	0.46	0.24	0.30
21	0.35	0.33	0.32	0.47	0.22	0.31
22	0.32	0.39	0.29	0.43	0.27	0.29
23	0.28	0.46	0.26	0.40	0.29	0.31

Table A.6. Weekly Distribution of Hourly Traffic