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Traffic, noise and air pollution in Las Palmas de Gran Canaria. An evaluation of the effects of the ring road

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Abstract

The main objective of this paper is the presentation and analysis of the results of an evaluation of noise and air pollution as a consequence of the road traffic in the city of Las Palmas de Gran Canaria (Canary Islands. Spain). before and after the construction of the projected ring road.
Methodology for evaluation is based on the following steps:

- Construction and calibration of an assignment traffic model to replicate actual traffic conditions and predict main changes of traffic volumes on the main roads of the city after the new road in service.
- An assessment of noise impact. by determination of the population affected by different levels of noise before/after the ring road. Levels of noise are estimated having into account the most important variables with influence in emission and reception of noise: traffic flow. traffic composition (ratio heavy/light vehicles). speed. distance and reflection.
- An assessment of the air pollution through the total emissions of carbon monoxide (CO). nitrogen oxides NO_x and Hydrocarbons (HC). The emission of each pollutant is calculated as a function of the road length. traffic flow. traffic composition. speed and a rate of emission for heavy and light vehicles.

1 Introduction

The city of Las Palmas de Gran Canaria (LPGC) has a population of 360000 inhabitants, with a density of 50000 inhabitants/Km^2 at the city centre. This density descends to 4000 inhabitants/Km^2 at the outskirts. This high density of population and the high rate of vehicle ownership (500 vehicles per 1000 inhabitants) brings out the necessity of high investments in order to satisfy the mobility demand. One of the main projects in progress is a new ring road with a total cost of 250000 ECUS.
The Transport Group in the Department of Mechanical Engineering of the University of Las Palmas de Gran Canaria has developed a traffic model of the city, using the suit of programs SATURN, Van Vliet and Hall[1]. This model allows the evaluation of traffic management measures and new infrastructure. Adding the ring road to the model, it is possible to evaluate what changes will happen in the traffic flow. These changes will have an effect on the environment

and this is what we study in this paper. Only noise and air pollution will be analysed, using a simplified method proposed by the Spanish Ministry of Transport[2], which is applicable at city level.

2 Definition and calibration of the traffic model

A roads network and an origin-destination matrix (O-D) have been developed in order to reproduce the behaviour of supply and demand of transport in LPGC. The O-D matrix consists of 39 zones (35 internals and 4 externals which represent the main entries/exits to the city) and the network consists of 151 nodes and 474 links. It is a conventional traffic assignment model, capacity-restraint is handled by link-based flow-delay curves whereby the travel time on a link is assumed to be a function of the flow on that link. Also, delays at the junctions have been considered in an approximately way.

The methodology used during the elaboration of the model it is shown in the following paragraphs:

- Construction of an initial O-D matrix, based on household and screen-line surveys made by a local specialised consulting (EDEI Consultores) in 1986 and 1987.
- Codification of the city network in 1990, using the following hierarchical levels for the assignment model:
    1. External roads, with high speed and capacity, two or more lane per direction and practically without at level crossings. In these cases, a free flow speed of 90 km/h and a speed at capacity of 45 km/h have been considered.
    2. Internal roads, wide and with enough visibility, with junctions normally regulated by traffic lights. Free flow speed is 60 km/h and speed at capacity 30 km/h.
    3. Internal roads, with high activity and continuous flows of pedestrians and vehicles, usually controlled by traffic lights at junctions. Free flow speed is now 36 km/h and speed at capacity 18 km/h.
- Actualisation of the O-D matrix in 1990, using traffic data from the Traffic Control Centre of the city council for internal traffic, and from the Regional Government for enter/exit traffic of the city. A computer program was developed to make the traffic assignment, using the Frank-Wolfe algorithm, and a maximum likelihood method to estimate the O-D matrix.
- Calibration of the model in 1990, using complementary traffic data.
- Actualisation of the O-D matrix and the network in 1995. This work was based on surveys and traffic data, and there were considered the most important changes in the city network. SATURN programs were used in this step (SATASS fro traffic assignment and SATME2 for matrix estimation).
- Addition of the projected ring road links with the network and traffic assignment to the new network using the SATASS program.

3 Methodology for environmental evaluation

3.1 Evaluation of sound levels

For noise impact assessment, the method proposed by the Spanish Ministry of Transport[2] is used. This method consists, basically, in the determination of a sound level of reference, dependent on the most important traffic characteristics (flow, proportion of heavy vehicles) and the introduction of some correction coefficients which depend on other parameters such as traffic speed, distance between the emission point and the receiver, etc.

The equivalent sound level (L_m) in an homogeneous section of road is calculated using the next expression:

$$L_m^{(25)} = D_v + D_s + D_{refl} \quad (1)$$

where:

$L_m^{(25)}$ = equivalent sound level at 25 metres of the noise source and a traffic speed of 100 km/h.

D_v = correction by speed.

D_s = correction by distance.

D_{refl} = correction by reflection.

The value of the sound level of reference is calculated using the formula (2):

$$L_m^{(25)} = 37.3 + 10 \log [M (1+0.082 h)] \quad (2)$$

where:

M = hourly mean volume of traffic.

h = percentage of heavy vehicles.

The calculation of D_v is done by the use of the expression:

$$D_v = L_h - 37.3 + 10 \log (100+(10^{0.1 D} -1) h)/(100 + 8.23 h) \quad (3)$$

where:

$L_h = 27.7 + 10 \log (1 + (0.02 V_h)^3)$

$L_l = 23.1 + 12.5 \log (V_l)$

$D = L_l - L_h$

V_h = mean speed (in km/h) for heavy vehicles.

V_l = mean speed (in km/h) for light vehicles.

The calculation of D_s is done using the expression:

$$D_s= 15.8-10 \log s - 0.0142 s^{0.9} \quad (4)$$

where **s** is the distance between the emission point and the receiver.

D_{refl} is used in order to take into account the effect of multiple reflections, produced by the rebound of sonorous waves on the buildings. Calculation of D_{refl} is done using the next formula:

$$D_{refl}= 4 h_{Beb} / w < 3.2 \quad (5)$$

where:

h_{Beb} = mean high of the buildings.

w = horizontal distance between frontages.

3.2 Evaluation of pollutants emission rate

Methodology proposed by the Spanish Ministry of Transport was also used to calculate the effects on the pollution in the city. This method calculates global emissions of CO, NO_x and volatile organic compounds due to traffic for each considered option. This model of emission, very useful due to its simplicity, it's based on the decomposition of the process, in such a way that each polluting agent can be analysed separately.
Emission of pollutant (E_k) in each link is calculated using the next expression:

$$E_k = L\,[M\,h\,K_h + M\,(100-h)\,K_l]/100 \qquad (6)$$

where:
L = length of the link (km.)
M = hourly mean volume of traffic
h = percentage of heavy vehicles.
K_h = pollutant emission factor (gr./km) for heavy vehicles
K_l = pollutant emission factor (gr./km) for light vehicles

Table 1: Emission factors for heavy vehicles (g/km).

CO	NO_x	VOC
18.8	8.7	2.75

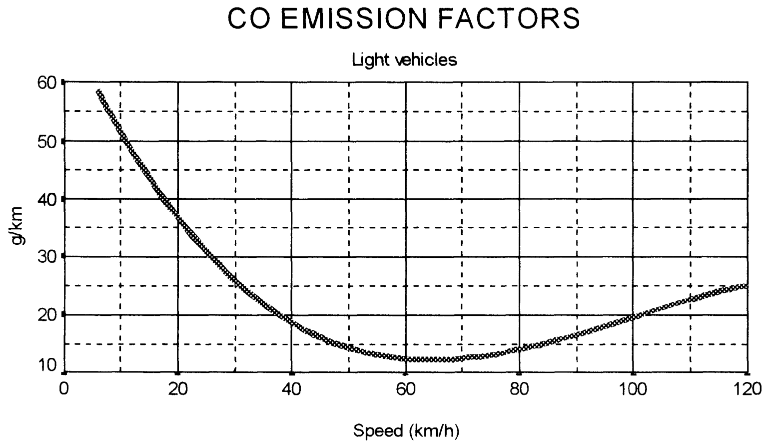

Figure 1: CO emission factors for light vehicles

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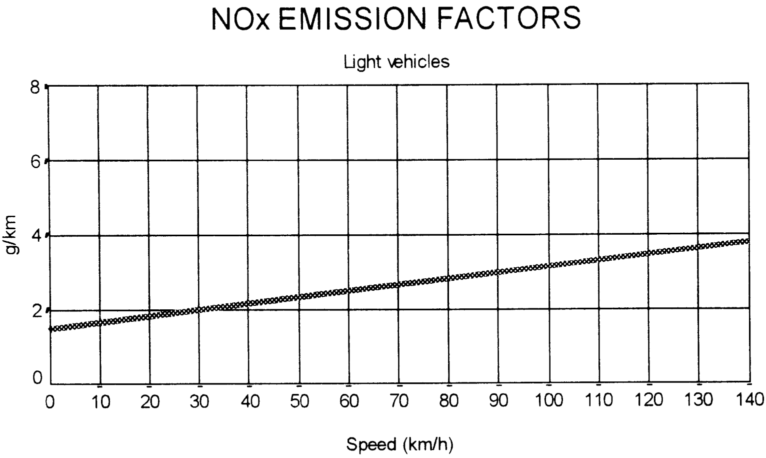

Figure 2: NO_X emission factors for light vehicles

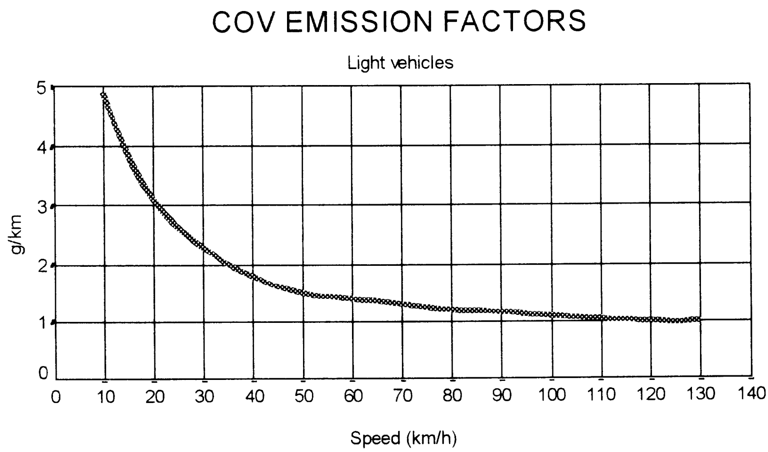

Figure 3: VOC emission factors for light vehicles

4 Analysis of the results

4.1 Sound levels

Limits usually accepted for noise are the following ones: sound levels of 55 dB(A) are considered unsatisfactory, and sound levels higher than 65 dB(A) are unacceptable. This level appears in streets with high flow of vehicles, and causes severe disturbances to sleep, communications, and after a long exposure it will produce a loss of hearing.

Traffic noise in Las Palmas de Gran Canaria (LPGC) is very close to those limits, and in many streets they have been exceeded. So, most of the main streets in LPGC can be considered as "black points" (areas where a sound level of 65 dB(A) is exceeded). After studying 130 kilometres of streets, 94 of them exceed 65 dB(A), that is to say, 72,3% of the total length.
From the analysis of results with ring road, a decrease in flows of vehicles in many streets is expected. Such decrease in flows brings out slight speed rise inside the city, and very high flows of vehicles with a high average speed circulating by the ring road. These changes mean that even though noise levels remain higher than desirable, it can be observed a general decrease in them.
From a total of 168 kilometres of streets, 120 kilometres exceed 65 dB(A), that is to say, 71,4% of the total length. This percentage is very similar to the one obtained for the situation of the city without ring road, but it is important to see that, in those 168 kilometres of streets, the ring road appears now, a very long road with high flows and high average speed, where 65 dB(A) will easily be exceeded. That new road will be a black point, so even though sound levels inside the city have been reduced, in percentage of investigated areas, the results look similar.
For the assessment of the environmental impact of every transport policy, it must be obtained the population exposure to each noise level (Table 2).

Table 2: Population exposure to different sound levels

	LPGC without Ring Road	LPGC with Ring Road
Level A: $L_m > 75$ dB(A)	10835 (6.5%)	10799 (6.2%)
Level B:$65 < L_m < 75$ dB(A)	57543 (34.2%)	56791 (32.6%)
Level C: $L_m < 65$ dB(A)	99567 (59.3%)	106800 (61.2%)

People living at the inner city will get a decrease in sound levels, but approximately 6300 inhabitants (people who live near the ring road) will suffer a very important increase in noise levels near their homes.
This results confirm one of the main difficulties to be faced when trying to decide between policies to control noise impact: costs and benefits usually affect different groups of people.

4.2 Pollutant emissions

In this paper it was only evaluated the pollutant emissions in global terms. This measurement of emissions is an indirect indicator of the contribution of vehicles to air pollution. The estimation of air pollution suffered by population (pollutant inmission and concentration) depends on topographic,

meteorological variables and chemical reactions very difficult to model, which is beyond the objective of this paper.
The results of pollutant emissions are similar to those of sound levels. Streets with higher flows of vehicles suffer the highest sound levels and the highest emissions.
CO emissions grow from 67 to 72 tons/day, NO_x emissions from 13 to 14 tons/day, and VOC emissions will remain to, approximately, 6 tons/day. These changes mean increases of 7% and 11% in CO and NO_x emissions, and a 3% decrease in emissions of VOC.

Table 3: Changes in pollutants emission

	CO	NO_x	VOC
Central Area	-27%	-26%	-30%
Global	+7%	+11%	-3%

Table 3 shows changes in emissions with ring road. In global terms, these emissions grow, but they decrease considerably in the central area of the city, because of the reduction in the number of vehicles circulating inside it.
As the amount of emissions in global terms will not be so significant for people who are not skilled in air pollution, it is interesting to compare the results with those for the rest of the country, and other countries in Europe. So, OECD publications show that the whole emissions in Spain were 577000 tons/year (NO_x) and 513000 tons/year of VOC, Brow et al[3].
With ring road, the emissions in LPGC will reach 5376 tons/year (NO_x) and 2210 tons/year of VOC. So (realising we are comparing amounts in different years), NO_x and VOC emissions mean, approximately, 0.9 and 0.4% of the whole emissions in Spain. In order to compare, it is necessary to take into account that the population of the city is about 1% of the Spanish population.

Table 4: Emissions from mobile sources in Europe (1988).

Country	NO_x (kg./inhabitant)	VOC (kg./inhabitant)
Germany	30.1	21.7
Italy	18.4	15.4
France	18.6	N.D.
U. K.	24.7	17.0
Spain	14.9	13.2
LPGC	15.6	6.4

Considering the population, and studying official statistics of OECD, Brow et al[3], NO_x and VOC emissions per inhabitant due to transport sources in some European countries are shown in Table 4.
In the light with the results in Table 4, it can be observed that pollutant emissions in Spain are still lower than those of the rest of European countries. On the other hand, emissions in LPGC are similar to those of the rest of Spain.

5 Conclusions

The results of the present paper show that the reassignment of traffic, and the speed rise caused by the construction of the ring road will have the following effects:

- The amount of people affected by the higher sound levels will slightly decrease.
- Despite of the decrease of the sound levels, these will remain much higher than recommended.
- People living near the ring road will suffer an important increase of the sound levels in their environment.
- There will be a decrease of the pollutant emissions inside the city, but they will globally grow.
- These redistribution of emissions will let them concentrate outside the city, with low density of population and topographic and meteorological conditions which improve dispersion.
- The amount of expected emissions with ring road will remain lower than those of other countries in Europe.

From the conclusions that have been presented it is easy so see that the ring road is not so positive for environment as it would be desirable. In the long term it will bring an important increase in the amount of trips, and with it, higher sound levels and higher emissions. However, it should not be missed the chance of its construction to try other mobility policies: improving collective transport systems, and promotion of walking and bikes, with zones for their exclusive use that were safe, pleasant and really feasible of being used.

6 References

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