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Accuracy requirements for strategic noise mapping

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About this presentation

The aim of this document is to give a practical approach to the development of strategic noise maps.

The following slides show the problem regarding the issue of **uncertainty in making noise maps and address the management of acoustic software in an efficient manner while preserving the accuracy of the results**.

All the topics and recommendations are based on our experience on a Environmental Quality Control Project of Algeciras Bay, the WG-AEN Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure (version 2) and the Imagine Project documents

Environmental quality control of the Bay of Algeciras

Brief description of the Item: Noise

- This project has been financed by the Andalusia Regional Government through its Environmental Agency.
- One of the aims of this project is to turn Algeciras Bay into a “Noise testing laboratory in situ” for interchanging experiences in the developing of strategic noise maps, contrasting methods and software packages, comparisons between labs, etc.
- The Environmental Agency of the Regional Government is also concerned about two things which can compromise the reliability of the development of action plans against noise:
  - the reliability of the noise maps of main road infrastructures made by Road General Directorate of the Infrastructure Ministry and affecting Andalusia Agglomerations
    - It is not planned to carry out any kind of measurements to validate the outcome of the software
    - Rigor in the software handling requirements
  - and the consequences the lack of quality data has for mapping agglomerations

The Algeciras' Bay

The singularities of the study area:

- The area is one of the most industrialized in Andalusia with large industrial facilities. The harbor of Algeciras is the most important of Spain in cargo and passengers.
- The population is growing very quickly and a lot of dwellings are situated very close to the infrastructures and industries.
- Difficulty to model the great number of special vehicles like motorcycles, modified mopeds, quarks and cars with loud music.
- Persistent and heavy winds from West and East complicate the long-term noise map

Developing an acoustic map. First approximation to the process, step by step

A catalog of recipes which help the lab to avoid the bad decisions:
- The lab's Know-How
- Good Practice Guide

1. The objectives of the noise map

2. The raw data entry

3. Set of measurement to complete the lack in data

4. Handling
-Data Input
-Parameters of Software Package.

G.I.S. and Noise Prediction Software Package

5. Representing the acoustic reality. Noise maps. Data on Noise Exposure

6. Analysis of the situation. Noise management. Action Plans. Policy decisions

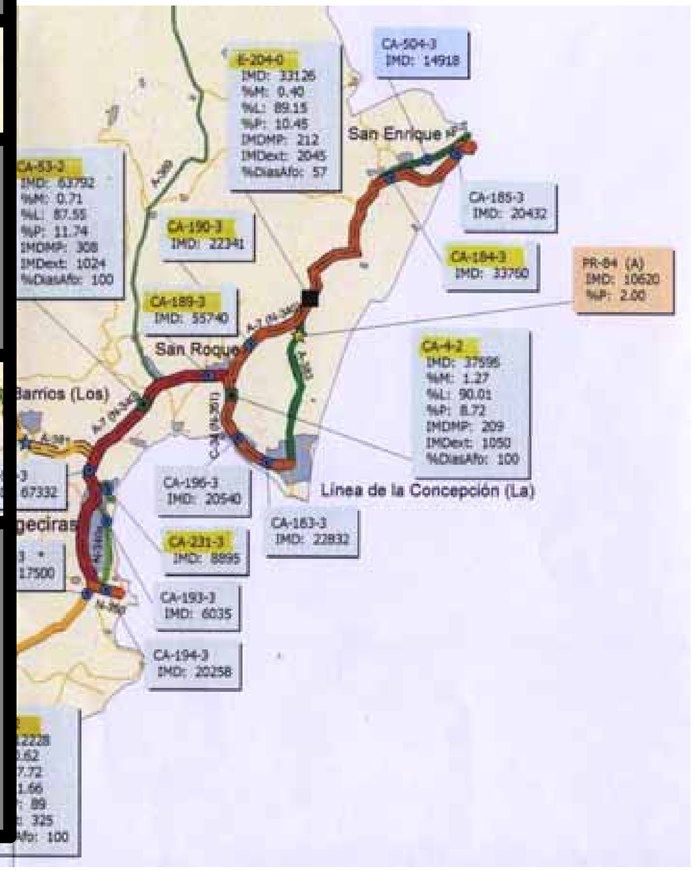
Geo-data available

- Vector cartography geo-referenced. Scaled 1/25.000. *.DXF and *.DWG (AutoCAD). National Geographic Information Center
- Vector cartography geo-referenced. Scaled 1/2.000 and 1/10.000 *.DXF (AutoCAD) and *.SHP (ArcGIS) format. The City Councils of the Algeciras' Bay
- Digital Orto-photos scaled 1/20.000. Geotiff geo-referenced. Raster model pixel resolution 0,5 m. Cartographic Service of the Regional Government of Andalusia.

Attribute-data available. Noise Sources (Roads)

Light vehicles	Mean Daily Intensity values Not provided for all the segments of the road
Light vehicles Speed	**Only information about the Speed limit along the roads**
Heavy vehicles	Mean Daily Intensity values Not provided for all the segments of the road No other composition of the traffic flow is provided
Heavy vehicles Speed	**Only information about the Speed limit along the roads**
Traffic flow	Continuous. National Administration recommend not to take into account accelerated or decelerated traffic outside agglomeration
Gradient, Number of lanes, width of lanes, etc	**Only the delivered through the Topographic information**
Road surface	By default Smooth asphalt. Information is released about location of Porous. National Administration recommend not to take into account other surfaces as cement concrete, paving stones smooth texture and paving stones rough texture

Database from the Main Roads delivered by the National and Regional Administrations and updated to 2005. No INFO from the roads inside agglomeration



Using WG-AEN Good Practice Guide for Strategic N.M. in the first estimation of the uncertainty we can reach in the characterization of the main roads

Traffic Flow for day, evening and night

Tool 2.2: Traffic flow for a full 24-hour day			
Method	complexity	accuracy	cost
If no distribution data (official statistics) available:			
Apply distribution along the lines of that in the examples given below:		1 dB 17	
Examples For the default duration defined in the END: day (12h: $7^{\underline{00}}$ - $19^{\underline{00}}$), evening (4h: $19^{\underline{00}}$ - $23^{\underline{00}}$), night (8h: $23^{\underline{00}}$ - $7^{\underline{00}}$)			
○ 24h counts (important see footnote[18]) ○ day = 70% of counts ○ evening = 20% of counts ○ night = 10% of counts		1 dB	

[18] These figures are based on an analysis of several years of traffic counts obtained with a permanent automatic hourly traffic counting station installed on a major road in Berlin/Germany and are only provided as an **example**. As with many examples provide in this Position paper the situation will vary from country to country and, in this case, possibly for different types of road. For instance, in Demark traffic counts on minor roads show a distribution of 80% during the 12 daytime hours, 10-12%in the evening and 8-10% during the night.

Tool 2.5: No traffic flow data available			
Method	complexity	accuracy	cost
Make traffic counts for each of the three periods: daytime, evening and night time		< 0.5 dB	
Select sample roads and **do traffic counts** there; **extrapolate to other roads** of same type		2 dB	

Average speed for every vehicle class and for every period of time

Tool 3.5: No speed data			
Method	complexity	accuracy	cost
Measure time vehicles take to travel along a road section of known length and calculate average traffic speed		< 0.5 dB	
Determine average traffic speed by **driving in the average traffic flow**		1 dB	
Use the **speed limit** (e.g. from traffic signs)		2 dB	

% Heavy Vehicles for day, evening and night

Tool 4.3: Percentage of heavy vehicles data for a full 24-hours day (or longer period of time)			
Method	complexity	accuracy	cost
If no distribution data (official statistics) is available:			
Make traffic counts on all roads		< 0.5 dB	
Make sample traffic counts and generate distribution, then **apply distribution** to generate day, evening, night data		< 0.5 dB	

Tool 4.5: No heavy vehicle data available			
Method	complexity	accuracy	cost
Make traffic counts for each of the three periods: daytime, evening and night time		< 0.5 dB	
Select sample roads and **do traffic counts** there; **extrapolate** to other roads of same type		< 0.5 dB	

Location of Accelerating segments

Tool 6.1: Location of junctions with traffic lights are known			
Method	complexity	accuracy	cost
If driving directions are separated and known:			
Divide the roads into segments with accelerating, decelerating and continuous traffic flow The length of a road segment with accelerating/decelerating flow is: decelerating: 3 * V (in m, before the centre of the junction) accelerating: 2 * V (in m, beyond the centre of the junction) where V is the speed limit in km/h		< 0.5 dB	

Tool 6.2: No data available			
Method	complexity	accuracy	cost
Make **on-site visits** and detect junctions with traffic lights, then use Tool 6.1		< 0.5 dB	
Use **aerial photographs** for detection of junctions with traffic lights, then use Tool 6.1		< 0.5 dB	

Why is accuracy an important factor in the developing of noise maps?

Remembering
the Main Objectives of Noise Mapping

- To describe and explain the actual acoustic pollution presented in one area.
- To detect and characterize a noise source, to know in what way it is affecting the overall level of environmental noise, its time behavior (schedule), the quality of every such noise, etc. For example in Punitive studies to find out which facility exceeds the noise limits allowed in a particular area
- To study the acoustic environmental impact of a new project. For example as a result of modification in the infrastructure, new residential planning's, etc
- To compare the real situation with limits recommended in the applicable legislation. Detecting conflictive zones based on sensibility criteria for that area surveyed
- To estimate how this noise is affecting people, in other words the noise dose that population supports.
- To offer to the administration a management tool in order to control the present and futures levels of acoustic pollution. Noise maps is the key to improve the urban planning by taking into account the noise variable (Action Plans).
- To verify the effectiveness of diverse kinds of corrective measures and environmental policies

Ultimately it is an economic question

The accuracy of strategic noise maps is not an optional matter. Authorities are responsible for designing and developing actions plans. This means Public expenditures assigned to noise policies which is being set incorrectly and can lead a mismatch between the expectation of local communities and actual experience

- Noise maps can be affected by bias (systematic errors). Then, the hot spots (noisy and quiet areas) can be correctly identified but they are overestimated or underestimated. This means that too much or too little investment is going to be devoted to resolving the problems of high noise areas (or to protect the quiet areas).

- Noise maps can be affected by variance (random errors). The spatial distribution of hot spots could be incorrectly identified. The subsequent action plans could be inefficient

Where is the uncertainty hidden in the process of development noise maps?

Quotations about models:

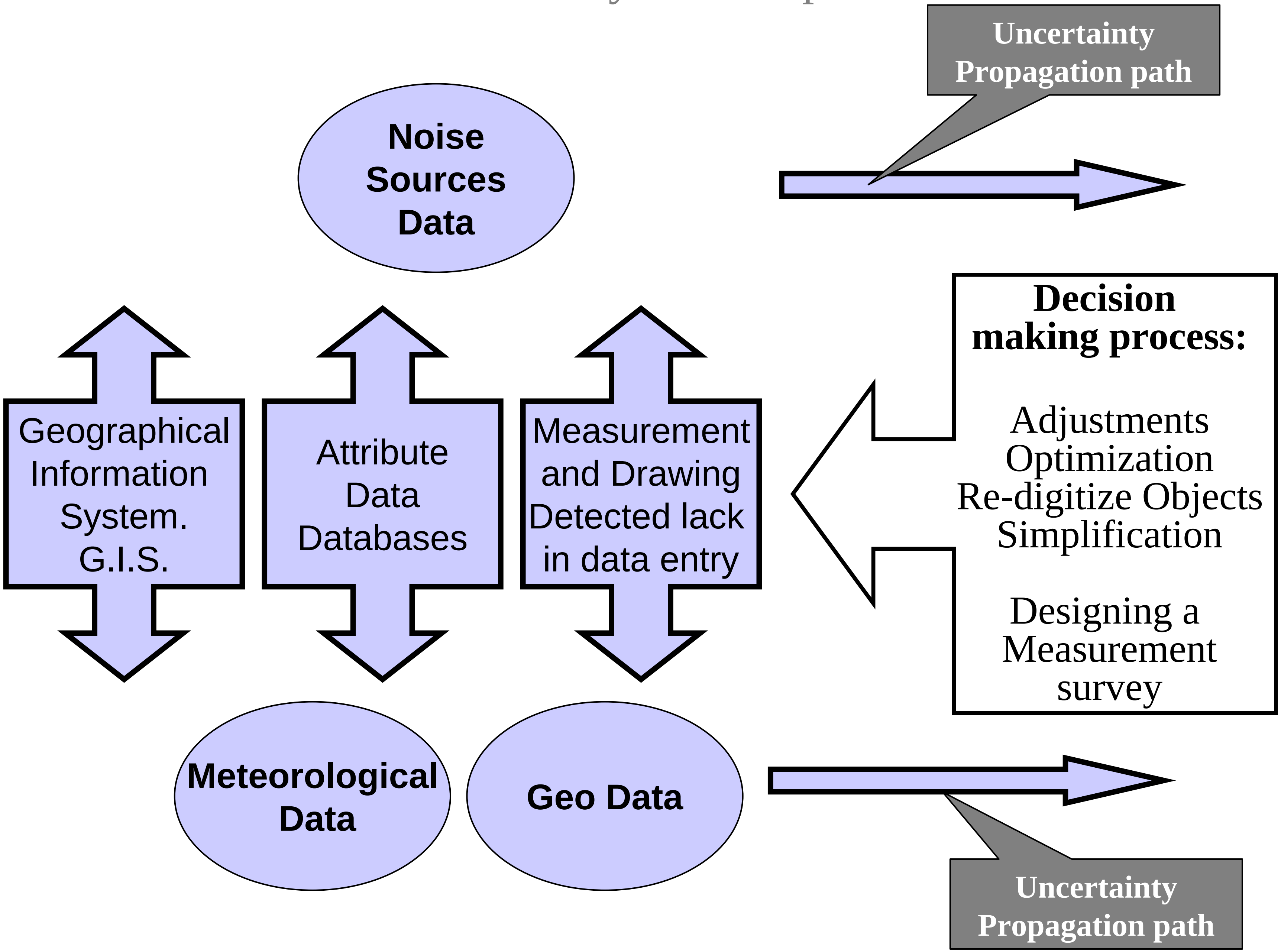
“There are three kinds of lies: lies, damn lies, and statistics.”

– Benjamin Disraeli

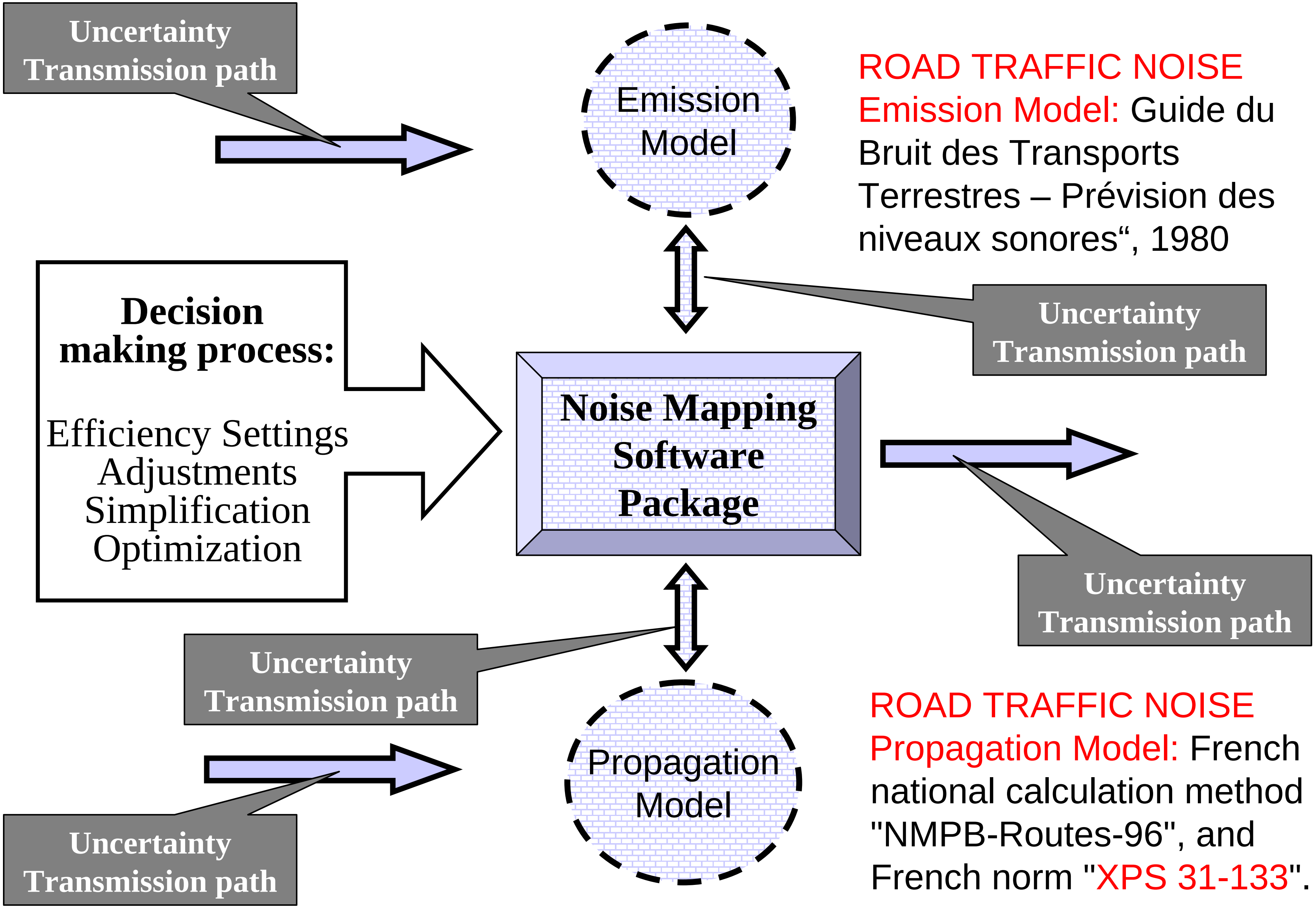
“All models are wrong. Some are useful.”

– George E. P. Box

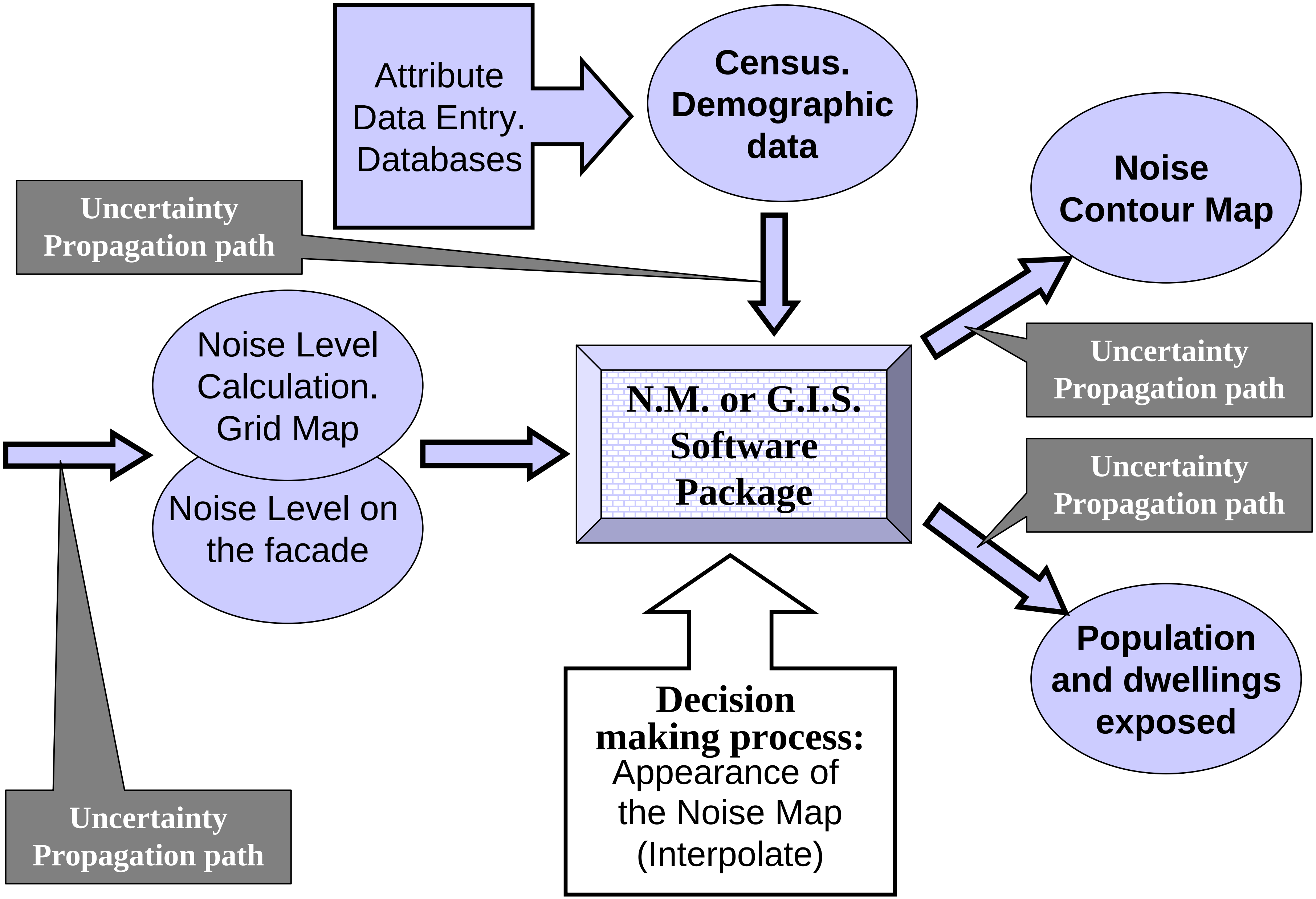
Uncertainty of the input



Uncertainty of the calculation process



Uncertainty at the output



What can we do to avoid errors and preserve the quality of noise maps?

• In this first stage we are going to consider the core of the software packages almost perfect and we are going to focus on the quality of the data and the data handling

• There will always be limits to the accuracy of input data. Data accuracy can often be improved but at different costs, more often calculation time. So, one key is to know how sensitive the output accuracy of the model (robustness) is to inaccuracies in different types of input data. Another key is to investigate the impact on the final accuracy of various efficiency settings and other parameters of the software. Then we can decide where to focus our limited resources to improve input data

1. Quality assurance of laboratory processes

2. Control and check the available data

3. Decision Making Process. Geometric Data handling

4 Decision Making Process. Noise Sources Data handling

5. Decision Making Process. Software parameter handling

1. Quality assurance of laboratory processes

One of the Minimum Technical Standards required from candidates who like to participate in the awarding public contest for the development of Noise Maps financed by the Spanish Government, is to demonstrate their Technical Competence by adopting an quality management system which comply with the requirements of *ISO-17025. General Requirements for the Competence of Calibration and Testing Laboratories*.

Making noise maps properly depends not only on how powerful the tool is (the calculation software), but on how the laboratory operate.

Quality of the map is obtained by making the huge process of developing noise maps a reliable, traceable, reproducible and repeatable issue.

The technical procedures must guarantee all steps involved in the development of the map have been validated in statistical manner to ensure realistic maps.

2. Control and check the available data.

Land and Geometric Data entry

Problems arise in the Physical Scenario when the data is collected without any consideration about the demanding of acoustics software's

- **Examples about more usual land info and buildings problems.**
  - **In a raster model the grid height points of the terrain must be transformed into terrain contour lines (better diffraction prediction)**
  - **Terrain level lines crossing one others must be re-drawn manually.**
  - **A contour poly-line contain too many vertexes and this excess of info must be simplified.**
  - **A terrain contour has been split in different segments which must be merged**
  - **Take care with ridge edge models because it manage too much redundant land information**
  - **Geo Models from different sources don’t fit. You must decide which is the best for every task**
  - **Buildings and other surfaces drawn like poly-lines must be closed (transformed into Polygons)**
- **Examples about to change 2-D GIS object in 3-D. You can find Buildings, barriers, cuttings, embankments, walls, bridges not defined in height.**
  - **Merge a database to 2-D GIS model to produce a high quality 3-D model.**
  - **Textual information, e.g. number of floors, that is not linked to buildings may be utilized when they are placed inside the building polygon**

2. Control and check the available data. Attribute Data entry. In situ Measurements.

Noise Measurements "in situ"

- A catalog of the largest Industrial facilities must be developed.
  - ISO 8297: 1994 'Acoustics - Determination of sound power levels of multisource industrial plants for evaluation of sound pressure levels in the environment - Engineering method'
  - Reverse Engineering is used to determine source levels based on noise measurements

Calculate the uncertainty due to the equipment and the method of measurement

Main Road Traffic data lack:

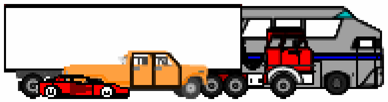
- When no traffic data is available or need to be completed
  - Automatic traffic detectors systems "in situ"
  - Man made counts

Others kind of measurements can be defined

- Height of buildings, GPS position of interesting points on the map, etc.

3. and 4. Decision Making Process.
Geometric and Noise Sources Data handling

To preserve the reliability of a Main Road's noise map we act in two directions: 1. Taking care of accuracy of geometric info close to the main roads which is an important issue. 2. Make sure that characteristics of the main roads must be well achieved



GIS tasks

Check the quality of data and re-digitize it.

- ***Check with various GIS maps that the relevant Noise Sources are unambiguously defined and well located (horizontal definition)***
- ***The road layout must be well fitted to the terrain model (vertical definition)***
- ***Choose the best possible resolution of topographic lines near the main roads.***
- ***Check the number of carriageways on a road and the total width by aerial photograph***
  - ***Consider dual carriageway as two different roads when the reservation width is more than 10 meters or those carriages differ in height by more than 2 meters.***
  - ***Consider Bus lanes, taxi lanes and special lanes.***
- ***Road crossings, roundabouts, junctions, traffic lights, bridges and tunnels identified by aerial photography***

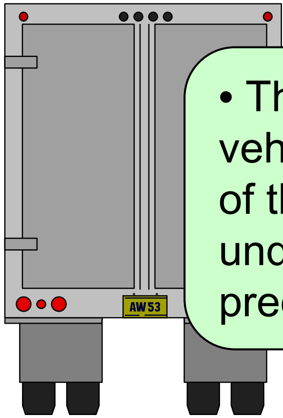
Measurements tasks

- ***Measure the Height of buildings most exposed to the relevant noise sources***
- ***In situ measurement of traffic flow, speed and percentage of heavy vehicles and the surface characteristic of asphalt source***
- ***Barriers, cuttings, embankments, walls, bridges close to the noise sources must be geometrically defined as correct as possible***

Noise software tasks

- ***Segmentation of the roads taking into account the changes in traffic or road characteristics (mean speed, flow, %age of Heavy Vehicles, areas of acceleration or deceleration characteristics of the road basis)***

4. Decision Making Process. Noise Sources Data handling Sensitivity of the model to the input traffic data. FACTS

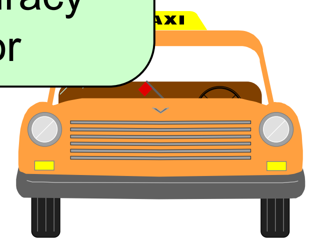


- The presence of special vehicles in the composition of the traffic flow tend to underestimate noise prediction in urban roads

- The correct velocity estimation of the fleet is the most important accuracy factor

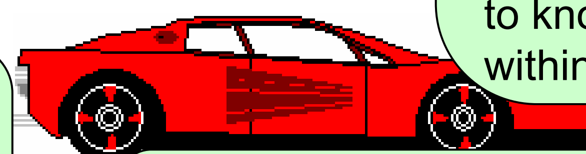
- Excesses in the speed of lone vehicles tend to yield underestimated night noise prediction

- Motorways is more influenced by rolling noise and need to be focused in the accuracy determination of speed and fleet composition.



- Two situation are considered depending if the % of heavy vehicles in the total flow is over 20% or under this percentage. In the first case, in order to obtain a deviation of 1 dBA we need the percentage of these vehicles within 10 %. In the second case we need to know that composition within 5 %.

- In general the deviation in the velocity of heavy vehicles and motorcycles (1 dBA per 5 Km/h) is worse than in light vehicles 1 dBA per 10 Km/h) in the estimation of noise.



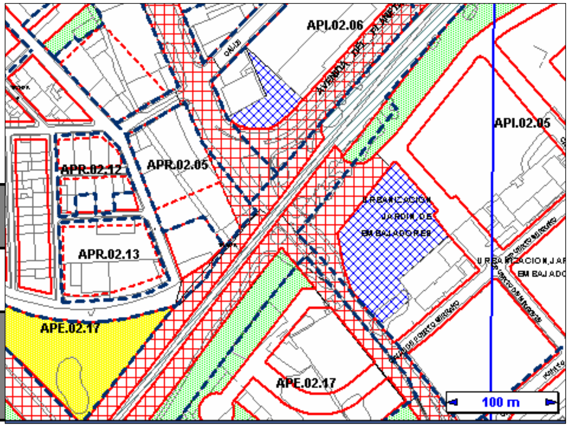
- Urban roads noise are dominated by the propulsion noise and this is the reason why it is more sensitive than motorways on overall uncertainty of flow and fleet composition of the traffic.

- An accuracy of 1dBA in the calculation of noise due to the traffic intensity requires the flow can be estimated accurately within 25%

5. Decision Making Process. Software parameter handling

- Efficiency Calculation Setting has the purpose of reducing calculation time at any accuracy cost. It can be divided in two classes:
  - Those which require to define the parameter value adopted during calculation
  - Switches which can be turned on or off

Example of task: Urban areas affected by a motorway



Neglecting Irrelevant Noise Sources by Dynamic Error Margin	**Less than 1dB**
Angle Increment	**Off or the minimum allowed**
Maximum Error allowed	**Less than 1dB**
Source Search (Fetching) Radius	**2.000 – 3.000 meters**
Borders of the study	**Not less than 1,5 times inmision range of Lden>55 dB and Lnight>50 dB. Extending the calculus as much as necessary to estimate the noise in the tails of the road**
Borders of every calculation area	**The "calculation tile" must exceed the "resulting tile" by the fetching radius chosen**
Reflection Fetching Radius	**30 – 50 meters**
Order of reflection	**2**
Grid	**Adaptive grid. From 2 meters in narrow streets surrounded by tall buildings until 30 meters in open spaces out of urban areas**

What can we do to avoid errors and preserve the quality of noise maps?

• In a second stage we are talking about the accuracy of the overall process. This mean that the software package is going to be included in the final validation and verification of the data levels outcome

6. Calibrating the output

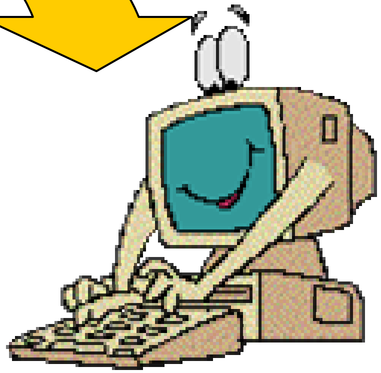
7. Comparisons with a “benchmark noise map” and between laboratories

6. Calibrating the output. Quality Control of the final Map

3. Design of measurement survey when a lack in data entry is detected

4. Handling Data Input and the Parameters of Software Package.

- **The data that feed the noise prediction software**
- **Handling the Noise Map Software Package.**



THE MODEL

5. Representing the acoustic reality. Noise maps. Data on Noise Exposure

7. Noise monitoring or Noise estimated by the use of FEM or BEM models

8. Calibration of the Acoustic Noise Map

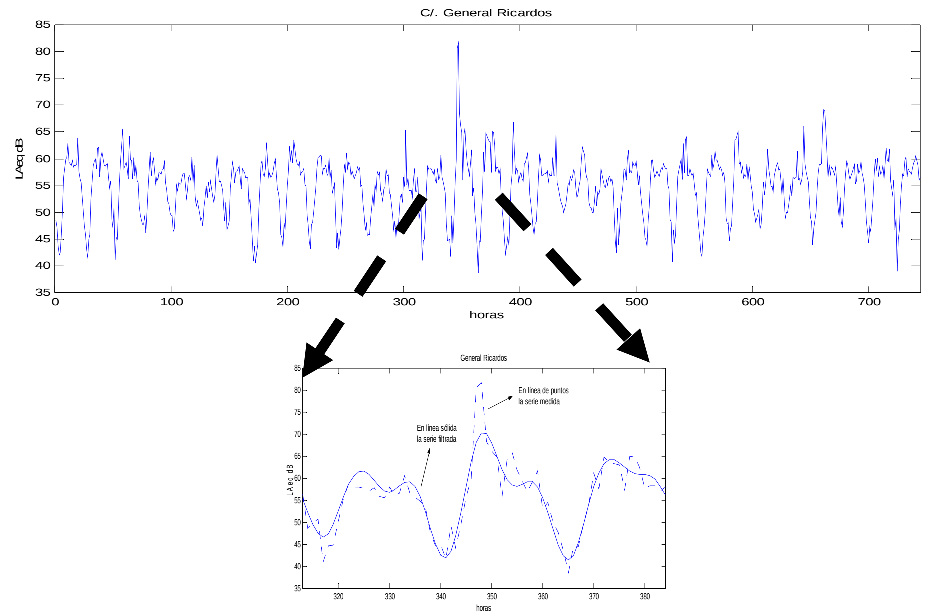
6. Calibrating the output. Matching the model with the “real” data coming from measurements

- Are you trying to describe the total noise presented at one receiver point?
  - You need a long-term monitoring (unattended) station of that point
  - With a set of these stations strategically distributed around the working area you can check at the same time the accuracy of all of the factors involved in the map and their implication in those points

- Or maybe you are only interested in the noise emitted by one noise source?
  - Perhaps you need shorter measurements but attended ones
    - The points selected and the schedule of measurements must guarantee the accuracy in the definition of the noise sources in space and time.
    - Strategies to discriminate the noise under consideration from the noise from other sources.
  - With these measurements you can check the accuracy of the prediction of noise emitted from the noise sources in different situations

6. Calibrating the output. Long-term Monitoring

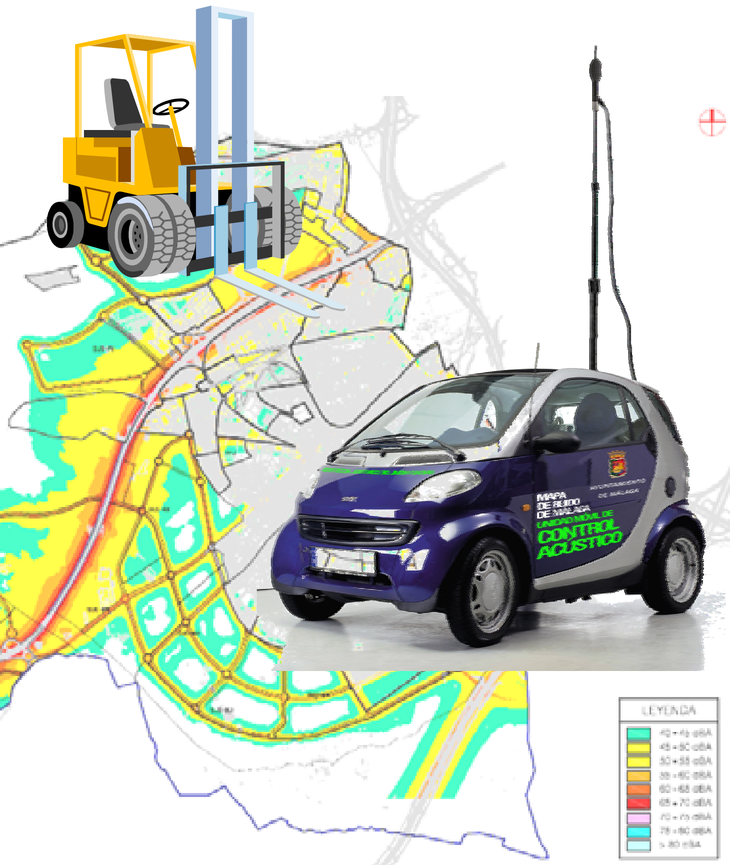
- What is short-term and what is long-term? It depends on
  - The time evolution of the noise source emission
  - The different propagation conditions during a year
  - Even, the different behavior of receivers during a year



- The issue of Filtering: This example of a noise signal (more than 5 years of mainly traffic) is composed of certain variability components:
  - A daily behavior of noise (periodicity of 24 hours) which explains 40 % of the total variability
  - A Semi-diurnal component (periodicity of 12 hours) which explains 20 % of the total variability
  - An annual component and possible a trend which explains 5% of the total variability
  - A weekly signal which explains 5% of the total variability
  - A random signal around 30 % of the variability

6. Calibrating the output. Short-Term Measurements (attendant)

- It is necessary, while the noise is being measured, describing the situation around
- Wind, pressure, temperature and humidity
- The precise situation by GPS
- Description of the target noise source (specific sound). For example, traffic flow, speed and composition of a main road.
- Description of the possible residual source
- Calculate the uncertainty of every repeatable noise test



The combination of Short-Term Measurement and Monitoring

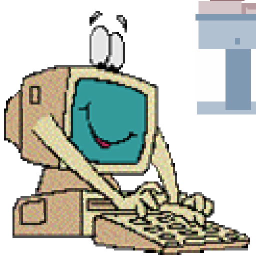
- Using Correlation algorithms in combination with long-term monitoring can extrapolate the short-term measurements to give a more complete picture of the noise in town

7. Comparisons with a "benchmark noise map" and between laboratories

2. 3. 7. All the information available is transparent for the two equipments

9. Selecting the target spots that LAB 2 are to investigate in depth

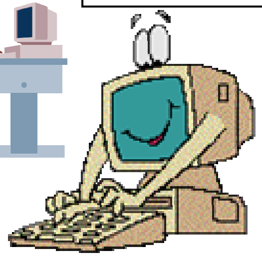
LAB 1



SOFTWARE 1

4. 8. LAB 1 operate as they usually do

LAB 2



SOFTWARE 2

4. 8. Possibly new data info can be registered. In deep approximation with the best resolution possible. Managing a large amount of info applied to a limited area. Excluding Software's Efficiency Settings

5. Noise maps

10. Analyzing the deviation

5. Noise maps representing the targeted areas with the best level of approximation

7. Comparisons with a "benchmark noise map" and between laboratories