DELIVERABLE 2

"Noise propagation model optimized and validated"

LIFE 09 ENV/IT/102

NADIA
Noise Abatement Demonstrative and Innovative Actions and information to the public

Working group of the project

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1 Introduction

The noise propagation model used within NADIA project was, as stated by European Directive 2002/49/EC [1] also called END, the NMPB-Routes-96 [2]. The END was acknowledged in Italy by the Legislative Decree 194/05 [3]. Italy has not a national computation method therefore the realization of noise maps and strategic noise map for the evaluation of the parameters requested by the END has to be done with the interim methods. In fact the Annex 2 of the END specified that:

> *"For Member States that have no national computation methods or Member States that wish to change computation method, the following methods are recommended: ..... For ROAD TRAFFIC NOISE: The French national computation method 'NMPB-Routes-96 (SETRA-CERTU-LCPCCSTB)',referred to in 'Arrêté du 5 mai 1995 relatif au bruit des infrastructures routières, Journal Officiel du 10mai 1995, Article 6' and in the French standard 'XPS 31-133'. For input data concerning emission, these documents refer to the 'Guide du bruit des transports terrestres, fascicule prévision des niveaux sonores, CETUR 1980'."*

In order to evaluate the propagation of noise emitted by roads with the NMPB, the following input data should be used:

- Annual average of lightweight vehicles (under 3,5 tons) traffic flow and velocity;
- Annual average of heavyweight vehicles (over 3,5 tons) traffic flow and velocity;
- Type of traffic flow (steady, unsteady, accelerated, decelerated);
- Type of road surface;
- Road gradient;
- Type of ground surface;
- Meteorological data.

The Deliverable 2 aims at defining a standard methodology to organize the aforementioned input data using GIS (Geographic information System) files. All the input data should be given in a GIS format (or shapefile, file extension .esri and related), in order to analyse and verify them even through open source software. The GIS technology allows to relate cartographical data with other information (population inside a building, traffic flow of a road, kind of road surface, etc.). Last but not least, the shapefiles can be easily imported in noise simulation software.

The Deliverable 2 defines a standard identity code for the shapefiles name and for their attributes. This procedure aims at performing noise simulation activities in a fast, accurate and efficient way because:

- the methodology simplifies the input data collection. The data to be collected are listed;
- standardized shapefiles make the organization of the input data easier and more functional;
- standardized shapefiles reduce the duration of the simulation s activity, because the input data are organized in a proper way. This allows to spend more time on the optimization of the noise simulation activities making their outcome more realistic.

The methodologies developed in NADIA project and reported in the Deliverable 2 can be easily applied in other road noise mapping activities using the NMPB-Routes-96.

2 Roads mapped within NADIA Project

Within the activities of the NADIA project 3 roads managed by the Province of Savona (PROVSV), 5 by the Province of Genova (PROVGE) (Table 1) and parts of the agglomerations of Prato (COMPR) and Vicenza (COMVI) were modelled.

Table 1: List of the roads managed by the Provinces of Genova and Savona and mapped within NADIA Project

Managing Authority	**Road**	**Managing authority**	**Road**
PROVSV	SP28 bis	PROVGE	SP35
PROVSV	SP29	PROVGE	SP225
PROVSV	SP334	PROVGE	SP333
PROVGE	SP33	PROVGE	SP523

Each road listed in Table 1 has more than three million vehicle passages per year, so the Managing Authorities were in charge to fulfil the requirement of the END within June 30 2012 (Article 7 of [1]). The agglomerations of Prato and Vicenza have more than 100.000 inhabitants (but less than 250.000), so their Managing Authorities should meet the same deadline for their strategic noise maps.

3 Collecting data

The quantity of data needed for the realization of noise maps in compliance with the END is very high, so the collection of the input data from the Managing Authorities can be problematic without a proper guideline. For this reasons a document in Italian language containing some useful indication, named M1 "*Data quantity and quality with regards to model specification*", was given to the other partners of the project to ease the collection of input data. This document is currently available at the Nadia website [4].

The quality and kind of input data collected by the NADIA partner were included in the first deliverable of the project, D1, "*Survey report*" [4].

The data input analysis model for NMPB described in the M1 takes into account the useful indications of the European Commission Working Group Assessment of Exposure to Noise (WG-AEN) [5], of the Italian Standard UNI/TS 11387:2010 [6], of the Scientific Literature (for instance [7]) and of previous experiences of CIRIAF in the field of noise simulations (for instance [8]).

The M1 describes how data should be collected and elaborated to fulfil the requirements of the END. During the noise map activity, Action 3 of the Project, it was observed that the M1 should be corrected in some parts to make the simulation activity more practical, fast and easy.

The models for input data collection and analysis are reported in the following section, that reports also some useful indication for technicians working on noise maps and strategic noise maps in compliance with the END requirements. The noise simulation approach for agglomerations, in most cases constituted by network of short roads, is substantially different from the one for major roads. For this reason the model for input data analysis and collection was divided in two parts, one for agglomerations and one for roads.

All the partners of the project are requested to submit the data related to their roads in GIS format.

4 Data input collection and analysis model: Agglomerations

What is an agglomeration?: 'Agglomeration' shall mean part of a territory, delimited by the Member State, having a population in excess of 100.000 persons and a population density such that the Member State considers it to be an urbanised area [1];

What are the requirement of the END for the agglomerations ?: Member States shall adopt the measures necessary to ensure that **no later than 30 June 2012, and thereafter every five years**, strategic noise maps showing the situation in the preceding calendar year have been made and, where relevant, approved by the competent authorities for all agglomerations [1];

What are the noise sources to be considered for the END noise simulations?: road traffic, rail traffic, airports, industrial activity sites and ports [1];

(the indications given in this report regard only traffic noise since NADIA project deals only with this source).

4.1 Calculation area

The calculation area coincides with the boundary of the agglomeration. The limit of the agglomeration does not necessary coincide with the limit of the municipality but:

- should comprehend only a part of a municipality, excluding the other one that couldn't be considered as urbanised areas;
- should comprehend a group of municipalities, between which there is a residential building continuity. This have been done for instance in Torino [9].

The limit of the agglomeration should be submitted by the Municipality (or the consortium of Municipalities) in a shapefile named *AGGLOMERATION_LIMIT*. No particular attributes are needed.

4.2 Traffic flow

The shapefile (*AGGLOMERATION_ROAD*) should contain the 3-D layout of each road that constitutes the road network of the agglomeration. Each road should have the following attributes:

- *NAME:* Name of the road [TEXT];
- *NMA*: Name of the Managing Authority [TEXT];
- *NLANE:* Number of lanes [INTEGER];
- *ONEWAY:* Yes=1, No=0 [BOOLEAN];
- *WLANE:* Lane width [REAL];
- *DLF:* Hourly average traffic flow of lightweight vehicles in daytime period (in Italy 06-20) [REAL];
- *ELF:* Hourly average traffic flow of lightweight vehicles in evening period (in Italy 20-22) [REAL];

- *NLF:* Hourly average traffic flow of lightweight vehicles in night period (in Italy 22-06) [REAL];
- *DHF:* Hourly average traffic flow of heavyweight vehicles in daytime period (in Italy 06-20) [REAL];
- *EHF:* Hourly average traffic flow of heavyweight vehicles in evening period (in Italy 20-22) [REAL];
- *NHF:* Hourly average traffic flow of heavyweight vehicles in night period (in Italy 22-06) [REAL];
- *DLS:* Average speed of lightweight vehicles in daytime period (in Italy 06-20) [REAL];
- *ELS:* Average speed of lightweight vehicles in evening period (in Italy 20-22) [REAL];
- *NLS:* Average speed of lightweight vehicles in night period (in Italy 22-06) [REAL];
- *DHS:* Average speed of heavyweight vehicles in daytime period (in Italy 06-20) [REAL];
- *EHS:* Average speed of heavyweight vehicles in evening period (in Italy 20-22) [REAL];
- *NHS:* Average speed of heavyweight vehicles in night period (in Italy 22-06) [REAL];
- *PAVCORR*: The noise emitted by a road depends on the characteristics of the pavement surface and in particular on its roughness. At this purpose [5] proposes corrective coefficients in function of the pavement type classified in terms of physical properties (Table 2) or visual inspection(Table 3) [REAL];
- *DTFLOW:* Traffic flow typology for day period: 0 for steady, 1 for unsteady, 2 for decelerated, 3 for accelerated [INTEGER]. Road emission may vary near junctions: NMPB model requires additional information about the flow of vehicles in order to consider this issue. The best practice is to divide roads into segments with accelerating, decelerating and continuous traffic flows in this way:
    - the length of a road segment with accelerating traffic flow is given by 2*V (in m, before the centre of the junction); V is the vehicles average speed;
    - the length of a road segment with decelerating traffic flow is given by 3*V (in m, beyond the centre of the junction). For instance if the vehicles average speed is of 80 km/h, the road segment length with accelerating flow is 160 m, while the one with a decelerate flow is 240 m[1];
- *ETFLOW:* Traffic flow typology for evening period: 0 for steady, 1 for unsteady, 2 for decelerated, 3 for accelerated [INTEGER];
- *NTFLOW:* Traffic flow typology for night period: 0 for steady, 1 for unsteady, 2 for decelerated, 3 for accelerated [INTEGER];
- *BRIDGE:* Yes=1, No=0. The segments of the road located in bridges should be considered separately from the others [BOOLEAN];
- *TUNNEL:* Yes=1, No=0. The segments of the road located inside tunnel should be known [BOOLEAN];

The value of *DLF, ELF NLF, DHF, EHF, NHF, DLS, ELS, NLS, DHS, EHS and NHS* should be obtained elaborating, in order of priority, weekly measurements, daily

[1] The procedure, described in [5], is very complex and is not practical. It should be applied only in the most important junctions with traffic lights.

measurements, results of a traffic flow simulation software and measurement from a peak hour flow.

Concerning the traffic flow, if only the peak hour flow is available the table given by [5] (Table 4) should be used, but it is strongly recommended to verify the outcome of noise simulation with a larger number of noise measurements. In Table 5 Q_d is the hourly average traffic flow in daytime, Q_e the hourly average traffic flow in evening, Q_n the hourly average traffic flow in night and Q_{peak} the hourly average of traffic flow in the peak period.

Sometimes the determination of the traffic flow through measurements or simulation software is not possible. In these cases the roads that constitute the network should be classified in terms of equivalent traffic characteristics. The number of classes may vary and depends on the kind of the agglomeration; an example of road classification is given in the following bulleted list:

- *Roads in residential areas:* sub-classified in high, mid and low traffic;
- *Road inside historical centre:* considering also restricted traffic zones;
- *Road in industrial areas:* this area should be considered separately because of heavyweight vehicle;
- *Etc.*.

The traffic flow characteristics of a class should be gathered from sample measurements on roads belonging to the same class. The operation of road classification requires a strong collaboration with the traffic management department of the municipalities being part of the agglomeration.

However highways traffic flow information must be obtained from measurements.

If data about the velocity of the vehicles are missing [5] suggests to use the speed limit or to make assumptions based on experience from similar road types. The second approach should be suggested for the roads inside residential areas in which the traffic flow seems to be high. A joint effort with traffic management department of the municipality is required.

The noise emission database used by the NMPB model considers only two kinds of vehicles, lightweight and heavyweight, including the motorcycles in the first class. For this reason the emission of the road could be underestimated because generally the noise emitted by motorcycle is higher than car. Moreover the noise emission database used by NMPB overestimates the noise emission of heavyweight vehicles, in particular in condition of low speed. Concerning this, a useful traffic correction has been created and successfully tested for Italian urban areas [10]. The efficiency of this correction has been tested also by CIRIAF [11].

Table 2: Kind of pavement surface based on physical properties and corresponding noise correction [5]

Uneven pavement stones	PS uneven	4.8
Even pavement stones	PS even	3.1
Cement concrete, transversely brushed Cement concrete, longitudinally brushed Exposed aggregate Burlap treated cement concrete Surface Dressing 0/11 Grip-surface Hot rolled asphalt	CCB tr CCB lo EA CC burlap SD GR HRA	1.1
Gussasphalt Asphalt concrete 0/16 Asphalt concrete 0/11 Drainage asphalt more than 5 years old Stone mastic asphalt 0/11	GA AC 0/16 AC 0/11 DA 0/11 g5 SMA 0/11	0.0
Drainage asphalt 0/16, 3-5 years old Drainage asphalt 0/11, 3-5 years old Drainage asphalt 0/8, 3-5 years old Drainage asphalt 0/16, less than 3 years old Drainage asphalt 0/11, less than 3 years old Drainage asphalt 0/8, less than 3 years old	DA 0/16 3-5 DA 0/11 3-5 DA 0/8 3-5 DA 0/16 k3 DA 0/11 k3 DA 0/8 k3	-2.7 (-1.7)
Twin layer drainage asphalt, more than 5 years old Twin layer drainage asphalt, 3-5 years old Twin layer Drainage asphalt, less than 3 years old Porous Thin Layers 0/8 Porous Thin Layers 0/6	DA twin g5 DA twin 3-5 DA twin k3 Thin 0/8 Thin 0/6	-3.5 (-2.5)
Remark: for 50km/h roads with drainage or low noise asphalt -1.7 and -2.5 dB		

Table 3: Noise pavement correction given by [2]

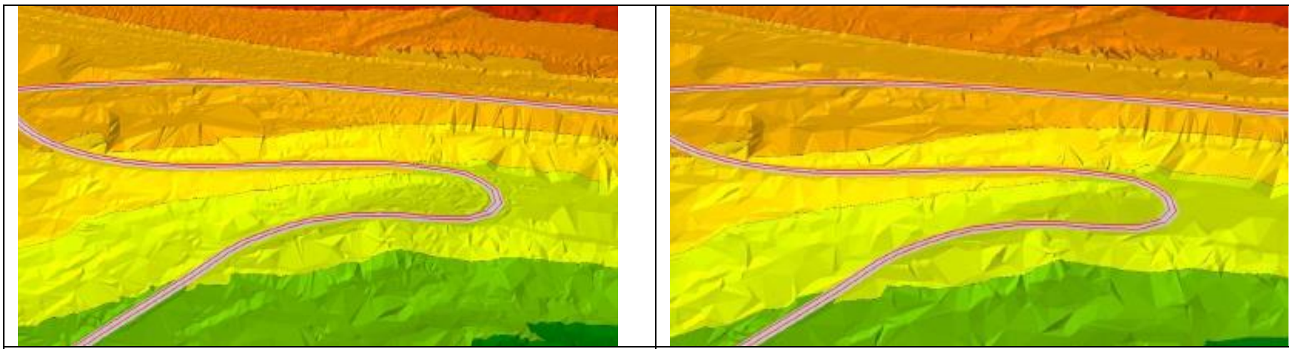
Uneven pavement stones	PS uneven	4.8
Even pavement stones	PS even	3.1
Cement concrete / Rough asphalt	Con / Ror	1.1
Smooth asphalt (reference)	Ref	0.0
Drainage asphalt < 5 years	DA	-2.7 (-1.7)
Low noise porous asphalt	LN P	-3.5 (-2.5)
Remark: for 50km/h roads with drainage or low noise asphalt -1.7 and -2.5 dB		

Table 4: Determination of the hourly average traffic flow from peak hour measurements

Period (Italy)	Metropolitan/Main roads	Inter-District Roads
Day (06-20)	$Q_d=Q_{peak}$	$Q_d=0,7*Q_{peak}$
Evening (20-22)	$Q_e=0,7*Q_{peak}$	$Q_e=0,5*Q_{peak}$
Night (22-06)	$Q_n=0,2*Q_{peak}$	$Q_n=0,1*Q_{peak}$

4.3 DGM data

The shapefile (*AGGLOMERATION_DGM*) should contain all the information needed for the realization of the Digital Ground Model (DGM), as elevation points, isohypses and 3-D layout of roads, rails, cuttings, embankments and bridges. DGM realization for agglomeration requires a lot of elevation points whereas the isohypses should not to be considered sufficient. If the output of a laser scanning is available there should be the problem of the large amount of data (DGM larger than 2 GB). In these cases, a filtering operation is necessary. For instance, a deviation from the original points of 20-50 cm could be allowed (Figure 1).



Allowed distance 20 cm (in a test case only the 19,3% of the originary point was used)	Allowed distance 50 cm (in a test case only the 4,7% of the originary point was used)

Figure 1: Example of a filtering point operation. Images and data taken from [13]

If the quotes of roads are not available, they should be deduced from the DGM; in this case the roads should be laid over the DGM. The quote of roads that run over a bridge should be found from the bridge elevation.

4.4 Ground Factor

The kind of ground surface deeply influences the propagation of the sound emitted by road; for instance the presence of an asphalted surface (like parking) fosters the propagation of noise thanks to its low sound absorption coefficient. The NMPB model considers the above-mentioned effect through a coefficient named "Ground Factor" (GF). The highest value of GF is 1 and it means that the ground is completely absorbing. The smallest value is 0 (ground completely reflecting). The land usage maps should be used to determine if an area have a high noise absorption or not (Table 5). Each area taken from the land usage maps should have the following attributes of the shapefile *AGGLOMERATION_GF*:

- *LANDUS*: Land usage [TEXT];
- *GF:* Value of the ground factor taken from Table 5 [REAL]

Table 5: Assignment of Ground Factor [5]

Land Usage	Ground Factor
Forest	1
Agriculture	1
Park	1
Heat land	1
Residential	0,5
Paving	0
Urban	0
Industrial	0
Water	0

4.5 Noise barriers

The layout and the acoustic properties of the noise barriers located inside the agglomeration should be considered. The propagation model does not consider the propagation of noise trough the barrier, but only the diffraction over its edge. Nevertheless the model considers the reflecting/absorbing properties of noise barrier surface. The acoustic properties of barriers should be contained and indicated in the following shapefile (*AGGLOMERATION_BARRIER*) attributes:

- *HBARR:* Height of the barrier [REAL];
- *A125Hz:* Acoustic absorbing coefficient of the barrier at 125 Hz [REAL];
- *A250Hz:* Acoustic absorbing coefficient of the barrier at 250 Hz [REAL];
- *A500Hz:* Acoustic absorbing coefficient of the barrier at 500 Hz [REAL];
- *A1000Hz:* Acoustic absorbing coefficient of the barrier at 1000 Hz [REAL];
- *A2000Hz:* Acoustic absorbing coefficient of the barrier at 2000 Hz [REAL];
- *A4000Hz:* Acoustic absorbing coefficient of the barrier at 4000 Hz [REAL];
- *BNOTE:* If the acoustic absorbing coefficient is given at different frequencies from those over mentioned, it should be reported in this attribute [TEXT].

4.6 Building

This shapefile (*AGGLOMERATION_BUILDINGS*) should contain the information about every building located inside the calculation area. Each building should be characterized by information about its usage, inhabitants, height, and number of floors and type of façade; at this purpose each building need the following attributes:

- *BUSAGE:* 0 for residential, 1 for industrial, 2 for garage/box, 3 for hospital, 4 for school and kindergarten, 9 for others [INTEGER];
- *BHEIGHT:* Height of the building, in m [REAL];
- *BFLOOR:* Number of floors [INTEGER];
- *BPOP:* Number of inhabitants inside the buildings [INTEGER].

Sometimes these parameters are not completely known; in these cases some useful operations should be done.

4.6.1 Usage

If the usage of buildings is not known, it is strongly recommended to:

- Assign *industrial* usage to buildings with a surface larger than 300 m^2 (this value should be raised or lowered, depends on the characteristics of the agglomeration). Before assigning an industrial usage, aerial photos should be checked;
- Assign *garage/box* usage to buildings with a surface area less than 30 m^2;
- Erase buildings with a surface lower than 1 m^2.

Concerning school and hospital, they should be identified cooperating with the Municipality offices.

4.6.2 Height

Sometimes the height of the buildings is not known and it is difficult to determine this parameter trough on-site visit or using aerial images. Therefore one of the following methods should be chosen (in order of priority);

- The elevation of the building should be obtained multiplying the number of floors with the average floor height (e.g. 3 m);
- The building height should be obtained comparing the DGM and building roof quote;
- Divide the agglomerate in sub-areas characterized by homogeneous buildings height; then assign to each building inside a sub-area the standard building height value of the sub-area. These standard values should be different for industrial and residential buildings.

4.6.3 Floor

If the number of floors is not known it should be sufficient to divide the height of the buildings with the average floor height (e.g. 3m).

4.6.4 Population

Sometimes the number of inhabitants on each residential building is not known and its evaluation trough surveys could not be practically possible. In these situations it could be useful to adopt the procedure suggested by [5] that requires knowing the census sections of the agglomerate; so an addition shapefile should be given (*AGGLOMERATION_CENSUS*) in which each section should have the following attributes:

- *SID:* Census identity code [TEXT] OR [INTEGER];
- *SPOP:* Inhabitants registered inside the census section [INTEGER].

Data contained in this shapefile should be linked to the ones of the buildings in this way:

- Evaluate the entire residential area of each census area, multiplying for each residential building the number of the floor by its surface area;
- Calculate the population density of each census area dividing the number of its inhabitants by its entire surface area;
- Multiplying for each building its residential area by the population density of its census area.

4.7 Meteorological data

The meteorological conditions are considered by the NMPB model in terms of percentage of the occurrence of favourable propagation conditions (as defined by the standard ISO 1996-2[12]) during the year for the day, evening and night period. The procedures to determine the meteorological data are reported in [6] and [12]. The recommendation of the WG-AEN (Working Group Assessment of

Exposure to Noise of the European Commission) is to consider a 10-year average of the occurrence of the different type of weather conditions. Data should be taken in-site or in a representative area. If this data are not known or could not be evaluated, [5] establishes the following standard value: 50% for the day period, 75% for evening and 100% for night. If the buildings are located nearby the noise source, the effect of this parameter is not important.

5 Data input collect and analyse model: Major road

What is a major road?: 'Major road' shall mean a regional, national or international road, designated by the Member State, which has more than three million vehicle passages a year [1];

What are the requirement of the END for the major roads ?: Member States shall adopt the measures necessary to ensure that **no later than 30 June 2012, and thereafter every five years**, strategic noise maps showing the situation in the preceding calendar year have been made and, where relevant, approved by the competent authorities for all mayor roads [1];

5.1 Calculation area

The calculation area is evaluated through a preliminary noise map of the road in free field. Then the greatest distance *d* between the L_{den}=55dB and L_{night}=50dB noise contours from the noise source . The parameter d_1 is evaluated multiplying *d* for a correction factor equal to 1.5. The area to be mapped starts from the road and ends at a distance of d_1 [5].

5.2 Traffic flow

The shapefile (*MAJORROAD_ROAD*) should contain the 3-D layout of each road segment that constitutes the entire major road. Each segment should have the following attributes:

- *NAME:* Name or identity code of the road segment (e.g. SP10_1, SP10_2) [TEXT];
- *NMA*: Name of the Managing Authority [TEXT];
- *NLANE:* Number of lanes [INTEGER];
- *ONEWAY:* Yes=1, No=0 [BOOLEAN];
- *WLANE:* Lane width [REAL];
- *DLF:* Hourly average traffic flow of lightweight vehicles in daytime period (in Italy 06-20) [REAL];
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- *PAVCORR:* The noise emitted by a road depends on the characteristics of the pavement surface and in particular by its roughness. At this purpose [5] proposes corrective coefficients in function of pavement type classified in terms of physical properties (Table 2) or visual inspection (Table 3) [REAL];
- *DTFLOW:* Traffic flow typology for day period: 0 for steady, 1 for unsteady, 2 for decelerated, 3 for accelerated [INTEGER]. Road emission may vary near junctions, that NMPB model requires additional information about of the flow of vehicles in order to consider this issue. The best practice is to divide roads into segments with accelerating, decelerating and continuous traffic flow in this way:
    - the length of a road segment with accelerating traffic flow is given by 2*V (in m, before the centre of the junction); V is the vehicles average speed;
    - the length of a road segment with decelerating traffic flow is given by 3*V (in m, beyond the centre of the junction). For instance if the vehicles average speed is of 80 km/h, the road segment length with accelerating flow is 160 m, while the one with a decelerate flow is 240 m[2];
- *ETFLOW:* Traffic flow typology for evening period: 0 for steady, 1 for unsteady, 2 for decelerated, 3 for accelerated [INTEGER];
- *NTFLOW:* Traffic flow typology for night period: 0 for steady, 1 for unsteady, 2 for decelerated, 3 for accelerated [INTEGER];
- *BRIDGE:* Yes=1, No=0. The segments of the segments of the major road located in bridges should be considered separately from the others [BOOLEAN];
- *TUNNEL:* Yes=1, No=0. The segments of the segments of the major road located inside tunnel should be known [BOOLEAN].

The value of *DLF, ELF NLF, DHF, EHF, NHF, DLS, ELS, NLS, DHS, EHS and NHS* should be obtained elaborating, in order of priority, weekly measurements, daily measurements and results of a traffic flow simulation software and measurement from a peak hour flow.

Concerning the traffic flow, if only the peak hour flow is available the table given by [5] (Table 4) should be used, but it is strongly recommended to verify the outcome of noise simulation with a larger number of noise measurements. In table 5 Q_d is the hourly average traffic flow in daytime, Q_e the hourly average traffic flow in evening, Q_n the hourly average traffic flow in night and Q_{peak} the hourly average of traffic flow in the peak period.

If there is a lack of data about the velocity of the vehicles the [5] suggests to use the speed limit or to make assumptions based on experience from similar road

[2] The procedure, described in [5], is very complex and is not practical. It should be applied only in the most important junctions with traffic lights.

types. The second approach should be suggested for the roads inside residential areas in which the traffic flow seems to be high. A joint effort with traffic management of the municipality should be established.

The noise emission database used by the NMPB model considers only two kinds of vehicles, lightweight and heavyweight, including the motorcycles in the first class. For this reason the emission of the road should be underestimated because generally the noise emitted by motorcycle is higher than car. Moreover the noise emission database used by NMPB overestimate the noise emission of heavyweight vehicles, in particular in condition of low speed. Concerning this, a useful traffic correction has been created and successfully tested for Italian urban areas [10]. The efficiency of this correction has been tested also by CIRIAF [11].

5.3 DGM data

The shapefile (*MAJORROAD_DGM*) should contain all the information needed for the realization of the Digital Ground Model (DGM), as elevation points, isohypses and 3-D layout of roads, rails, cuttings, embankments and bridges. DGM realization for major roads requires elevation points for the flat areas and isohypses for the hilly ones. If the output of a laser scanning is available there should be the problem of the large amount of data (DGM larger than 2 GB). In these cases, a filtering operation is necessary. For instance, a deviation from the original points of 20-50 cm could be allowed (Figure 1).

If the quotes of the road are not available, they should be deduced from the DGM; in this case the roads should be laid over the DGM. The quote of roads that run over a bridge should be found from the bridge elevation.

5.4 Ground Factor

The kind of ground surface deeply influences the propagation of the sound emitted by road; for instance the presence of an asphalted surface (like parking) fosters the propagation of noise thanks to its low sound absorption coefficient. The NMPB model considers the above-mentioned effect through a coefficient named “Ground Factor” (GF). The highest value of GF is 1 and it means that the ground is completely absorbing. The smallest value is 0 (ground completely reflecting). The land usage maps should be useful to determine if an area have a high noise absorption or not (Table 5).

Each area taken from the land use maps should have the following attributes of the shapefile *MAJORROAD_GF*:

- *LANDUS*: Land usage [TEXT];
- *GF:* Value of the ground factor taken from Table 5 [REAL]

5.5 Noise barriers

The layout and the acoustic properties of the noise barriers located on the roadside or nearby the major road should be considered. The propagation model does not consider the propagation of noise trough the barrier, but only the diffraction over its edge. Nevertheless the model considers the reflecting/absorbing properties of noise barrier surface. The acoustic properties of barriers should be contained and indicated in the following shapefile (*MAJORROAD_BARRIER*) attributes:

- *HBARR:* Height of the barrier [REAL];
- *A125Hz:* Acoustic absorbing coefficient of the barrier at 125 Hz [REAL];
- *A250Hz:* Acoustic absorbing coefficient of the barrier at 250 Hz [REAL];
- *A500Hz:* Acoustic absorbing coefficient of the barrier at 500 Hz [REAL];
- *A1000Hz:* Acoustic absorbing coefficient of the barrier at 1000 Hz [REAL];
- *A2000Hz:* Acoustic absorbing coefficient of the barrier at 2000 Hz [REAL];
- *A4000Hz:* Acoustic absorbing coefficient of the barrier at 4000 Hz [REAL];
- *BNOTE:* If the acoustic absorbing coefficient is given at different frequencies from those over mentioned, it should be reported in this attribute [TEXT].

5.6 Building

This shapefile (*MAJORROAD_BUILDINGS*) should contain the information about every buildings located inside the calculation area. Each building should be characterized by information about its usage, inhabitants, height and number of floors and; at this purpose each building need the following attributes:

- *BUSAGE:* 0 for residential, 1 for industrial, 2 for garage/box, 3 for hospital, 4 for school and kindergarten, 9 for others [INTEGER];
- *BHEIGHT:* Height of the building, in m [REAL];
- *BFLOOR:* Number of floors [INTEGER];
- *BPOP:* Number of inhabitants inside the buildings [INTEGER].

Sometimes these parameters are be not completely known; in these cases some useful operations should be done.

5.6.1 Usage

If the usage of buildings is not known, it is strongly recommended to:

- Assign *industrial* usage to buildings with a surface larger than 300 m^2 (this value should be raised or lowered). Before assigning an industrial usage, aerial photos should be checked;
- Assign *garage/box* usage to buildings with a surface area less than 30 m^2;
- Erase buildings with a surface lower than 1 m^2.

Concerning school and hospital, they should be identified cooperating with the Managing Authority offices.

5.6.2 Height

Sometimes the height of the buildings is not known and it is difficult to determine this parameter trough on-site visit or using aerial images. Therefore one of the following methods should be chosen (in order of priority);

- The elevation of the building should be obtained multiplying the number of floors with the average floor height (e.g. 3 m);
- The building height should be obtained comparing the DGM and building roof quote;
- Assign a standard elevation to buildings height considering their position (high density city, low-density city..) and usage.

5.6.3 Floor

If the number of floors is not known it should be sufficient to divide the height of the buildings with the average floor height (e.g. 3m).

5.6.4 Population

Sometimes the number of inhabitants on each residential building is not known and its evaluation through surveys could not be practically possible. In these situations it should be useful to adopt the procedure suggested by [5] that requires knowing the census sections of the zones crossed by the calculation area of the major road; so an addition shapefile should be given (*MAJORROAD_CENSUS*) in which each section should have the following attributes:

- *SID:* Census identity code [TEXT] OR [INTEGER];
- *SPOP:* Inhabitants registered inside the census section [INTEGER].

Data contained in this shapefile should be linked to the ones of the buildings in this way:

- Evaluate the entire residential area of each census area, multiplying for each residential building the number of the floor by its surface area;
- Calculate the population density of each census area dividing the number of its inhabitants by its entire surface area;
- Multiplying for each building its residential area by the population density of its census area.

5.7 Meteorological data

The meteorological conditions are considered by the NMPB model in terms of percentage of the average probability of occurrence of favourable propagation conditions (as defined by the standard ISO 1996-2 [12]) during the year. The procedures to determine the meteorological data are reported in [6] and [12]. The recommendation of the WG-AEN (Working Group Assessment of Exposure to Noise of the European Commission) is to consider a 10-year average of the occurrence of the different type of weather conditions. Data should be taken in-site or in a representative area. If this data are not known or could not be evaluated, [5] establishes the following standard value: 50% for the day period, 75% for evening and 100% for night. If the buildings are located nearby the noise source, the effect of this parameter is not important.

6 List of shapefile

6.1 Agglomeration

AGGLOMERATION_LIMIT: Limit of the agglomeration;

AGGLOMERATION_ROAD: Cartographic and traffic flow information of the agglomeration road network;

AGGLOMERATION_DGM: Information for the realization of the Digital Ground Model;

AGGLOMERATION_GF: Information about the ground usage;

AGGLOMERATION_BARRIER: Information about the noise barrier;

AGGLOMERATION_BUILDINGS: Information about buildings;

AGGLOMERATION_CENSUS: Information about inhabitants registered inside the census areas.

6.2 Major road

MAJORROAD_ROAD: Cartographic and traffic flow information of the major road;

MAJORROAD_DGM: Information for the realization of the Digital Ground Model;

MAJORROAD_GF: Information about the ground usage;

MAJORROAD_BARRIER: Information about the noise barrier;

MAJORROAD_BUILDINGS: Information about buildings;

MAJORROAD_CENSUS: Information about inhabitants registered inside the census areas.

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