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NEW AIRPORT NOISE MANAGEMENT TECHNIQUES

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ABSTRACT

The Lombardy airport system is composed by the three international nodes of Malpensa, Linate (respectively the second and the third Italian stopovers) and Orio al Serio (third Italian freight node). They involve almost the 23% of the totality of the Italian airport departures and approaches. Montichiari airport is included as well: less important than the others, it is assuming a growing strategic role.

Thus, airport noise pollution is one of the main issues in the Lombardy environment care framework. It has led to the realization of three noise continuous-monitoring systems in correspondence of the three main airport nodes. In order to face the existing population demand of noise control, the Regional Environmental Protection Agency (ARPA) together with the Lombardy Regional Administration, has set up a specialized technical centre (PTA – Presidio Tecnico Aeroportuale). The main activities and aims are:

1. Monitoring system checking;
2. Elaboration of airport noise impact scenarios;
3. Estimation of population noise exposure.

The first one is a technical-instrumental activity. A *checklist* has been carried out, which allows an effective, systematic evaluation of the airport monitoring activities.

As far as modelling activities are concerned, the PTA is currently testing the input data of the INM model computational algorithms, in order to enhance the evaluation of the environmental noise impact and improve the analysis of local scenarios.

The exposed population assessment represents a meaningful issue both for the environment and inhabitant’s protection, and for regulatory purposes as a valid decisional tool.

The PTA is implementing a new land use–based methodology with the application of computational algorithms that can assign different population density weights to territorial areas.

Even if recently established, the PTA has achieved encouraging results. The monitoring system checking activities have allowed a reliability improvement, while the noise impact evaluation has led to the optimisation of INM model application. Finally, the development of a reference methodology of the exposed population assessment constitutes a useful and easy to apply regulatory tool. This aspect will be the subject of the following paper.

INTRODUCTION

The noise produced by transport infrastructures is a critical environmental problem, especially in the densely populated areas: is that the case of the Linate and Malpensa airport.

Under these circumstances it's mandatory to apply a mathematical simulation model analysis in order to investigate different traffic sceneries and to define the noise level contours around the airport areas. The aim is to minimize the take-off and landing operation impact.

For this kind of investigation, the PTA technical centre uses one of the more diffused airport noise statistical model, the FAA's (Federal Aviation Administration) Integrated Noise Model (INM 6.1).

By choosing appropriate acoustical pressure indicators, it's possible to build-up a well defined and geo-referenced noise contours produced by airport traffic. Such contours are then imported in the PTA's Geographical Information System for environmental impact analysis. This approach permits to evaluate the noise affected areas extension and to define the involved land use classification, through a comparison with other geographical databases. The natural and most important evolution of this kind of study consists in estimate the population involved in the noise affected areas.

ARPA Lombardia has created a new methodology to evaluate the noise exposed population through the information obtained with the photo-interpretation of the ortho-photo digital images acquired in the 1994 for the whole Lombardy country -- the DUSAF (Use Destination of Agricultural and Forest Soil) dataset. The main process consists in assigning the total citizen population in the different territorial sub-areas (which represents the different land use classified areas) defined through photo-interpretation.

By the interception between noise contours and the sub-area edges defined in the dataset DUSAF, it's then possible to evaluate the population exposed to different noise level.

The DUSAF cartography represents the Lombardy territory subdivided in its different employs: agricultural, urbanized residential, industrial, commercial. It doesn't give quantitative information (such as population, density, assigning) on different territorial areas, but just qualitative (extension and land use).

THE METHODOLOGY

Hypothesis

The main methodology hypothesis consists in assuming that the whole population is distributed exclusively in areas where the soil has been classified as "Urban" in the DUSAF dataset.

The "Urban" class is subdivided in different subclasses: we assume that the population is distributed just in subclasses defined as "Residential". In the DUSAF dataset, the "Urban" "Residential" subclasses are defined as follow:

- Class 1: Dense residential tissue: urban areas characterised by high residential buildings (blocks, skyscrapers) and down-town areas where more buildings constitute complex units. Buildings, roads and artificial surfaces covering from 80% to 100% of total area.
- Class 2: medium dense mixed residential tissue: urban areas characterised by residential buildings and small residential units. Buildings, roads and artificial surfaces covering from 80% to 100% of total area
- Class 3: discontinuous residential tissue: buildings, roads and artificial surfaces covering from 50% to 80% of total area.
- Class 4: thin unit residential tissue: areas characterized by distinct residential building, grouped in small units. Buildings, roads and artificial surfaces covering from 50% to 30% of total area.
- Class 5: scattered residential tissue: residential building within semi-natural or agricultural spaces. Buildings, roads and artificial surfaces covering less than 30% of total area.

Another hypothesis consists in considering the population repartition in terms of "occupied surface", i.e. the residential tissue area density, and consequently the different building heights are not taken into account .

Procedure

The DUSAF informative layer classifies the land use as a function of building density: an a-dimensional weight p_i, proportional to building density, is assigned to each surface.

For every main area (town, municipality), the total surface belonging to each of m (m = 1, 2, 3, 4, 5) classes is determined and then multiplied by the corresponding class weight.

The next step consists in summing the m values obtained; the result represents the "Weighted Surface" (S_p).

Representing with

s_{ij} the surface of the j-th area (polygon) belonging to the i-th class;

n the polygon number of the i-th DUSAF class;

p_i the weight of the i-th class;

m the number of classes presents in the main area (town, municipality);
we obtain :

$$S_p = \sum_{i=1}^{m} \left(p_i \cdot \sum_{j=1}^{n} s_{ij} \right) \quad [1]$$

The number of inhabitants Ab_{ij} is assigned to each j-th polygon, belonging to the i-th DUSAF class having surface s_{ij} with the formula:

$$Ab_{ij} = \left(\frac{p_i \cdot Ab_{tot} \cdot s_{ij}}{S_p} \right) \quad [2]$$

Where Ab_{tot} is the total population of the main area.

Testing

To verify the methodology consistence, a test experiment has been performed in the areas around the Linate and Malpensa Airport. The municipality administrations involved in the test have gently grant the access to their own population data. Where possible, the geo-referenced data have been acquired and imported in the PTA's GIS.

Municipality	**Territorial pop. data detail**
Peschiera	Roads
San Donato	Block, set of blocks
San Giuliano	Block, set of blocks
Arsago Seprio	civic address, for each road
Segrate	civic address, for each road

Table 1 – Level of detail of the population data provided by Municipalities

The precision level in the geo-referenced data has been supplied in different formats: from a well detailed information regarding the citizen number for each civic address, for every road, to a less detailed data concerning the citizen number for every block or set of blocks.

The weight assigned to a land-use class has been set equal to the normalized mean of the building occupied surface percentage, as defined in DUSAF cartography. For example, regarding Class 1, with a residential surface coverage defined from 80% to 100% of the total area, the weight has been set equal to 90 and successively normalized to 0.295. Then a different weighting set has been computed in order to minimize the standard deviation from real and forecasted data.

Classe	DUSAF Weights normalized	"Estimated" weights
1	0.295	0.3
2	0.295	0.23
3	0.213	0.17
4	0.131	0.15
5	0.066	0.15

Table 2 – DUSAF and Estimated weight definition for each urban class

The "real" inhabitant number is assigned to each DUSAF-defined area by intercepting it with the urban area supplied from the Municipality. In the eventuality that the sum of the DUSAF-defined areas shouldn't match with the sum of the "real" urban areas as provided by the Municipality itself, the total real population will not match with the total forecasted population.

Defining:

- Real inhabitants = geo-referenced inhabitants as provided from Municipality databases.
- Forecasted inhabitants = inhabitants distributed with the DUSAF methodology
- Real area = urban area as defined in the Municipality databases
- DUSAF area = area of polygons defined in DUSAF dataset
- Forecasting error = difference between real and forecasted inhabitants

Results

The test experimentation has involved 5 different Municipalities, with a total of 121605 inhabitants; the total forecasting error has been quantified in –25234 units, a total over-estimation equal to 20.75%, with a standard deviation equal to 10%. In the result analysis, it's necessary take into account the different nature of data provided by Municipalities: Segrate and Arsago Seprio, with a dataset permitting an accurate polygon inhabitant evaluation, show a low total error respect to other Municipalities:

Municipality	DUSAF population	Real population in urban areas	Forecasting Error	% Forecasting Error
Arsago	4588	3954	-634	-13.8%
San Donato	32376	24389	-7987	-24.7%
San Giuliano	31280	22633	-8647	-27.6%
Segrate	34088	31875	-2213	-6.5%
Peschiera	19273	13520	-5753	-29.9%

Table 3 – Real and estimated population and consequent forecasting error

A single-polygon investigation shows how the forecasting error is inversely proportional to the polygon extension: in wide areas (>25000 m^2) the territory properties are less significant and the errors are spread on the whole surface.

The forecasting procedure could be significant for medium extended areas (from 10000 m^2 to 25000 m^2), such as the resulting interception between noise contours and the DUSAF polygons.

On small areas (<10000 m^2) the weight of secondary variables, such as the peculiarity of the territory considered (football fields, kind of buildings, parks, parking places) or the unavoidable DUSAF cartography simplification, become significant, leading to a high forecasting error. There are situations where polygons classified Class 4 which contains condominiums or block of flats: without considering the building heights, a smaller inhabitants number is assigned to these polygons, while they're densely populated.

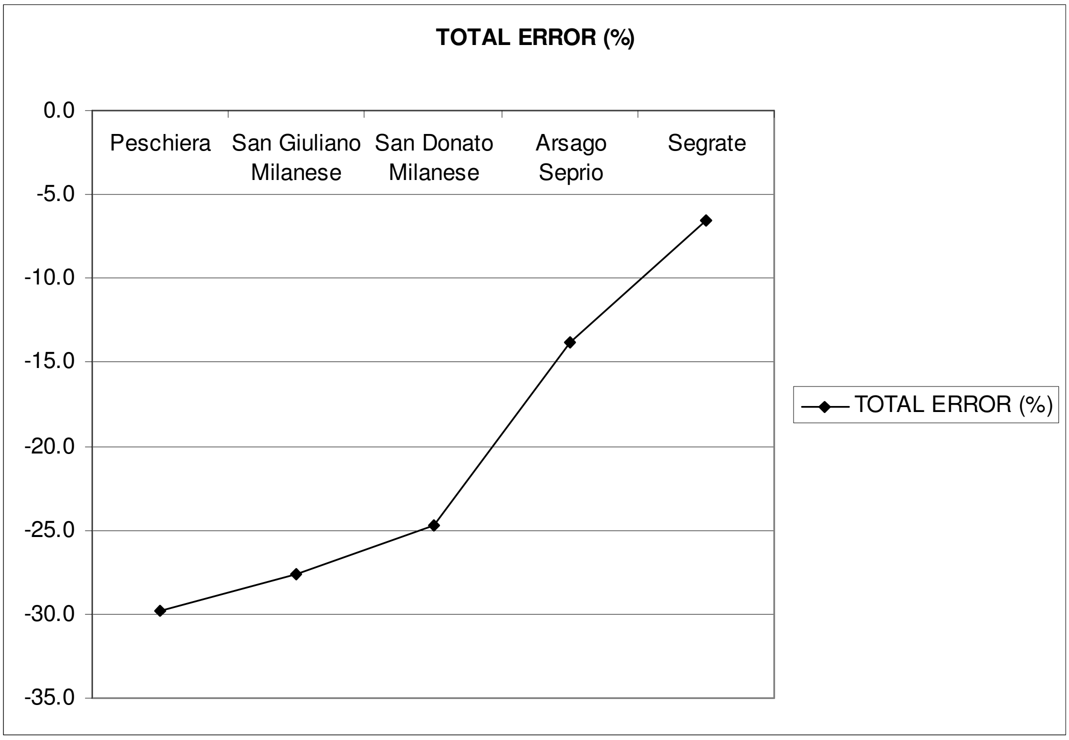

Figure 1 - Forecasting error (%) between real population and estimated population for each municipality

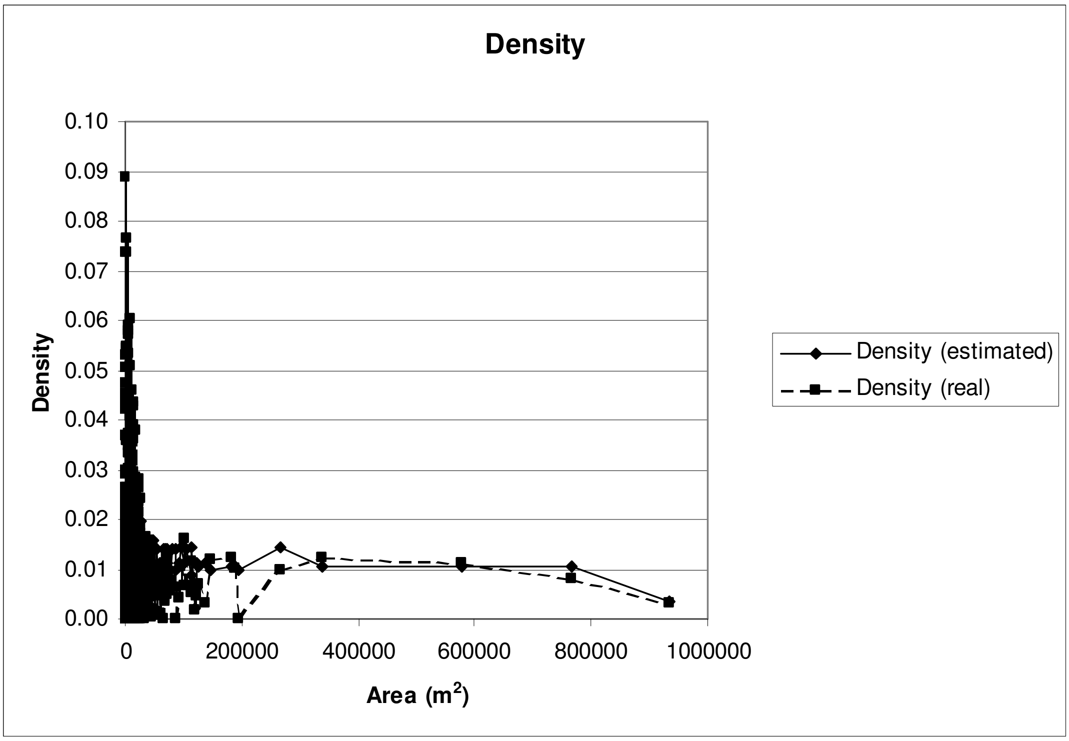

Figure 2 – Evaluated density and real density for each polygon in DUSAF's dataset

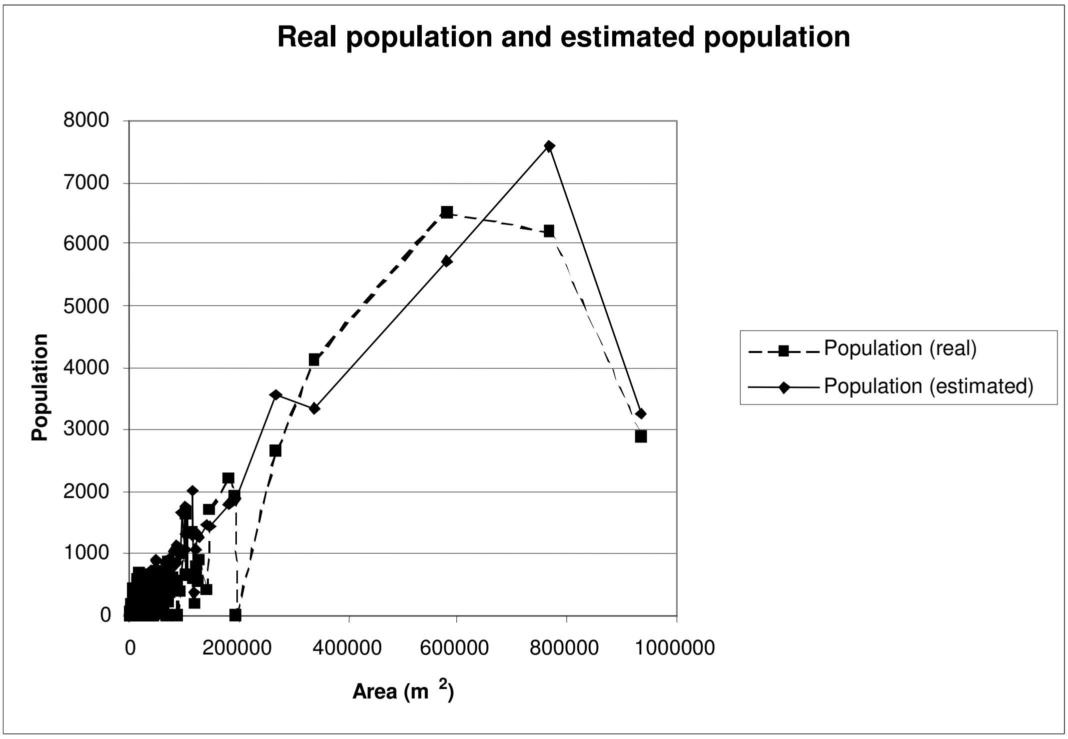

Figure 3 - Evaluated population and real population for each polygon in DUSAF's dataset

Another problem consists in the updating of the reference cartography: it's mandatory that, in the land-use map, the urban residential areas be the most defined and updated. Furthermore, since the methodology process is normalised, the more the difference between real and DUSAF-defined areas increases, the more the difference between "real" and estimated inhabitants will grow.

CONCLUSIONS

The illustrated methodology has the advantage to be simple and quick to apply, permitting, in lack of well detailed and geo-referenced population data, an immediate and reliable estimate of population in an area. The forecast reliability is higher in wide and medium extended areas (such as blocks or blocks agglomeration), while in smaller areas the population estimate will suffer the influences of the territorial peculiarity.

This methodology could be well applied in the estimate of population exposed to airport noise pollution or traffic pollution; if more punctual evaluation are required it must be taken into account that the forecasting process suffers certain limitations, such as the normalization property or to the urban tissue among on it's applied.

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