EXPERIMENTAL STUDY ON THE INFLUENCE OF TRAFFIC ON POLLUTANTS IN A STREET CANYON FROM BUCHAREST

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Scopul principal al lucrării îl constituie reducerea poluării în marile oraşe aglomerate, poluare provenită din amestecul de noxe ce sunt evacuate pe țeava de eşapament a vehiculelor. Se urmăreşte aplicarea unor măsuri pentru protejarea anumitor zone în care este importantă calitatea aerului, cum ar fi spitale, parcuri, locuințe. Ideea de bază de la care pleacă elaborarea proiectului constă în măsurarea calității aerului în intersecții şi de-a lungul străzilor de tip „canion" şi pe baza acestor rezultate se vor aplica diverse masuri ce ce au în vedere reducerea şi fluidizarea traficul din zona supusă monitorizării. Pentru evoluții curente a calității aerului se folosesc senzori şi traductori care colectează date exacte din mediu la un moment dat, dar se pot face şi estimări viitoare în vederea impactului pe care le-ar putea avea unele măsuri asupra mediului.Pentru previzionarea condițiilor de mediu se va folosi un program de simulare, program ce a fost creat de Agenția de Protecție a Mediului U.S.A. (EPA). Este un program de calculator care estimează factorii de emisie de hidrocarbon (HC), monoxid de carbon (CO) şi oxizi de azot (NO_X) pentru vehicule cu motoare pe benzină şi motorină care circulă în zonele urbane.

The main purpose of the paper is to study the reduction of pollution in the big crowded cities, pollution originating from noxious mixture that is discharged by the exhaust of vehicles. The goal of the paper is application of measures to protect certain areas where air quality is important, such as hospitals, parks, and housing. The basic idea from which, the elaboration of the project starts is to measure air quality at crossroads and the streets of "canyon" type and, based on these results, to apply various measures that are considered to reduce and streamline the traffic in the area subjected to monitoring. For current developments in air quality, sensors and transducers are used to collect accurate data from the environment at a time, but is also possible to estimate the future impact that some environmental measures could have. To predict environmental conditions, we used a simulation program/a simulation program shall be used, program that was created by USA Environmental Protection Agency (EPA). It is a computer program that estimates the emission factors for hydrocarbon (HC), carbon monoxide (CO) and nitrogen oxides (NO_x) for vehicles with engines running on petrol and diesel which, circulate in urban areas.

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1. Introduction

Intelligent Transport Systems have knew a rapid developed on advanced communication technologies and information processing, also because of worsening problems caused by increasing passenger number and cargo volume. The intensification of traffic determined the development of control systems to ensure the efficient use of limited space affecting movement, in increased safety and reduction of pollution. Intelligent transport systems include a wide range of wireless and without lines based on information, control and electronics technology. When they are integrated in transport system infrastructure and even vehicles, these technologies support the monitoring and managing of traffic flow, reduction of congestion, provide alternate routes to travelers, and increase productivity, save lives, time and money. The main benefits of Intelligent Transport Systems Technology are: reduction of accidents, help unlock congestion, save people, increase of safety, reduction of travel times and trip planning, diminution of some of the effects of transport on the environment, save time and money. The congestion is an important issue for all groups of actors involved in transport. Intelligent Transport Systems Services can help reduce congestion by:

- Management application: access control, electronic payment.
- Improvement of the efficiency of the network: traffic control, driver information, rate control, incident detection, incident management, measurement of the slope (ramp).
- Eneouragement of the transition from one mode to another: planning before the trip, informing passengers, priority for different types of vehicles, monitoring and environmental protection.

Recently, however, increased interest in these systems had effect on vehicle emissions and pollution. Regarding to this, there are two main objectives:

- Where a function of traffic management system addresses the safety or traffic congestion, the respective function should be designed so that it does not lead to increased emissions.
- Special systems can be designed to reduce emissions.

  In a rather complex process, design and optimization of traffic management systems with reduced pollution is based on better understanding of the connection, since the management system itself does not directly affect emissions rates. The initial impact of a traffic management system on the driver often involves a large number of decisions.

Depending on traffic management system, the driver can choose if he/she respect or not the speed limit, if he/she decides a change of route or mode of transport, when he/she grants or not public transport priority.

2. Modeling of atmospheric dispersion in urban canyons

The most severe effects related to air pollution from road are located in urban areas. In these habitats, the traffic density reaches maximum levels and atmospheric concentrations of exhaust gases from motor vehicles are often several orders of magnitude higher than in rural areas. Urban areas can clearly be considered as a homogeneous entity; the highest pollution levels are recorded on canyon type streets (street canyons), in which the dilution of the exhaust gas is substantially limited by the presence of tall buildings and relatively narrow road route. This is particularly important because in architectural terms a street canyon is one of the basic geometric structures of urban topography. The geometry report of the canyon street, defined as the ratio of street width l (measured between adjacent building facades) and height H of the buildings on both sides, is a parameter of prime importance.

Air pollution forecasting system includes:

1. Weather forecast to national scale with a resolution of 10 km grid step within 48 hours forecast.

2. Air pollution forecast for major chemical components (CO[3], SO_2[4], NO_x[5], dust etc.) produced by large sources of pollution.

3. Air pollution forecast caused by traffic in the streets.

4. Air pollution forecast to regional scale when a chemical or nuclear accident occurs.

5. Scenarios to reduce emissions and traffic if maximum allowable concentrations are exceeded.

6. Evaluation of dispersion of pollutants in the atmosphere caused by new sources (point or area in industrial areas).

The methodology used for estimating and reporting emissions is according to the Guide elaborated in 2007 under the patronage of the Executive Committee of the CLRTAP. While elaborating the national inventory for emissions, the CORINAIR calculation methodology was used, according to the SNAP classifications, and the emission factors utilized were those indicated in the „CORINAIR the Atmospheric Emission Inventory for Europe"- 2007.

[3] CO – Carbon monoxide
[4] SO_2 - sulfur dioxide
[5] NO_x - Nitric Oxide

The input data was stored in a data base processing applications. The emissions obtained according to this program are used to complete the reporting formats requested by the UNECE/CRLTAP Secretariat.

3. Estimation of emissions

The estimation of concentrations of pollutants arises from a chain of models, built from a dynamic model of emissions, a staging algorithm and possibly a dispersion model. For the dispersion model, data obtained from other models can be used to see how the queue length affects the amount of pollutant emissions from vehicles crossing. To calibrate each dispersion model, experimental data was used. The models were applied to different periods to observe their performance. Finally, it was noted that the empirical model was more accurate than Gaussian models.

Intersections are points where emissions from vehicles are concentrated. Concentrations of these emissions may be very high here. Once considered the data on topography and geometric shape of the road, the flow of vehicles and the intersections (jump) settings, parameters such as traffic, maximum length of vehicles' queues, number of vehicles stopped and average delay can be evaluated. Such data are processed on acceleration, braking, parking vehicles or leaving the intersection. These are raw data for the model to estimate the emissions of access roads along each intersection and to evaluate the concentrations of emissions using a dispersion model.

For the study, it was considered an intersection as shown in figure 1, in which were defined:

- *Free walking area* **-** a straight segment, which has the following parameters: width, height, walking speed, volume of traffic and emissions emitted from vehicles that are considered constant**.** The location of this area is given by the coordinates of start and ends points, (X1, Y1), (X2, Y2). It is not necessary to specify the direction of movement in this area, but the length of the road sector should be higher than its width. The zone width is equal to the width of the road plus 3 meters on each side of the road to take into account the dispersion of pollution. The zone height may not exceed 10 meters (raised section) or be less than 10 meters (depression).
- *Parking area* **-** a sector with a wide straight road and a quantity of emissions observed on the stationary vehicles for a limited time (eg. traffic lights). The location of this area is given by coordinates of start point (stop line of intersection (X1, Y1)) and an end point arbitrarily chosen (X'1, Y'1). The width of the parking area is equal to the width of the road.

Sensor locations are given by coordinates (X, Y, and Z). The sensors must be located outside the joint area (equal to the area width away free) in order to acquire accurate data.

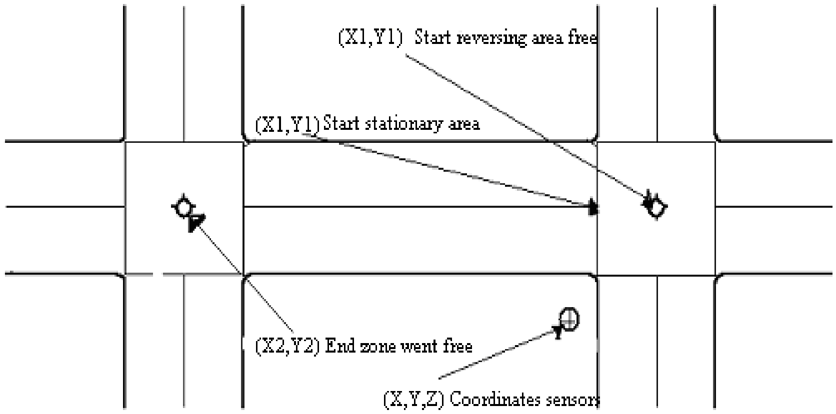

Fig. 1. Defining areas went for an intersection

The mixed area is an area where emissions are uniform and without aerodynamic turbulence. In most case the height of sensor location is approximately 1.8 meters

3.1 Areas of estimating emissions

- *Free walking area*

Vehicles are assumed to be in constant movement in this area, without delays. Speed of vehicles movement is considered to be the maximum legal speed on that part of the road. However, in urban areas, a lower speed than the legal maximum (about 35km / h), would be considered because there are delays due to traffic, pedestrians, cyclists etc. Composite emission factor (in grams/vehicle · miles) is obtained using a model for calculating emissions, the average speed of walking on the sector.

- *Parking area*

In parking, area is assumed that vehicles are stationary for a limited time; this time was chosen as a red traffic light. The stationary emission coefficient (in grams/vehicle · hours) must be converted in μg/(m · s) to calculate the amount of emissions linear(Q).

Q's formula for a single lane for one second is the following:

$$Q_1 = \frac{\text{stationary emission coefficient}\,(\text{g/veh.-hour})\cdot 10^6}{3600\cdot 6} \quad [\mu g/m\text{-}s] \qquad (1)$$

To determine the total Q (Q_t), the following formula is used:

$$Q_t = Q_1 \cdot \text{number of lanes} \cdot \%\ \text{from the red time}\ [\mu g/m\text{-}s] \qquad (2)$$

3. 2 The estimation of vehicles' queue

Input parameters required for determining the length of the queue are: volume of traffic on the road, traffic lights' cycle length, length of the red time, and lost time between intervals. Sometimes, optional parameters are used:

X_c – Flow saturation [vehicle per hour during the green, vphg];

T – Type of lights [default (=1), update in real time (=2), or semi update (=3)];

T_s - "Arrival time" of the platoon of vehicles [worst (=1) to the most favorable (=5)];

Intersection capacity per lane is calculated as:

$$C = \frac{(X_c) \cdot (C_0 - T_r - I - T_p)}{C_0} \tag{3}$$

Where:

Co = hourly capacity of each lane [vehicle /hour/lane];

X_c = flow saturation [vehicle /lane/green hour];

L = cycle length [s];

T_r = length of time red [s];

I = delay [s] = 2 s;

T_p = lost time between intervals [s];

The vehicles, which arrive at a signalized intersection during the red light period, form a queue behind the stop line. After the lights turn green, the first vehicle starts after a delay of about 2 seconds, followed by the remaining vehicles. Such a delay is propagated back to the vehicles so that vehicles, which arrive during the green time, before dissipating the queue, are stopped and join the queue end. When the road capacity is near saturation and traffic light is divided between 50 - 50 times red and green, the total delay of vehicles on each lane, I_T, can be approximated as:

$$I_T = N_m \cdot D \cdot 1/2 = N_m \cdot T_r \tag{4}$$

where:

I_T= total delay of vehicles on each lane during a cycle of traffic lights [Vehicles · second/lane];

N_m = average number of vehicles queued per lane at the beginning of the green time [vehicles];

D = cycle time [s];

T_r = length of red time [s];

- *Estimation of queue for application of un saturation*

In unsaturated traffic conditions (volume ratio on the capacity is less that (4) the number of vehicles in queue from an intersection at the start of green time, is estimated using Webster's formula :

$$FB = N_u = MAX\,[N \cdot I_m + (T_r/2) \cdot N,\ N \cdot T_r] \tag{5}$$

where:

N_u = average number of vehicles of vehicle of the beginning of green phase in under - saturated conditions [vehicle/lane];

N = number of vehicles which arrive on each lane [vehicle/lanes/s];

I_m = average vehicle approach delay [s/vehicle];

T_r = length of red phase[s];

Average delay of each vehicle, which arrives, I_m, in equations (5) is estimated using the following relationship:

$$I_m = i_m \cdot f \cdot f_c \tag{6}$$

where:

i_m = average stopped delay per vehicle [s/vehicle];

f = progression adjustment factor;

f_c = stopped delay to aproach delay conversion factor (= 1,3);

- *Estimation of queue for oversaturated conditions*

In oversaturated conditions traffic (volume ratio on the capacity is greater than 1), vehicles queue consists of two components, N_1 and N_2. N_1 can be approximated at the beginning of green time with the following formula:

$$N_1 = N_u' = MAX\,[q' \cdot D' + (r/2) \cdot q',\ r \cdot q'] \tag{7}$$

where:

q' = rate of vehicles arrival at maximum capacity of the road (V/C = 1.0) [vehicle/lane/s];

D' = average delay of vehicles at maximum capacity of the road (V/C = 1.0) [s/vehicle];

D_r = length of red time (phase) [s];

N_2 is the additional queue due oversaturated and is calculated with the following formula:

$$N_2 = (1/2) \cdot [A'(t) - A(t)],\ \ At.\ \ t = 1hour = (1/2) \cdot (V - C) \tag{8}$$

where:

N_2 = average additional queue per lane due to over – saturation conditions [vehicle/lane];

$A'(t)$ = cumulative vehicles arrivals per lane in over - saturated conditions [vehicle/lane];

$A(t)$ = cumulative vehicles arrivals per lane in at - saturated conditions [vehicle/lane];

V = hourly approach volume per lane ((A'(t) at t = 1hour) [vehicle/lane/hour];

C_o = hourly capacity per lane (A(t) at t = 1hour) [vehicle/lane/hour];

Thus, the average queue at the start of green time in oversaturated traffic conditions, N_0, can be approximated by the formula:

$$N_0 = N_1 + N_2 = MAX\,[q' \cdot D' + (r/2) \cdot q',\ r \cdot q'] + (1/2) \cdot (V-C) \qquad (9)$$

Where:

q', D', D_r, V and C are the same variables defined in equations (7) and (8).

For both situations of unsaturated or oversaturated traffic, the length of sector analysis is calculated by multiplying the number of vehicles in queue to 6 feet. Several emissions models were used, namely,[5], [6]:

- **MODEM**[6] model, specific European fleet. This model is able to estimate the inert pollutant emission rates depending on the speed (v) of the vehicle and according to the product of speed and acceleration ($v \cdot a$).

- **INSEC**[7] model form the APRAC/3 model was used in the processing queue of vehicle parameters. This model is based on the Webster's algorithm. Using input data such as: vehicle flow, phases of traffic lights, intersection geometry and morphology, parameters such as: maximum length of vehicles' queue, number of vehicles stopped and the maximum delay per vehicle on a whole cycle of the intersection can be calculated.

- **EMITX**[8] model from APRAC/3 model, estimates the emissions during acceleration, cruising speed, deceleration and stationary. This model is based on Kunselman model emission algorithm. Started to the prize estimates given by dynamic model MODEM, Kunselman model calculates the instantaneous emission rate based on vehicle speed and acceleration.

Finally, The EMITX model calculates the linear emission rates (mg / s) for each of the five sections and all roadways that converge in the intersection.

To obtain the section of pollutant gas dispersion a set of models from different algorithms was used. The aim was to compare the *Gaussian* model and *empirical* model.

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[6] MODEM – MODeling EMissions
[7] INSEC - Emission and diffusion modeling
[8] EMITX - Emission and diffusion modeling

Gaussian model is using algorithms implemented in APRAC/3 model (estimated concentrations of pollutants in the intersections of lights, called LINE) and CALIN 4 model (requires restoration input interface). A third dispersion intersection algorithm is applied to estimate the concentrations at the intersection point of acceptance. This algorithm is the result of an empirical approach, which uses a model of box type, simplified, applied to each street that goes to the intersection.

4. Pollutant concentration data

The calculation of the atmospheric pollutants emissions issued by the road transport has been done using the COPERT 3 program, adopted by CORINAIR guide for this activity. The data have been provided by Romanian Vehicles Register (RAR), National Institute of Statistics and consulting technical sheets of fuels present on the Romanian market [1], [3]. The data base is made of the following elements:

a. The vehicles number and the technical parameters concerning the motorization on the following categories:
   - Passenger cars
   - Light-duty vehicles with a capacity under 3,5 t
   - Heavy-duty vehicles with a capacity over 3,5 t
   - Mopeds and motorcycles with a capacity under $50cm^3$
   - Motorcycles with a capacity over $50cm^3$
b. The annual number of kilometers per motor vehicle category and per road categories:
   - Urban
   - Rural
   - Highway
c. The traffic average speed on motor vehicle category and on road category
d. The annual fuel consumption on fuel category

For 2007 new fuel characteristics were taken into account, characteristics especially focused on raid vapor pressure, heavy metal and sulfides content. Also some changes were made concerning activity data (mileage and average speed on rural, urban and highway)[2],[8]. The changes were made on the basis of a study elaborated in 2007 by the RAR.

A descending trend in emission evolution can be observed for some of the pollutants. This descending trend is determined by the improvement in the fleet motorization, by purchasing new vehicles instead of old ones. Hourly data of concentrations (CO, NO_x, NO2, O_3), measured for two days are shown below (Figs. 2 - 5).

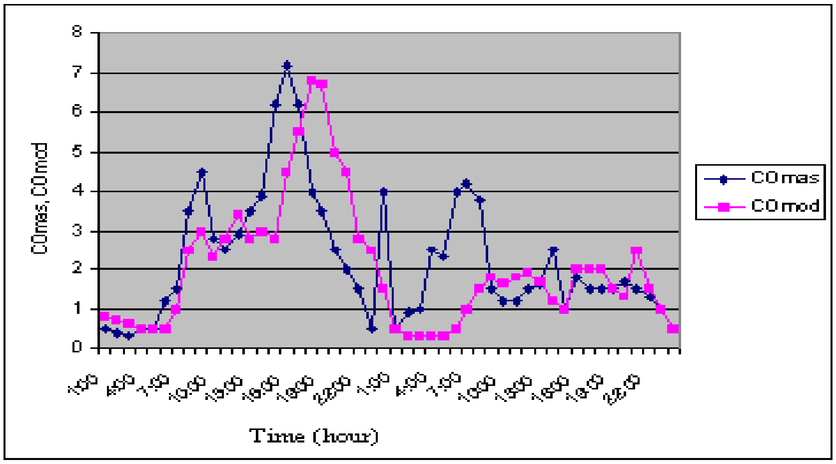

Fig. 2. Variation of CO concentration measures, CO mod are based on the time of movement

The Figs. 3 - 5 show the influence of wind speed and traffic flow on the of CO, NO_x, NO_2 and O_3 concentration. On Monday, 19th February 2007 there are big concentration when the wind speed is small. On 20th February, the wind speed becomes higher and concentration decres despite the fact that traffic has about the same value. Hourly data concentration (CO, NO_x, NO_2, O_3), mesurement for two days are showm below.

The Figs. 3 – 6 presents the influence of wind speed and traffic flow on the of CO, NO_x, NO_2 and O_3 concentration.There are large amounts of concentrations when wind speed is low. When wind speed is higher, the concantrations decrese despite the fact that traffic has around the same value. Figure 6 does not show the same type of concentration. Sometimes, O_3 is too high despite the fact that traffic is low. There might be other sources of O_3. This is the problem to be studied in the future [5], [6]. The diagrams show variability temporary levels of pollutants. By studying concentrations for the whole year, we may see that higher values are recorded for CO, while O_3 does not exceed 130 $\mu g / m^3$.

In Figs. 3 and 4 we can observe a good correlation between CO and NO_x concentrations despite the fact that NO_x participates in photochemical reactions. In correlation with O_3, inverse correlation between NO_x and O_3 (Fig. 3) that NO_2 and O_3 (Fig. 6), is the fact that emissions of NO_x causes a consumption of ozone. This inverse correlation is still very poor, so it may be another source of ozone.

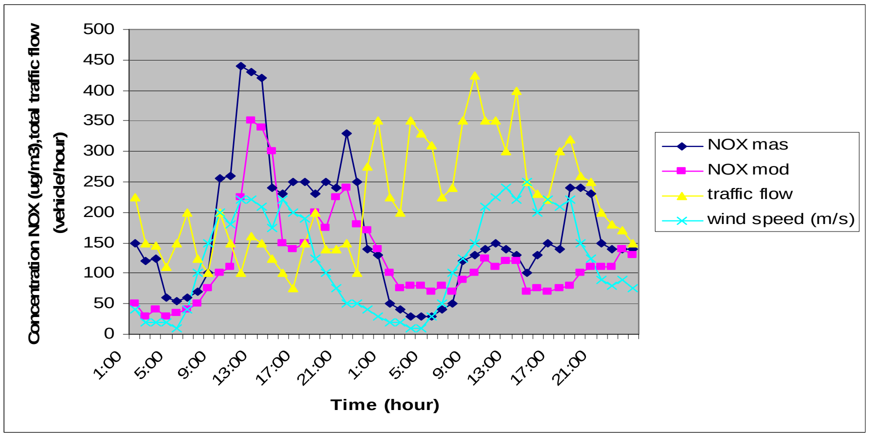

Fig. 3. Variation of concentrations NOx meas., NOx mod are based on the time of circulation

Such a distribution of concentrations proves that traffic is the most important source of CO and NO_x, these pollutants being emitted by the vehicles engine during its running.

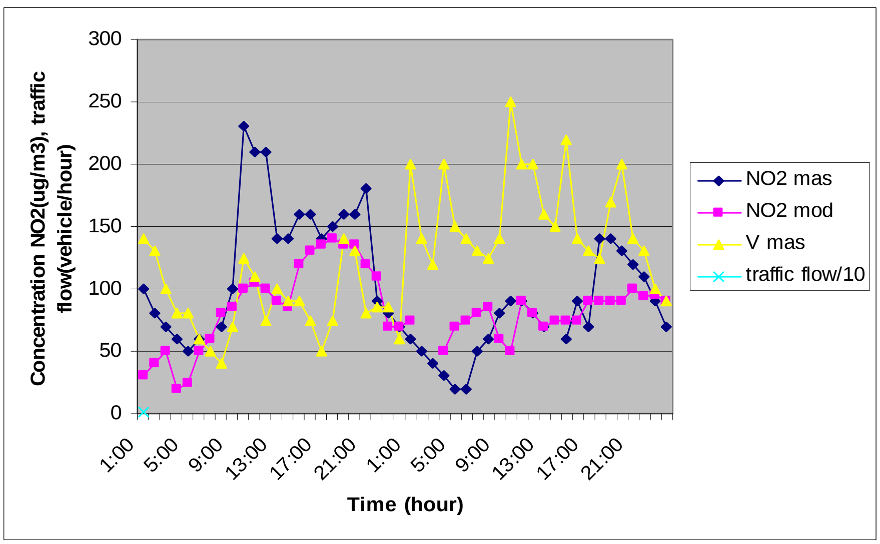

Fig. 4. Variation of NO_2 concentrations meas., NO_2 are based on the time of circulation

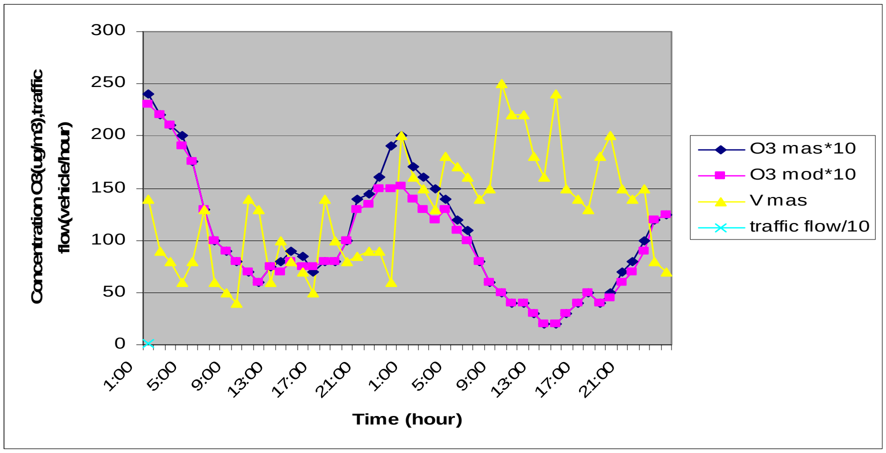

Fig. 5. Variation of O_3 concentrations meas., O_3 are based on the time of circulation

Such a distribution of concentrations shows that traffic is trhe most important source of CO and NO_x these pollutants being emitted from motor vehicles in operation. The graph shows a higher traffic in the working days, decreasing to half in the weekend period when people leave the urban area. Fig. 6 shows every working day, the morning peak, around nine o'clock (when peple go to work) and afternoon peak (when people come back home).

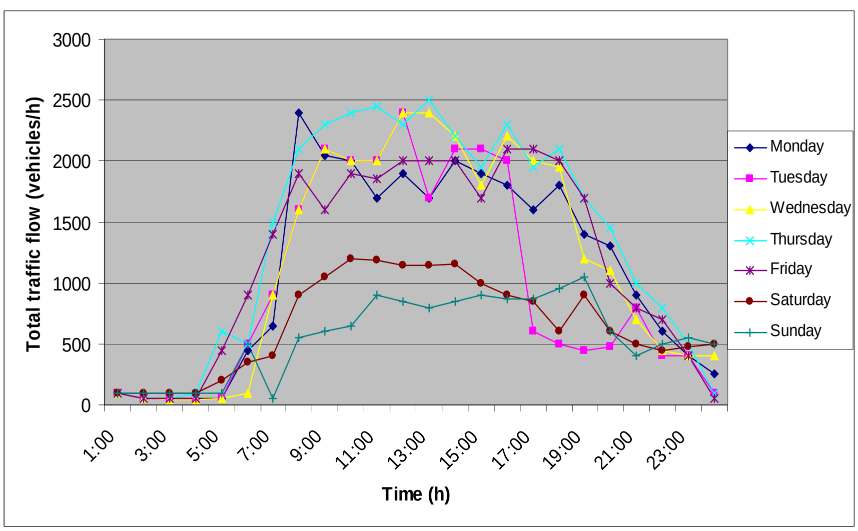

Fig. 6. Variation of traffic flow based on the time of circulation

A diagnostic evaluation of the model performance requires an analzsis of the behavior of model results in comparation with experimental data, with respect to the weather conditions. Such an analzsis is presented in Figs. 2 – 5 in which the measured and medeled CO, NO_x, respectivelz NO_2 concentrations are pltted against the wind speed and direction. The measured and modeled concentrations show verz similardependence on wind speed. The differences between measured and modeled data are caused bz inaccuracies in the traffic emission estimates or in the measured concentrations and meteorological data. Part of the differences is also due to the background modeled data and, of course, the dispersion model.

5. Conclusions

The problem of reducing concentrations of pollutants is one of the most pressing worldwide today. A number of organizations have emerged, both at national and regional level, organizations that are concerned with software development and implementation of methods and technologies that would reduce emissions of harmful pollutants. As you know, hot air masses are moving upward, and their place is taken by cold air masses that suffer a downward movement. The unity of these two motions generates air convection. Ceiling between two layers of cold air causes impurities to accumulate again in that area, near the place of discharge.

This paper examines the temporal variations in air pollution within realistic urban street canyon environment. What is novel about this study is that all aspects are considered: the links between traffic flow characteristics, background concentrations, weather conditions, pollutants concentrations in the street.

It follows the great importance of climatic factors both in the accumulation of pollutants and the natural process of reducing their (Air Self-purification). It is particularly important to understand the process of Self-purification and pollution of air, in order to determine the relationship between the amount of contaminants discharged into the atmosphere in a certain amount of time and their persistence, the last size being dependent on the removal mechanism.

Researches viewing the transit intersections directed, by road vehicles, have revealed that internal combustion engines of these vehicles are required to operate the transitional arrangements, characterized by significant reduction of economics, because of higher inertial losses, a worsening of the mixture formation process and combustion, etc. Finally, these schemes lead to significant increase in emissions of pollutants from exhaust gases**.**

It is important that what happens in the intersections is known and researched, to cut high pollution levels, preferentially located in the intersection.
If optimization of the urban spaces built in our years can be achieved relatively easily, in central areas, limited by existing buildings, the only way to optimize, in addition to the redistribution of traffic flow (the extent that there are side trails), remains the traffic light cycles optimization of central intersections.

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