The environmental impact of urban transport: a case study for a new road in Catania province

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Abstract

The opening of a new road to car traffic could represent a symbol of socioeconomic growth for a country, but in the meantime it could also cause significant impact to the local ecosystem in the absence of a preliminary study into the environmental impact which is able to forecast if it is necessary to carry out additional works to control the immissions into the atmosphere of the polluting exhausts of motor vehicles. The estimation of impact caused by the transit of motor vehicles is quite complex because it needs to know both the state of pollution at the present time and the forecasting of further immissions of polluting gasses caused by traffic on the planned future road. To achieve this, research evaluated the effect of the construction of a provincial road "S.P. Misterbianco-Nicolosi" in order to have both an experimental validation of a dispersion code for such an outdoor environment full of anthropic obstacles as well as to evaluate the respect of the limits of polluting gaseous concentrations fixed by current Italian regulations. This paper, therefore, intends to show the results of research and the adopted rules of procedure.
Keywords: air pollutants, exhaust by vehicular traffic.

1 Introduction

Atmospheric pollution from exhaust gasses of road haulage is produced essentially by carbonic oxide, coming from gasoline engines, and particulate matters, coming from diesel engines.

Carbon oxide emissions during the run of a vehicle is about ten times higher in comparison with other polluting substances contained in gasoline exhaust gasses. The ultrafine dusts that can be inhaled (PM10) and the ones that can be breathed (PM 2,5 and PM 1,0) originate from diesel exhaust gasses and reach

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more than 30% of urban aerosol coming from the total urban combustions. For these reasons carbon oxide and particular matters have been chosen as chemical tracers of air pollution of road haulage.

2 Study case

The study case wants to discover the evaluation of air pollution induced by future road traffic of provincial road (km 10,16), which is actually in the design phase, that will link the north bypass of Catania city with Nicolosi town crossing Misterbianco town too, Fig.1.

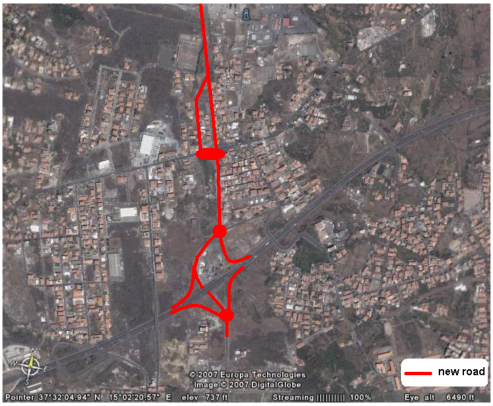

Figure 1: Provincial road "Misterbianco-Nicolosi".

The chemical tracers pollutants taken in consideration were CO and PM10. The research has been carried out through the following procedure:

- Analysis of every area crossed by the designed infrastructures.
- Campaign in situ of measurements both of PM10 and CO concentrations existing at the present state.
- Analysis of most significative meteoclimatic conditions presented by territory crossed by the road during the course of a year, that is a historical series of air temperature (°C), relative humidity (UR%), wind velocity (m/s) and its directions.
- Analysis of traffic flows at the present state.
- Forecast of traffic flow along designed road post operam aedificatam to forecast diffusion of air pollutants in comparison with data coming from the present state.
- Validation of the adopted model through comparison between the polluting concentration of data forecasted and those measured in situ during the campaign of measurements.
- Application of the same model but with input data related to design conditions and forecasted traffic flow of the new road.

The previous procedure was applied in three areas of territory considered as being particularly subject to pollution, that is: *Misterbianco* town, *Le ginestre Village*, and *Elio Vittorini* college area.

The calculus code CALINE [1], based on Gaussian model of dispersion, so called “at plume”, was used to measure the pollutant concentrations.

The values of emission factors for the pollutants considered have been extracted by the application of COPERT model [2].

Road traffic data is used to model the actual conditions which are measured in situ.

By comparing the data between the results of those from the actual location and the ones produced from the model, which relate to future conditions, it has been possible to value the “environmental compatibility” of the new road.

3 Experimental measurements

The whole route of the road has been subdivided into fifteen stretches so that each stretch may be considered “homogeneous” as regards traffic volume and meteoclimatic data.

Each one of the previous stretches have been allocated fifteen measure stations and further stations have been positioned near “sensible receptors” in the vicinity of the planned route of the road.

Both measurements of polluting gas and meteoclimatic conditions have been carried out as follows:

- Three days of measurements for each station: two on working days and one in a holiday period
- Four intervals of time (Observation Time) during each day of measurements, that is: 06-10h; 12-15h; 18-21h; 18-22h; 22-06h.
- Ten minutes of measurements for each Observation Time.

Results coming from measurements have been collected in tabular data: “cards of road traffic”, Tab.1 and “report of measure”, Tab.2.

4 Measure equipments

To measure the fractions of PM10, PM2,5 and PM 1,0 in the air, we utilized GRIMM MODEL 107. The technical characteristics of the instrument are shown in Fig. 2. To measure the concentration of toxic gasses in the air we utilized Multi Rae Plus able to measure concentrations of various gasses (O_2, CO, CO_2, $H2_S$, SO_2, NO_x) and combustible gasses too. The technical characteristics of the instrument are shown in Fig. 3.

5 Calculus model

The values of emissions have been calculated by the COPERT model [2].

To create a database for the COPERT model we utilized data related to yearly consumption of fuel [3], Tab. 3.

Table 1: An example of a "card of road traffic".

MEASURE POINT N.13 Misterbianco town									
Day	Road section	06-10 h		12-15 h		18-21 h		22-06 h	
		Vehicles/h		Vehicles/h		Vehicles/h		Vehicles/h	
		light	%heavy	light	%heavy	light	%heavy	light	%heavy
02/03/06 Thursday	A	606	10,89	684	6,14	1290	0,00	144	0,00
	B	894	21,48	1302	4,61	1086	0,55	324	0,00
	C	42	0,00	42	28,57	36	0,00	18	0,00
	D	6	0,00	12	50,00	0	0,00	0	0,00
	E	780	20,00	804	10,45	1230	0,98	294	0,00
03/03/06 Friday	A	462	16,88	618	6,80	1056	1,13	138	0,00
	B	1092	8,79	1320	7,73	1644	0,00	360	0,00
	C	42	14,29	36	33,3	54	0,00	24	0,00
	D	6	0,00	6	100,00	0	0,00	6	0,00
	E	811	9,62	786	11,45	1074	0,00	270	0,00
05/03/06 Sunday	A	216	0,00	582	0,00	642	O,93	117	0,00
	B	546	0,00	1272	0,47	1440	0,42	462	0,00
	C	54	0,00	36	0,00	48	0,00	12	0,00
	D	0	0,00	0	0,00	0	0,00	0	0,00
	E	486	0,00	618	0,00	564	1,01	204	0,00

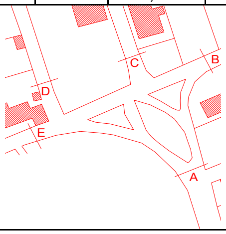

Table 2: Example of a "report of measure".

REPORT OF MEASURE							
MEASURE POINT N.2 Nicolosi town - *Gino Cervi* street							
Day	**Tr**	**To**	**Temperature °C**	**Relative Umidity %**	**Wind velocity m/s**	**PM10 µg/m³**	**CO ppm**
02-03-06	24 h	06-10	16	45	2,5	64,4	0,00
		12-15	17	36	2	48,0	0,10
		18-21	8,5	63	0,3	10,3	0,00
		22-06	8	65	0,5	13,1	0,00
03-03-06	24 h	06-10	13	55	1	11,5	0,00
		12-15	14,5	65	1	11,5	0,00
		18-21	6	90	1,5	23,6	0,00
		22-06	6,5	92	1,5	25,2	0,00
05-03-06	24 h	06-10	16	45	2,5	20,7	0,00
		12-15	19	48	2,5	22,5	0,00
		18-21	12,5	50	2	30,1	0,00
		22-06	12,5	49	1,5	25,6	0,00
					Min value	7,5	0,00
					Daily mean value	20,8	0,00
					Max value	71,0	0,10

Mass range	0-650 mg/m^3	
Accurancy	1-20 Mio Particle	
Flow	1,2 liters/min	
Working temperatures	+4°C to +45°C	

Figure 2: Particles analyzer.

Sensor	**Pollutant**	
infrared	CO2	
catalitic	Combustibile gas	
Electrochemical	O2 and toxic gas	
Working temperatures	= 2208C41458C	
Working UR%	= 0495	
Sensor accuracy = 04500 ppm		
Reply time= 20 s		

Figure 3: Toxic gas analyzer.

Table 3: Fuel consumption.

Yearly fuel consumption (t)	Italy	Catania Province
Gasoline	14559	265,64
Diesel	14682	267,88
GPL	1106	20,18

- Both the maximum and minimum values of environmental temperatures related to Catania province have been deduced by "meteorological day-books".
- The factors of emissions are calculated by the COPERT model.
- The modelling of the investigated areas has been done by CALINE 4 Caltrans implemented by the authors.

We considered each of the previous related fifteen stretches as one linear source of emission, each of them being homogeneous as regards:

- Geometrical features: typology, width of carriage way and altitude with reference to local ground.

- Traffic features: yearly amount of running motor vehicles and their typology [4].

With reference to definition of angles of wind, we chose the azimuthal ones regarding the North direction. The ruggedness of ground surfaces around the road route has been considered unvarying in all areas crossed by a single stretch.

The meteoreologic variables of atmospheric stability (wind velocity and direction) have been considered unvarying too for each stretch.

For each homogeneous stretch, Fig. 4, we defined the right area of study by a specific calculus grid as shown in Tab. 4.

With reference to the part of the route in the area of Misterbianco town, we chose fourteen strips of road each one of them showing the same homogeneous characteristics of emissions. As regards meteoreologic data, we adopted one set of data linked to all “stability class” adopting wind velocity always less than 2,5 m/s as discovered through the campaigns of measurements for the investigated area. In this way we fixed twelve input conditions with wind velocity varying from 1,5 to 2,5 m/s. As regards wind direction, measurements in situ show an excessive variability and for this reason we have been obliged to consider twenty four possible directions (0°,15°,30°...360°). After all, we considered 288 possible meteo conditions as shown in Tab. 5.

Table 4: Calculus grid.

GRID	
Origin : x-axis ; y-axis	677,51m ; 288,11m
N point x-axis ; y-axis	100 ; 100
Dx dy	3,16 m ; 10.48 m
Mean Altitude	230 m
Ground elevation	1.5 m
Roughness	10 cm

Table 5: Meteo conditions.

Wind Direction ° to North	***Wind Velocity m/s***	***Class of stability***					
		A	*B*	*C*	*D*	*E*	*F+G*
		Meteo conditions					
15	*1,5*	1	2	3	4	5	6
15	*2,5*	7	8	9	10	11	12
...	...	...	...	...	...	...	...
360	*1,5*	277	278	279	280	281	282
360	2,5	283	284	285	286	287	**288**

Figure 4: *Misterbianco* town: homogeneous stretch of road.

6 Results of simulations at actual state

Tab. 6 and Fig. 5 show the results respectively of concentrations of PM10 and CO in each receptor, the map of isoconcentration of PM10 and that of isoconcentrations of CO in one strip of the investigated area of Misterbianco town.

The validation of model has been done through comparison between data coming from campaigns of measurements, as previously related, and those by application of the Caline model: both data related to the same time of observation. One can observe the difference between the measured data and those forecasted in Tab. 7.

Such a procedure of comparison allows one to determine the range of diverging, that is the divergence of the values, between the two series of data (measured and forecasted) so to discover if such a difference can cause the exceeding of limits of concentrations fixed by rules in each single receptor and, consequently, to design the appropriate work of acoustical control when the limits are overcome.

Table 6: CO-PM10 concentration.

Reptors	**X (m)**	**Y (m)**	**PM10 ($\mu g/m^3$)**	**CO (ppm)**
1	677.51	891.41	20,5	O,12
2	759.45	929.16	21,0	0,15
…	…	…	…	
13	988.91	317.66	20,8	0,18

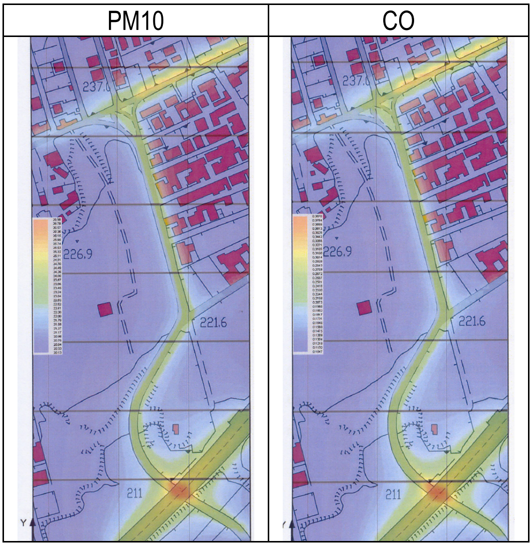

Figure 5: PM10 and CO isoconcentration maps.

Table 7: Validation of results.

Investigated Area	Measure point	(1)PM10 limit value (Italian regulation)	(2) PM_{10} mean measured value	(3) PM_{10} forecasted value	Δ=(1)-(3)
		μg/m³			
Misterbianco	12	50	20,2	21,2	28,8
	13		23,9	26,7	23,3
	14		23,2	27,0	23,0
	15		21,8	23,4	26,6
E. Vittorinil	9		21,7	26,60	23,4
Simulated Area	Measure point	(1)CO limit value (Italian regulation)	(2) CO mean measured value	(3) CO forecasted value	Δ=(1)-(3)
		mg/m³			
Misterbianco	12	15	0,11	0,55	14,45
	13		0,26	0,42	14,58
	14		0,24	0,50	14,50
	15		0,18	0,37	14,63
E. Vittorini	9		0,013	0,13	14,87

7 Results of simulation at the forecast state (post operam aedificatam)

The modelling of the forecasted state has been carried out by the same criteria previously referred, utilizing the same meteoclimatic and morphological characteristics and the same investigated areas. The only changing concerns were: very little diverging of road axis in same zones in comparison with the position of axis of the actual road, a little additional strip of road and some road steep slopes.

All these possibilities do not influence significatively the procedures previously adopted. Also the new road (Fig.6) has been schematized through fifteen links each one being homogeneous as regards polluting emissions.

Tab. 8 and Tab. 9 show the results respectively of concentrations of PM10 and CO in each receptor whilst figure 7 shows the maps of isoconcentrations both of PM10 and CO in the strip shown in Fig. 6.

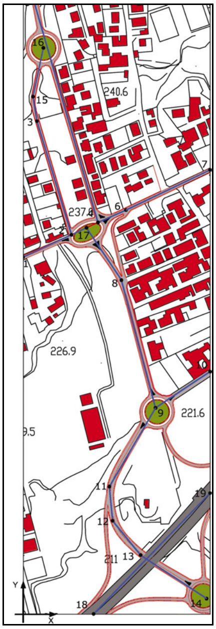

Figure 6: The future route of road.

Table 8: PM10 concentrations.

Investigated Area	Measure point	Measured value μg/m³	Forecasted value μg/m³	Δ μg/m³
1 – Misterbianco	(12) Misterbianco - Campo sportivo	20.1	24.2	4.1
	(13) Misterbianco - S.P.N12/I	20.8	23.4	2.6
	(14) Misterbianco – via Amenano	21.4	25.0	3.6
	(15) Misterbianco – Lineri	22.6	26.2	3.8

Table 9: CO concentrations.

Investigated Area	Measure point	Measured value ppm	Forecasted value ppm	Δ ppm
1 – Misterbianco	12) Misterbianco - Campo sportivo	0.00	0	0
	(13) Misterbianco - S.P.N12/I	0.00	0.11	0.11
	(14) Misterbianco – via Amenano	0.11	0.23	0.12
	(15) Misterbianco – Lineri	0.10	0.20	0.10

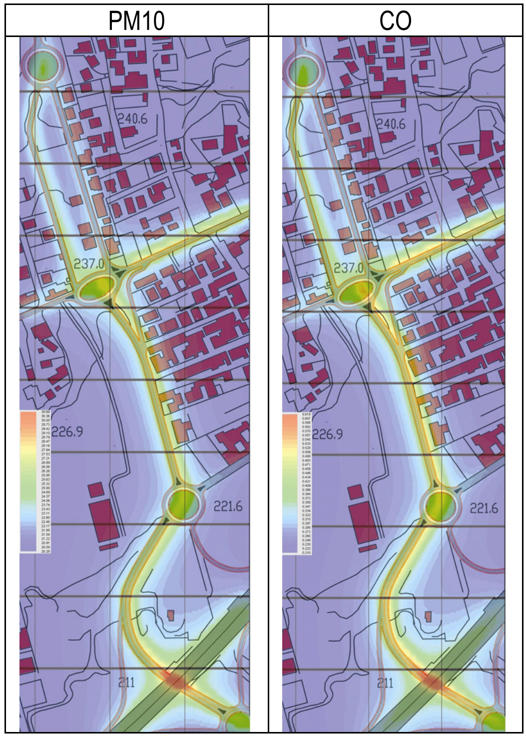

Figure 7: PM10 and CO isoconcentration maps.

Table 10: PM10 forecasted values.

Investigated Area	Measure point N.	(1) PM10 limit value (Italian regulation)	(2) PM10 mean forecasted value	(3) PM_{10} maximum forecasted value	Δ=(1)-(3)
		μg/m³			
Misterbianco	9	50	27,0	44,2	5,8
E. Vittorini	11		26,4	41,6	8,4
Le Ginestre	2		26,5	44,1	5,9

Table 11: CO forecasted values.

Investigated Area	Measure point N.	(1) CO limit value (Italian regulation)	(2) CO mean forecasted value	(3) COmaximum forecasted value	Δ=(1)-(3)
		mg/m³			
Misterbianco	9	15	0,50	1,17	14,45
E. Vittorini	11		0,16	0,45	14,55
Le Ginestre	2		0,27	0,99	14,01

8 Remarks on results and conclusions

Tab. 10 and Tab. 11 show in which receptors concentrations of PM10 and CO reach the biggest forecasted values, and the average and also the permitted values too.

It is can be seen that as regard PM10 pollution, the annual limits of concentration allowed by Italian rules is very unlikely to be exceeded and even random levels will be lower than permitted by Italian regulation (n.35/year).
For annual CO pollution in more impacted receptors, forecasted concentrations are amply lower than that allowed by the current rules and there is a large margin of safety for inhabitants. In conclusion, the construction of the new road does not present problems of pollution of the atmosphere or any danger to the health of the inhabitants of the area, so it is possible to confirm the environmental compatibility of the newly designed road.

In another paper the Authors will show the environmental incompatibility of the road as regards its acoustical impacts on resident people.

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