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STRATEGIC SECTION A:
SUSTAINABILITY OF THE ROAD TRANSPORT SYSTEM

MITIGATING THE IMPACT OF THE ROAD SYSTEM ON CLIMATE CHANGE

H. Alvarez Goris and

M. L. Alba Menéndez

Instituto Superior Politécnico José Antonio Echevarría,
Habana, CUBA
lili@civil.cujae.edu.cu

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ABSTRACT

Although Cuba's contribution to global warming and greenhouse gas emissions is very small, in our country climate monitoring of Greenhouse Gases (GHG) emissions is undertaken for years. The condition of archipelago that Cuba has becomes it in one of the most vulnerable countries to the climate changes.

In Cuba, there is a desire to reduce greenhouse gases between 2008 and 2012 by 5 percent over 1990. The determination of emissions and removals is done using the recommended methodologies for these purposes by the United Nations Framework Convention on Climate Change (UNFCCC).

From the standpoint of air quality, in Cuba there are regulations that establish requirements for environmental quality. Specifically in the area of transport, it has developed strategies and actions, both by the Ministry of Transport, rector of the roads, and by the Ministry of Construction, rector of the road construction, which incorporate the analysis of air pollution and Greenhouse Gases Emissions in policies, plans, projects and programs that perform each of these ministries, in correspondence with the model of Sustainable Development planned for the country.

Using the approach through study cases, the Procedures are showed in order to mitigate the impacts of the transport systems and their contribution to the emission of Greenhouse Gases.

1. INTRODUCTION

The Republic of Cuba is located in the largest of the territories that make up the group of the Antilles, located at the entrance of the Gulf of Mexico, between the Florida and Yucatan. The Cuban archipelago has an area of 110 922 km2 and is made up of the Isle of Cuba, the Isle of Youth and over 4500 keys and islets. It has a long and narrow shape, similar to that of an alligator. Its length is 1250 km, its maximum width is 193 km and a minimum of 32 km. It has a great landscape and ecological diversity as well as relative wealth in certain natural resources in relation the rest of the islands in the Caribbean region.

Cuba, despite economic limitations, is engaged in sustainable development and thus for sustainable mobility, which involves the ability to meet the needs of society to move freely, communicates trade and establishes links, without sacrificing ecological human values of current and future generations.

In 1992 took place the United Nations Framework Convention on Climate Change at the Earth Summit. The Summit adopted the Rio Declaration, which made new postulates and principles in environmental issues: the adoption of Agenda 21, which defined goals to reach for the XXI century, and the Framework Convention on Climate Change and Biodiversity. In 1997, industrialized countries agreed in Kyoto City, executing a set of measures to reduce greenhouse gases. The signatory governments of these countries agreed to reduce by at least 5% in average emissions between 2008 and 2012, with reference to 1990 levels

Although the Kyoto Protocol did not require the reduction of emissions in developing countries, it was signed by Cuba, so there is a desire to reduce greenhouse gases between 2008 and 2012 by 5 percent over 1990. As Cuba, one of the countries belonging to the United Nations Framework Convention on Climate Change must estimate the changes in carbon stored in their forests and report them. An inventory system to record the absorption and carbon emissions has been established.

2. CLIMATE AND GREENHOUSE GASES (GEI) EMISSIONS MONITORING IN CUBA.

It is undertaken in Cuba for years, climate monitoring and Greenhouse Gases (GHG) emissions.

The evidence clearly indicates that the climate has become warmer. From the middle of last century the average temperature has increased about 0.6 ° C.

Overall there has been an expansion of summer and a contraction of the length of winter in Cuba.

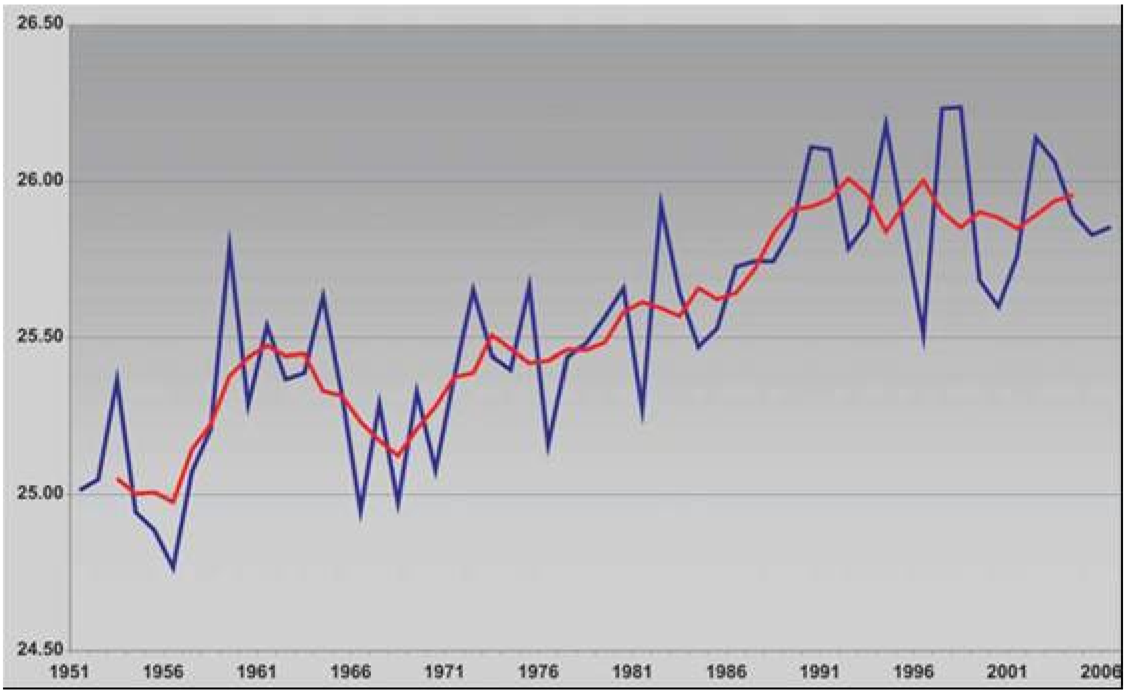

Figure 1. Cuba's annual average temperature between 1951 and 2006

The GHG emissions and removals are resulting from a large number of human activities. Methodologically are grouped into the following sectors: Energy, Industrial Processes, Solvent Use, Agriculture, Change of Land Use and Forestry, Waste. Moreover, each sector has an opening in "sub categories" and "sub-source" which, in the reports of emissions, are addressed separately in every detail (in total 30 categories and 123 subcategories of sources). It also includes a module dedicated to the assurance and quality control as well as the management of uncertainty in emission estimates made.

The estimate of emissions and removals of greenhouse gases in Cuba is assumed as a continuous process, whose results are updated and improved in each report. Following the recommendations of 'good practice' in each report emissions the entire series of data is recalculated in those source categories where changes have occurred in the calculation methods used, or have obtained new or improved activity data or emission parameters. This ensures the consistency of the time series of emissions. For this reason, the latest report issued contains always the best available emission data so far for the entire series.

The determination of emissions and removals is done using the recommended methodologies for these purposes by the United Nations Framework Convention on Climate Change (UNFCCC). These are the Guidelines Revised 1996 IPCC (IPCC, 1997) IPCC Guidelines for Good Practice and Uncertainty Management (IPCC-GPG, 2000). They are also used elements of the IPCC Guidelines on Good Practices in Use, Change of Land Use and Forestry (IPCC-LULUCF, 2003) and the 2006 IPCC Guidelines (IPCC, 2006).

Gross GEI emissions had a sharp decline in Cuba since 1990 earning the minimum in 1993. Since 1993 these have risen slightly in some categories of sources and stabilized or declined in others (Lopez et al., 2007). Drawing on findings derived from the last inventory conducted in 2004, the emission of gases causing the greenhouse effect is reduced in comparison with industrialized countries. "The values reported are typical and acceptable to our level of development”.

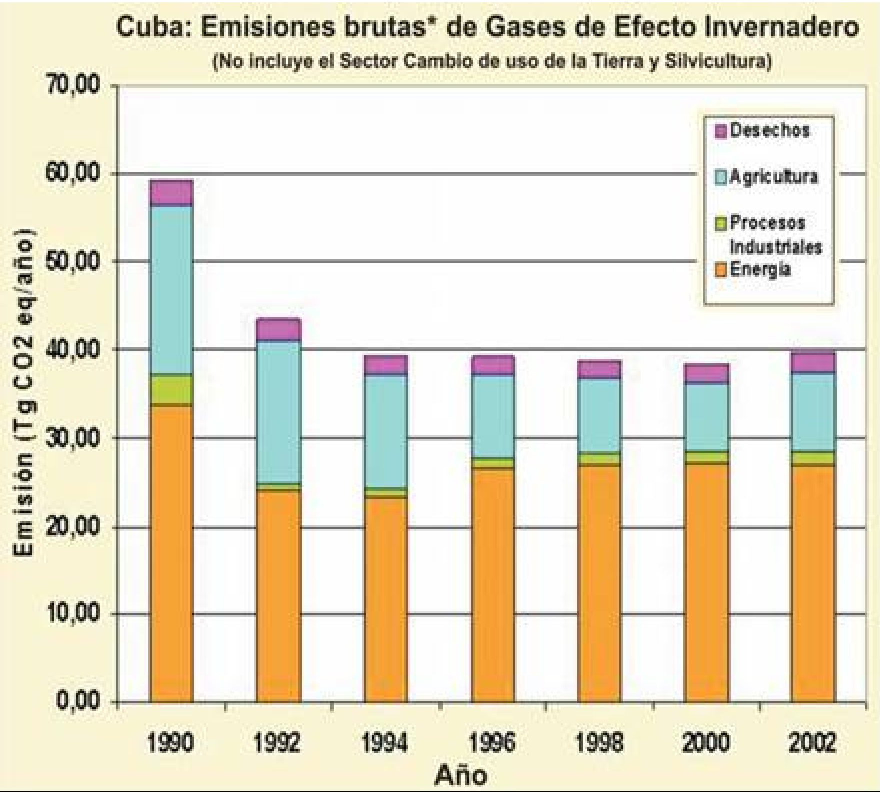

Figure 2. Gross GHG emissions in Cuba (Tg CO2 eq / year). Source: Lopez et al., 2007.

3. STRATEGIES AND ACTIONS IN THE AREA OF TRANSPORT IN ORDER TO MINIMIZE THE GREENHOUSE GASES (GEI) EMISSIONS

Specifically in the area of transport, it has developed strategies and actions, both by the Ministry of Transport, rector of the road, and by the Ministry of Construction, rector of the road construction, which incorporate the environmental dimension in policies, plans, projects and programs that perform each of these ministries, in correspondence with the model of Sustainable Development planned for the country.

Thus, the Ministry of Transportation has developed a series of measures to minimize negative environmental impacts, particularly the reduction of pollutant emissions in order to achieve sustainable transport, including the most important:

- Development of non-motorized transportation alternatives, encouraging the use of bicycles, tricycles, animal-drawn vehicles and other facilities created for coexistence with motorized traffic.
- Increase of walking tours, facilities for pedestrians and traffic education.
- Development of multimodal transport, using rail for medium and long distances, as well as freight and cargo.
- Establishment of design standards for roads that involve the environmental aspect and in particular air pollution decision-making project.
- Traffic Ordinance and establishment of measures to reduce congestion on the basis of emissions of polluting gases.
- Creating good condition in Vehicles Technical and Environmental Inspection Centers in all provincial capitals.
- Introduction of alternative fuels such as Compressed Natural Gas, reducing emissions or air pollutants from transportation.
- Implementation of national technologies or leading to greater efficiency in the combustion and gas treatment in the current vehicle fleet, such as implementing electronic ignition and injection, the construction of catalytic converters, etc..
- Implantation of administrative regulations on the movement of vehicles in the city, taking into account age, fuel type, emission control standards.

From the point of view of the project, the Construction Minister has established two national regulations that relate to the design of roads to the environment, which are:

- "Procedures for environmental analysis of variants in the road design", incorporating environmental issues into the design process and providing the methodology for the analysis of alternatives, taking into account the impact that each lead on the environmental factors.

- "Design of roads in environmentally sensitive areas", which establishes the planning strategy for this type of road and areas and the geometric design parameters on the basis of the ability of the host territory.

The estimates of the environmental impacts in the Preliminary level, allows the analysis of alternatives to minimize disruption from this step. The environmental analysis of alternatives implies the need to know the initial environmental quality of the receiving environment without a plan, anticipate changes that could result, and evaluate the project final environmental quality, being able to assess the importance of impact as the difference in environmental quality initial and final.

Procedures for environmental analysis of alternatives.

- Establishment of the environmental characteristics of the area to intervene.
- Location on the topographic map of the area of the different variants proposed.
- Determination for each variant of the input data for forecasting models impacts of each environmental variable.

- Assessment of the impacts that each of the variants led on various environmental factors according to the procedure specified in each case.
- Harmonization of environmental criteria, economic criteria, etc.
- Selecting the final version.
- Preparation of final design which should include corrective actions and mitigation

From the standpoint of air quality, in Cuba there are regulations that establish requirements for environmental quality. (See Annex 1)

The impact indicator that is proposed is the radius of health protection, the established minimum safety distance between the emitting source, in this case the road and the limits of the residential areas and other objects of environmental protection .

The sanitary protection radius is calculated from:

- Degree of air pollution through the index P. (As NC 39, Atmosphere. Air Quality. Sanitary hygiene requirements.)
- Maximum admissible concentration standard substances for a certain time. (According to NC 39, Atmosphere. Air Quality. Sanitary hygiene requirements.)

Depending on the radio of health protection and the map of land use and occupation the importance of impact is established

3.1. Procedure for selecting the impact indicator for air quality.

1. Determining by the forecast model selected real concentration values of major pollutants (CO, SO2, NO2, and particulate matter) caused by the transport system in a network of receivers located around the road.

2. Generating a map of contours of equal pollution levels for each pollutant that is modeled.

3. Interpolating the contour lines of maximum allowable concentration level in each map generated.

4. Determining the area that is affected by pollution levels exceed permissible levels.

5. Determining the degree of air pollution by determining the rate P at each point for each receptor analyzed

6. Generating a map of isolines of equal degree of pollution (as P).

7. Interpolating contour lines on a map indicating the limits of P that define areas with different levels of air pollution (light, moderate, high or extreme).

8. Determining the radius of health protection (prescribed minimum safety distance between its source and limits of the residential areas, rest areas, population and other objects of environmental protection) to the road in question.

The sanitary protection radius can be calculated as the distance perpendicular to the axis of the road up to the line corresponding to the value of P corresponding to a level of light pollution from the map of each pollutant modeling, choosing the distance perpendicular to the path to curve of maximum allowable concentration level. The generation of the map can be based on a topographic map, aerial photography, and floor plan of the road in question or a photomontage. In all cases must be georeferenced. The map scale should be the highest possible and never less than 1:5000.

3.1.1. How to approach the analysis through a case study.

The prediction of atmospheric pollution levels and specific to the case of carbon monoxide that cause the Highway Project of entrance to Havana was the proposed goal and the determination of the radius of sanitary protection necessary for these purposes and elaboration of the map of carbon monoxide pollution to the study area.

The prediction of air pollution caused by traffic passing by the road decided to be made using the dispersion model of pollutants CALINE 4.

There were three runs of CALINE 4 obtaining the values of carbon monoxide concentration at 54 receivers located along the route of the new highway and interchanges. The points were placed on a plane in which it had placed the virtual highway then proceeding to obtain the isolines of equal concentration by interpolation with software, in this case SURFER.

There are a group of receptors whose concentration values exceed the limits allowed by the Cuban standard (NC 93-02-202, 1987), but the wind direction angles of occurrence is very unlikely.

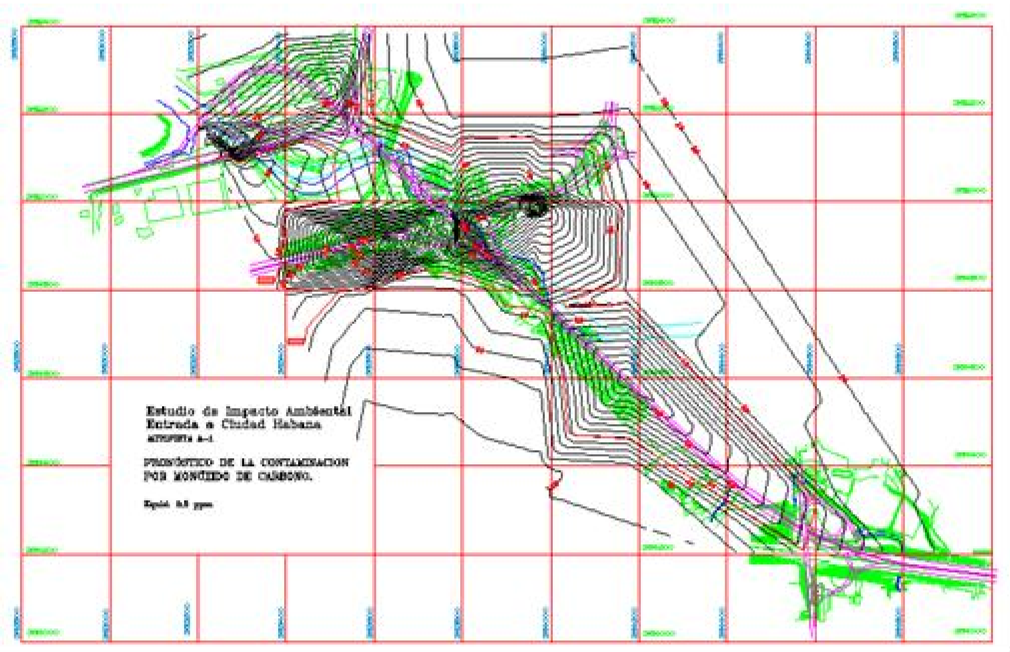

Figure 3. Results of modeling of pollution from carbon monoxide to the way a case study.

A prediction from the plane, which was located in the curve for the limit value of the standard, established a health protection radius of about 120m from the axis of the highway. However it is good to note that the worst conditions of atmospheric stability will occur with low probability of around 6%. For this reason, we decided to make a new modeling considering the most probable weather conditions, average wind speed 5m / s, average temperature 27 ° C, prevailing wind direction and stability class 5, and we obtain that for any receiver the limit is exceeded. It was not considered necessary to propose the health protection radius of 120m due to the low probability of occurrence of high concentrations modeled in the receptors that define it.

3.2. Case of roads in environmentally sensitive areas.

It also regulates the design of roads in environmentally sensitive areas, establishing the strategy for road planning and geometric design parameters of the roads on the basis of the ability of the host territory. The geometric design has a conceptual change of its criteria regarding the conventional design. It is aimed to determine in advance the environmental indicators acceptable levels for the area and from them calculate the traffic parameters needed for the geometric design of roads. (Alvarez, H.)

The design criteria are:

1. Noise levels at the sides of the road below a set level that will depend on the fragile ecosystem on which they perform the action.
2. Air pollution levels below established values depending on the fragility of the ecosystem.
3. Design speed in terms of achieving better adaptation to the characteristics of terrain and landscape.
4. Indicators of vegetation and fauna.

3.2.1. Design review from air quality indicator.

From the model to forecast air quality it was determined for values of number of vehicles calculated by the criteria of noise pollution the levels of monoxide for one hour in the sides of the road, considering the road at level ground and the worst-case meteorological conditions.

Table 1 shows the calculated levels of CO concentration in terms of traffic. The values are low and not at any time exceed the maximum allowable concentrations set by the standard NC Cuban atmosphere. Air Quality. Sanitary hygiene requirements ().
The limit values for carbon monoxide pollution to use can be determined based on the greater or lesser responsiveness of the species present in the environment.

Tabla 1 Limit values for carbon monoxide pollution in relation with traffic

PAIDT (cars/día)	**IHD (cars/h)**	**CO (mg/m^3)**
100	12	<1,5
300	36	<1,5
500	60	1,76
700	84	1,99
800	96	2,80

3.3. Congestion Analysis.

Reduce congestion also results in lower emissions of air pollutants, particularly greenhouse gases.

At present the issue of environmental impact from the point of view of traffic can be analyzed deeply thanks to advances in computer, as there are several softwares developed for this use.

While in Cuba it is difficult to make measurements of air pollutants it is generally used to predict a computer model that calculates the emissions of air pollutants generated by mobile sources and the dispersion of them in the environment.

The program CALINE3.QHC which is the commonly used means for evaluating a network of receivers immission values of air pollutants may be able to get through it the degree of air pollution as an indicator of impact and the radii of health protection the route or routes in question. The model calculates the total concentration of pollutants in the air both as much moving vehicles as in lag. It is a reliable tool for predicting concentrations of inert pollutants in the air near signalized intersections. Because in lag emissions are a major part of total emissions at intersections, the obvious model to some extent the speed of traffic, a parameter difficult to predict with a high level of accuracy in congested urban roads if not done in a considerable effort to collect data.

3.3.1. How to approach the analysis through a case study.

The intersection of 100th Street Vento, in Havana, had high levels of congestion, aggravated in the morning rush hour, especially in the 100 Street accesses from Lenin Park. All movements were permitted to access, so that the intersection was working with four phases and excessive cycle time, 110 seconds, generating excessive queues and delays for all access, in addition to traffic volumes higher than arrive at the intersection that exceeded the capacity for phase plan designed. These aspects are shown in Table 2. (L Alba, H Alvarez, S Pire, 2009).

Tabla 2. Parameters of movements in the intersection.

Accesses	**Mov.**	**Delay (s/veh)**	**NS**	**v/c**	**Length of the queue (m)**	**Number of cars that stop (car/h)**
P. Lenin	Straight	695,0	F	2,48	180,0	590
	Wright	64,4	E	0,56	14,2	59
Marianao	All	48,6	D	0,79	60	469
Boyeros (Vento)	All	187,2	F	1,33	191,4	907
Camagüey	All	104,5	F	1,05	53,5	341

To model the case study through software CALINE 3 QHC is needed to enter data from TRAFFICWARE program, this software was the basis for modeling and analysis in the new program.

The intersection analyzed is formed by four entrances. Central axis (453 362)

- East (679, 363)
- West (244, 362)
- North (498, 441)
- South (357 197)

Access was considered for each traffic sense in the light which is free and has tail. It was necessary to enter data to the program of 8 different sections of which data were taken as the volume of vehicles for each section and the initial and final coordinates indicating the meaning of the section.

In the sections with queu in addition to the above information, it is necessary to introduce other such as traffic lights cycle, time of red and yellow time

A fundamental data for processing case study in this software is the emission factor. To fulfill this stage, we use the values given in the model IVE (International Vehicle Emissions Model), because it is a relatively simple model, validated by its application in a number of cities around the world.

It was necessary a weather file that is obtained from data provided by the Institute of Meteorology which records the wind direction in degrees. It also offers as information the recorded wind speed and atmospheric stability class.

In Table 3 is provided the data offered by CALINE 3. QHC of the maximum concentration values for some of the receptors located and with the characteristics of the intersection screened:

Table 3 Details CALINE QHC.

# Receivers.	maximum concentration (mg/m3)	# Receivers.	maximum concentration (mg/m3)	# Receivers.	maximum concentration (mg/m3)
1	11,4	5	0,76	9	0,52
2	1,8	6	16,99	10	0,62
3	0,53	7	3,27	11	3,05
4	0,64	8	0,44	12	1,27

Of the values shown in Table 3 can make the critical area based on the emissions of carbon monoxide in the intersection analyzed from the points made in the Cuban Standard 39-02-202 where the permissible maximum instantaneous value of this pollutant is 5 Mg/m-3, therefore all this area that encloses the curve of this value can be defined as critical area, as shown in Figure 4

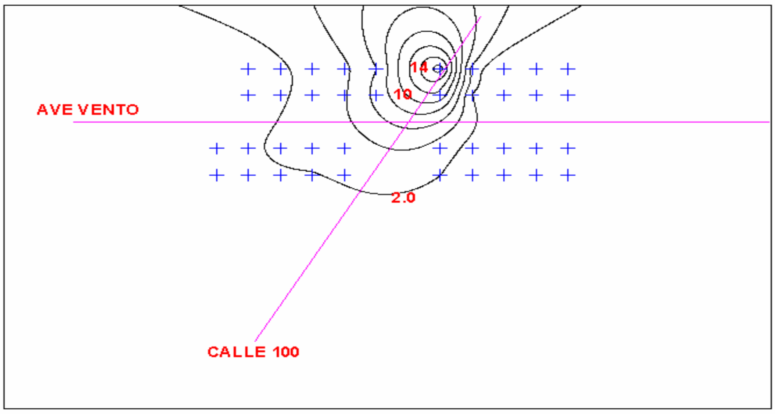

Figure 4. Isolines of concentration of carbon monoxide in the intersection analyzed.

$Ki = \frac{Ci}{Cmai(d)}$ =16.99/3*=5.66

With this value of Ki, degree of hazard 4 and instantaneous concentration entering the Table of Standard classifies as a light polluted area.

The measures taken consist mainly of the elimination of several movements in the intersection, contributing to decreased phases from four to three and the cycle time from 110 to 80 seconds, it is proposed to further modify the organization of traffic in the area, the two adjacent signalized intersections, working in a control group, or three signalized intersections governed by the same center, looks as shown in Figure 5 by a sketch of the area. Circulation parameters obtained for this condition is shown in Table 4.

Tabla 4. Parameters of movements in the intersection with the measures taken.

Accesses	**Mov.**	**Delay (s/veh)**	**NS**	**v/c**	**Lenth of the queue (m)**	**Number of cars that stop (car/h)**
P. Lenin	All	14,8	B	0,61	48,1	53
Marianao	All	35,8	D	0,89	35,8	84
Boyeros (Vento)	All	53,3	D	1,02	53,3	91
Camagüey	All	30,9	C	0,53	24,1	56

In the results of the previous table can be seen the improvements made in the quality of the operation, where significantly reduce the length of the queues, stopping vehicles and delays, although the parameter of capacity utilization remains high for access of Vento, from Rancho Boyeros, a situation that should only be maintained during peak hours. Once taken measures of mobility management in order to reduce congestion also modeled intersection in CALINE 3. QHC with the new restrictions and new data. It was kept the position of the receivers.

Table 5. Results from CALINE QHC.

# Receivers.	maximum concentration (mg/m3)	# Receivers.	maximum concentration (mg/m3)	# Receivers.	maximum concentration (mg/m3)
1	1,85	5	0,41	9	0,24
2	0,74	6	2,89	10	0,3
3	0,33	7	0,25	11	0,84
4	0,39	8	0,25	12	0,61

Of the values shown in Table 5 can make the critical area based on the emissions of carbon monoxide in the intersection analysis.

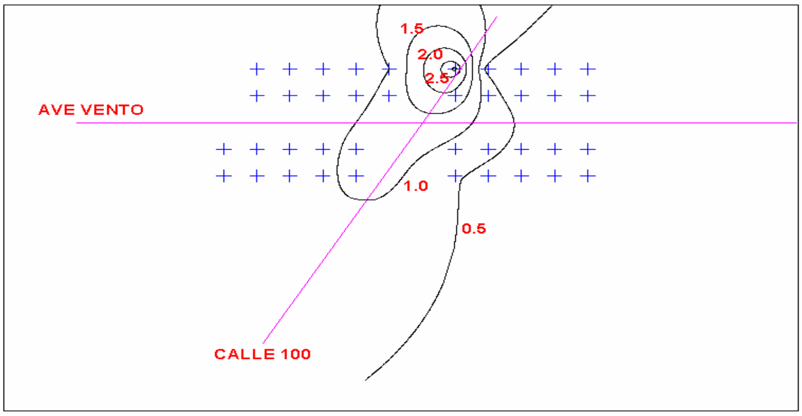

Figure 5. Isolines of concentration of carbon monoxide of the proposed solution.

As shown in Figure 5 there is no isoline 5 Mg/m-3, therefore does not appear contaminated area. For the Case Study, Intersection Vento Avenue and 100th Street, the scene before taking action, the air was contaminated in an area near the intersection with light level. After the measures taken, it is considered that the air pollution is eliminated as the maximum ground level concentration in any unit exceeds the value of 5 mg-m3 that the limit set in the standard.

4. CONCLUSIONS.

Although Cuba's contribution to global warming and greenhouse gas emissions is very small, it has been given special attention to this problem as well as the fulfillment of commitments made as part of the United Nations Framework Convention on Climate Change. Drawing on findings derived from the last inventory conducted in 2004, the emission of gases causing the greenhouse effect is reduced in comparison with industrialized countries. "The values reported are typical and acceptable to our level of development".

In the field of transport, although the Cuban vehicle fleet is small and its contribution to global pollution is little, it is taken into account in the planning, design, and organization of traffic, air pollution issues and their cause's contribution to the emission of Greenhouse Gases.

in Cuba, routine monitoring of emissions and removals of GHGs Is undertaken for years. This activity is developed by the Task Force on Greenhouse Gas coordinated by the Institute of Meteorology, and with the participation of specialists from different institutions and agencies in the country.

5. REFERENCES.

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ANEXO 1.

NORMAS CUBANAS RELACIONADAS CON LA CALIDAD DEL AIRE

NC39 99: Calidad del aire. Requisitos higiénico-sanitarios.

NC93-02-102:87: Términos y definiciones.

NC93-02-103:87: Clasificación y simbología de las expulsiones según sus características.

NC93-02-104:86: Reglas para la vigilancia de la calidad del aire.

NC93-02-105:85: Instrumentos para el muestreo del aire en los asentamientos humanos. Requisitos técnicos generales.

NC93-02-106:86: Métodos de determinación de los contaminantes. Requisitos generales.

NC93-02-203:86: Requisitos generales para el muestreo del aire.

NC93-02-207:87: Determinación del contenido de hollín.

NC93-02-208:86: Determinación del índice de corrosividad.

NC93-02-209:86: Determinación del índice de sulfatación.

NC93-02-212:87: Determinación del dióxido de nitrógeno.

NC93-02-213:86: Determinación del dióxido de azufre.

NC93-02-214:86: Expulsiones de sustancias nocivas, por automóviles, tractores y máquinas autopropulsadas agrícolas y de la construcción. Términos y definiciones.

NC93-02-215:86: Opacidad aparente del humo. Método visual.