

# **Web mapping solutions for the development of Emission Inventory Models**

Vitor Gois, Jorge Nelson Neves, Marco Freire, Hugo Maciel, Pedro Torres, Joaquim Muchaxo,  
Luisa Nogueira

InventAr, Est. Proj. Unip. Lda. R. Sarmento Beires, 15-8ºesq, 1900-410, Lisbon, Portugal  
Tel: +351 91 672 22 45, fax: +351 21 840 66 43  
[vitorgois@mail.telepac.pt](mailto:vitorgois@mail.telepac.pt)

Ithaca, Praceta Natália Correia, nº 9, R/C Dto, 7005-260 Évora, Portugal  
Tel: +351 210 936 418  
[info@ithaca.pt](mailto:info@ithaca.pt)

Comissão de Coordenação e Desenvolvimento Regional de Lisboa e Vale do Tejo  
Lisbon, Portugal

## **ABSTRACT**

The development of inventory models should be guided according to the needs of the air quality modellers and policy developers. Only this way inventory models can fulfil their task as an useful and efficient tool. Nowadays in developed countries, and except for ozone, most air quality problems are restricted to urban areas with denser traffic or in the vicinities of large industrial areas, and generally, policy teams want to define and test measures upon specific actors – point sources, traffic areas –at specific geographical locations. The development of the European Plans and Programs can be highly enhanced by a GIS tool, connecting the Inventory System and the Air Quality Models under the control of the policy team. It may integrate the inventory model in a simple set of indicators that can be appropriately manipulated at geographical level, and used dynamically as input to an air quality model. The policy developer can test modifications at precise geographical locations.

Although inventory users seldom need all their functionalities, dedicated GIS are usually too complex and would require substantial resource allocation and extensive training. The complete functional requirements of the vast majority of users can be fully covered with a geographical database and the ability to select and manipulate emission and emission parameters of geographical objects. SIMULAIR, the Web GIS solution proposed in this paper, combines OpenGIS standards - WMS (Web Map Service) - with innovative technologies for web mapping using open source software: open source web mapping server (UMN MapServer), a geographical database stored in PostGIS providing the geographical storage and querying functionality, and an open source map client (Open Layers).

## **INTRODUCTION**

An inventory model should not be considered an end in itself but as a tool supporting the work of air quality modelers and, above all, policy developers. Only with this objective in sight it may be possible that the substantial efforts and resources normally applied for the development and maintenance of inventories will result in a practical tool that may be used to select policies and measures, to explain air quality problems and to facilitate air quality management.

Recent legislation of the European Union (EU) made compulsory the development of “Plans and Programs”, a set of policies and measures for the improvement of air quality, whenever air quality concentration data shows an exceedance of limit values.

Nowadays urban areas in developed countries suffer from air quality problems, but these are more acute in localized places, or hot-spots, which are usually under the strong influence of concentrated traffic flow or heavy industrial areas. Hence, at regional level, measures that can be established to reduce emission and improve air quality must have a strong concern about the specific spatial placement of economic activities and resultant emissions. In that sense, policy developers working at regional level generally discuss and select measures upon precise entities – point sources, traffic line sources, airports, industrial units – and at specific geographical locations. This is particularly true when setting the actions to control outbreaks of pollution episodes. As an example, a policy developer expert could want to restrict traffic in central urban areas to buses and public transportation. In practical terms, that would mean selecting the road-links in the area and reduce emission resulting from the elimination of private cars. Thereafter this new inventory scenario would generate a new input data for the air quality model that the policy expert could analyze.

Sometimes, when “Plans and Programs” are being developed, the inventory team, the model team and the policy developers team work together but in different locations, using different environments, and relying in systems that were not originally designed to work in tandem. This way of working may become cumbersome, slow, rigid, inflexible and inefficient. The major problem is that the choice of policies can take a long time to be translated to changes in the inventory and thereafter to changes into the model. Model result for a given policy will take weeks to return back to the policy team, most of the time involving substantial efforts by the inventory team.

There is clearly a need to develop a tool that could enable a more easy connection between the inventory system and the air quality model, under the control of the policy team, in that way improving substantially the work of the development of “Plans and Programs”. From previous experience the main requests of the policy team was to select specific objects – traffic lanes, industrial point sources – and to act on their variables in order do reduce emissions. The main objective of the current project was to create a system that may allow the policy team to become more independent of the inventory team.

However, the complete translation of the inventory into a stand-alone application, based on a GIS that could handle all changes required by the policy team is usually impractical. For instance, the original inventory in the Region of Lisbon and Tagus Valley (RLTV) is developed in a set of Microsoft Excel spreadsheets which enables the developer with a flexible workplace that builds graphs easily. The development of a dedicated program that could include all calculations and maintain Excel flexibility is out of reach of the resources available for the regional authority, apart from the considerable development time that that task would require.

The decision must be therefore to translate the original inventory system into a simplified mirror image having all information required to be acted upon by the policy expert, together with an appropriate presentation of the information in a spatial environment. This means that a simple set of indicators coming from the inventory could be appropriately manipulated at geographical level, and used dynamically as input to an air quality model. That way, policy developers would act directly in geographical objects, without having to change the inventory in detail, and see directly the outcome after sending the changed situation (scenario) to the air quality model.

The full capabilities of a commercial GIS are not needed for the system to operate conveniently. GIS are complex and require large resource allocation and extensive training, although inventory users

seldom need all the existing functionalities. The complete functional requirements of the vast majority of users may be covered with only a distributed geographical database and the ability to select and manipulate emission and emission conditions from geographical objects either point sources, area sources and line sources.

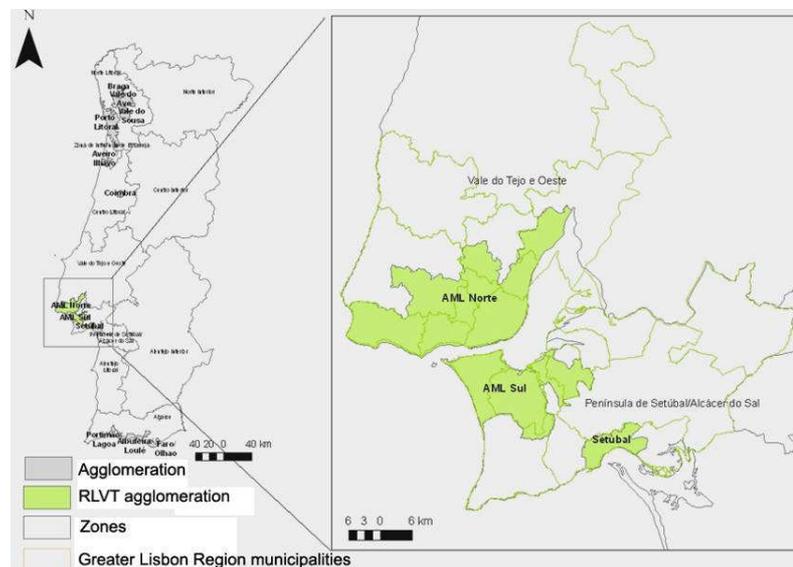
SIMULAIR, a web mapping solution was developed and proposed to be implemented as a pilot study in the Lisbon and Tagus Valley Region. The system is now under development and it is being implemented for SO<sub>x</sub>, NO<sub>x</sub> and PM<sub>10</sub>. A fully operational version is expected by the end of the year for evaluation.

## BODY

### Air Quality Problem in Lisbon Area

In recent years high concentration levels of pollutants were registered in the RLTV region<sup>1</sup>, causing frequent exceedances of the EU annual average limit value and daily limit values for Particulate Matter (PM<sub>10</sub>) with reference to human health protection. In traffic hot-spots exceedances have also occurred of the EU annual limit value for Nitrogen Dioxide (NO<sub>2</sub>).

Air Quality legislation in the European Union (EU) requires member states to identify specific zones<sup>1</sup>, which are defined using population and population density as indicators of the importance of air quality receptors, and in which areas air quality has to be assessed in more detail. For zones with higher population densities – “agglomerations” –, such as is the case of the “AML Norte”, “AML Sul”, and “Setúbal”, a more exigent surveying or analysis system had to be established. Hence, air quality in RLTV is monitored by a network of 23 monitoring stations and occasional extensive monitoring procedures using passive sampling or low-volume samplers.



**Figure 1.** Zones and agglomerations in the Lisbon and Tagus Valley Region

Consequently, the regional authority for air quality in Lisbon area - the Commission for Coordination and Regional Development of Lisbon and Tagus Valley (CCDR-LVT) - developed recently an Emission Reduction Plan<sup>2</sup>, where measures and policies are identified to solve the air quality problems. In order to elaborate this plan it was necessary, as a first step, to establish a detailed and

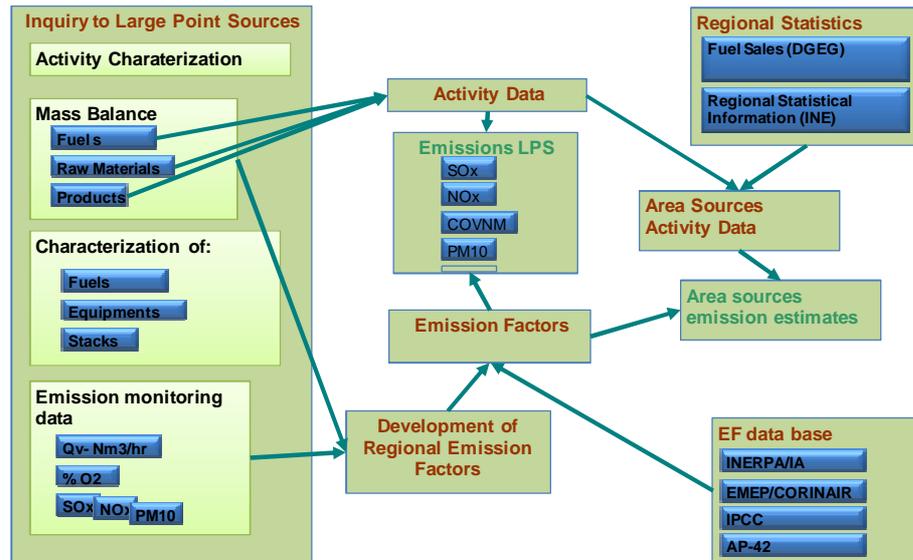
suitable Air Emission Inventory that could support the implementation of an urban air quality model, the Australian CSIRO's TAPM. This model would be used to identify major problems and to predict and assess the results of the measures and policies identified in the plan.

### **The Air Emission Inventory in the Region of Lisbon and Tagus Valley**

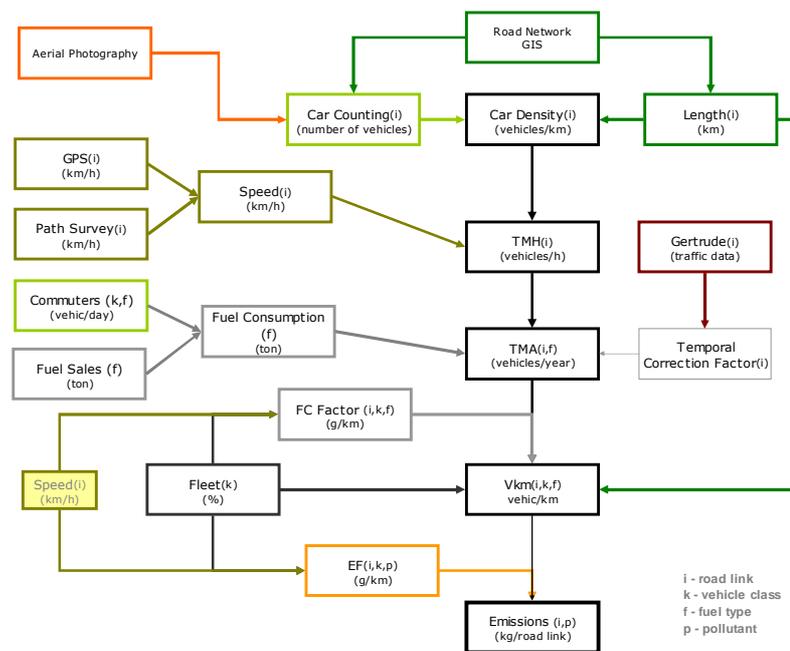
The inventory of air emissions covers the full area of the Region of Lisbon and Tagus Valley (RLTV)<sup>3,4</sup>, which spreads over 51 municipalities. It pretends to be a integrated inventory covering pollutants with diverse implications: compounds responsible for health hazards such as SO<sub>x</sub>, NO<sub>x</sub>, CO, particulate matter and heavy metals; effects on vegetation: SO<sub>x</sub> and NO<sub>x</sub>; acidification: SO<sub>x</sub>, NO<sub>x</sub> and NH<sub>3</sub>; eutrophization: NO<sub>x</sub> and NH<sub>3</sub>; ozone precursors: NO<sub>x</sub>, NMVOC, CO and CH<sub>4</sub>; precursors of secondary particles: NO<sub>x</sub>, SO<sub>x</sub> and NH<sub>3</sub>; and carcinogenic substances such as benzene and PAH. Nevertheless, due to the recent history of air quality problems, special focus has been given to PM<sub>10</sub> and NO<sub>x</sub>.

The inventory departs from a bottom-up approach, producing estimates for individual sources, either point sources, such as industrial plants, utility power plants or large commerce areas, or linear sources, which comprehends all road links in urban agglomerations and dominant high-ways. Finally, the inventory is coupled with a top-down approach, using data from regional statistics such as total fuel sales or total industrial production, in a way to guarantee that all emissions in the region are covered and the inventory is complete. The emissions estimated from the top-down approach, that are reminiscent of individual sources, are considered area sources and allocated to the administrative boundary from where statistical information was collected – usually municipal areas. Whenever further spatial disaggregation of data was necessary - emissions for most of these activities are estimated at sub-municipal level - generally population was used as a driver for the process.

Emissions from individual point sources were estimated using information collected directly from industrial plants using a dedicated inquiry or re-using the information delivery by the units during application for a environmental permit<sup>4</sup>. Monitoring data, collected by industrial units and submitted to CCDR-LVT under the "Auto-controlo" program, was used to derive plant specific or region-specific emission factors. A simplified description of this system is presented in the following figure.



**Figure 2.** Methodology used to estimate emissions from Large Point Sources and remaining industrial area sources



**Figure 3.** Overview of the methodology used to estimate emissions at urban roads

Emissions from road traffic are estimated<sup>3,4,5,6,7,8</sup> according to methodologies with 3 tiers, according to the type of road link being estimated:

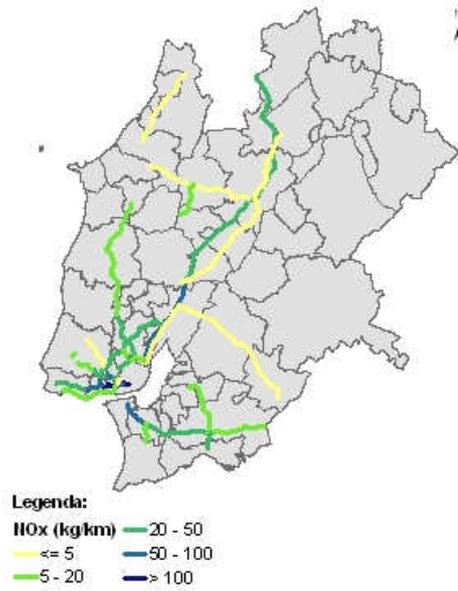
- (1) Road links in dense urban areas (agglomerations). Emissions are estimated at very fine detail (for all road links) using aerial photography and GPS data collection. A more detailed explanation of this methodology was explained before<sup>5,6</sup> and only a short synopsis is presented in the next set of figures.
- (2) Main road links in rural areas. Emissions are estimated using traffic monitoring data and regional emission factors resulting from the average regional fleet;



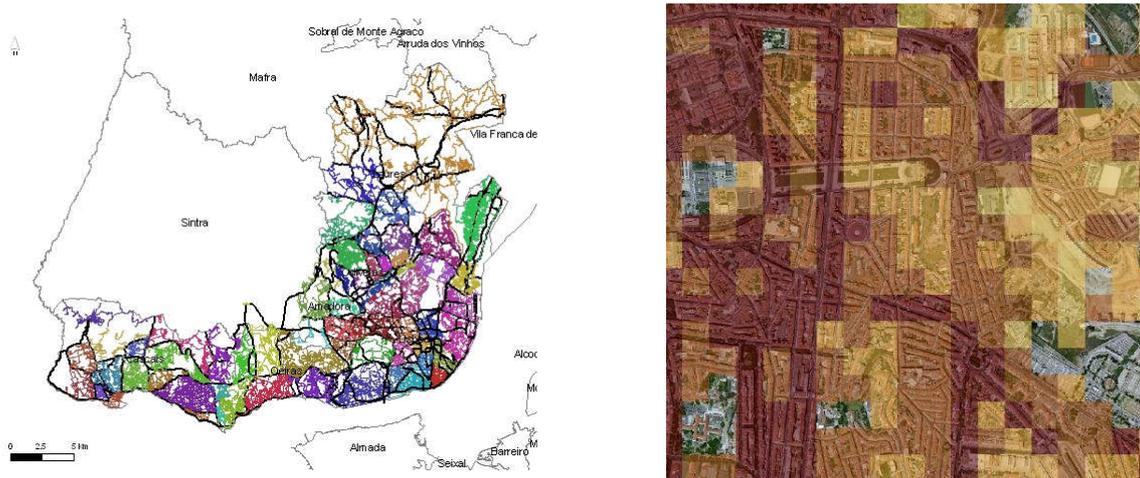
Summarizing, estimates made by the inventory are available for, (1) Large Point Sources; (2) Individual Rural line sources; (3) Individual Urban line sources; (4) Area sources.



**Figure 5.** Large Point Sources

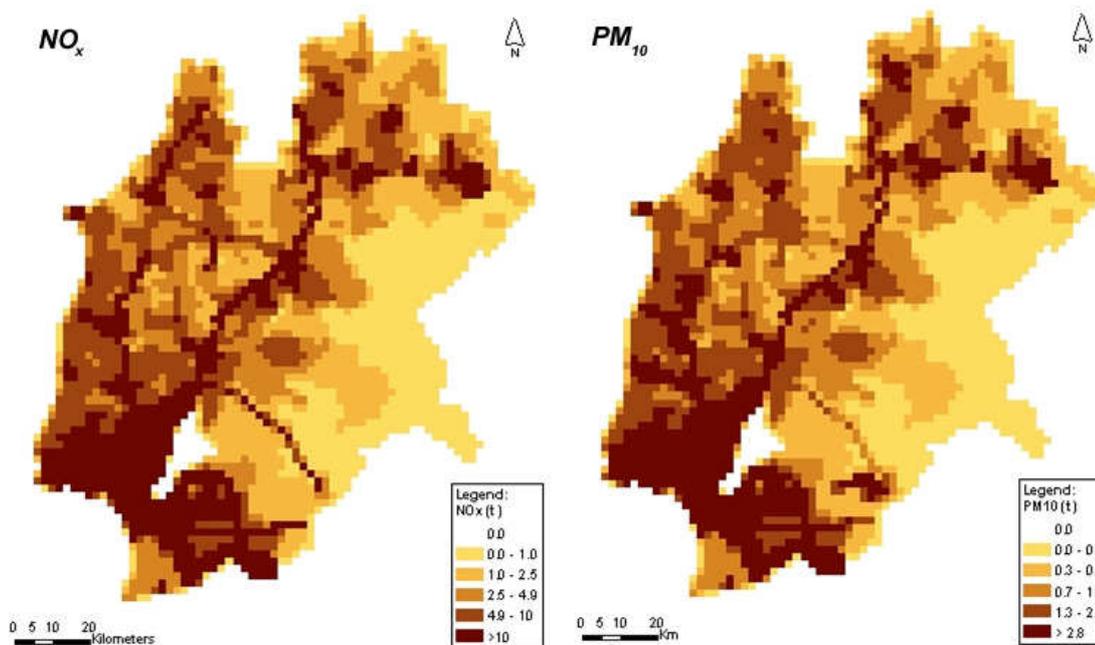


**Figure 6.** Individual Rural Line Sources



**Figure 7.** Individual Urban Line Sources

TAPM air quality model uses two sets of information: total emissions per pollutant aggregated in a regular 2 x 2 km grid matrix and a reduced number of Large Point Sources. Emissions per grid and the selected Large Point Sources are presented in the next figures.



**Figure 8.** Gridded emissions of NOx and PM10 in RLTV, for 2001. Input data for TAPM model



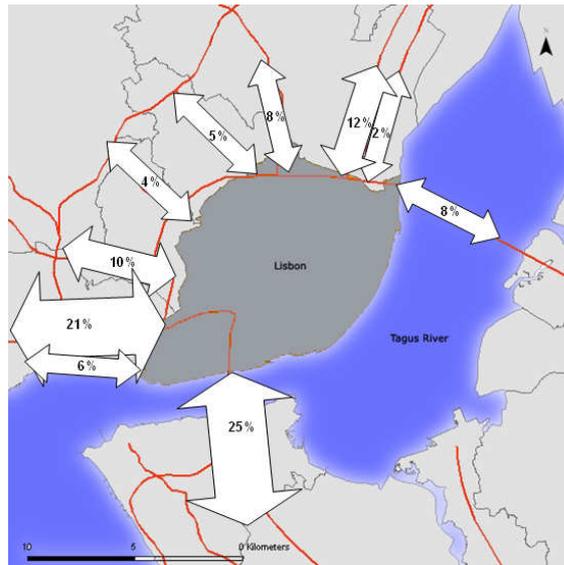
**Figure 9.** Identification of Large Point Sources in RLTV region used as LPS in TAPM model

## Plans and Programs

For those areas where human health related limit values were exceeded, directive 1999/30/CE of the European Union (UE), set the obligation for the development and implementation of Plans and Programs<sup>2</sup>. As presented before, exceedance of limit values had occurred recurrently since 2001 for  $PM_{10}$  and  $NO_2$ .

Most measures identified in Plans and Programs for Lisbon are related to air traffic emissions, which is comprehensible following the results of the air emission inventory which has shown the dominant influence of mobile sources in all area and in particular in the influencing area of the hot spots. Particular importance was given to the core of Lisbon city area and its boundaries, which acts as a strong magnet to daily commuting traffic, as may be seen in the following picture. According to the team responsible for the development of Plans and Programs, road traffic related measures applied in Lisbon city will have indirect effects in the all metropolitan area, including nearby municipalities<sup>9</sup>.

Fifty measures and policies were identified in Plans and Programs<sup>2</sup>. Because their relevance in air quality amelioration is very diverse, a simplified cost-benefit analysis was established and used to determine a feasibility ranking of measures<sup>9</sup>. The following table presents the list of the top measures that way identified. It can be seen that most show the importance of the determination of the exact and detail places where they will be applied.



**Figure 10.** Relative importance of commuting vehicles crossing daily Lisbon borders (IEP data for 2000).

**Table 1.** List of the main measures identified for agglomeration North of Lisbon<sup>2</sup>

Reduction Measure		Total PM10 reduction (t/yr)	Cost-Benefit	Relative ranking
M20a	Increase of the number of BUS corridors	2	5	1
M19	Implementation of differentiated payment schemes according to the occupation of vehicles on existing toll roads	8	1	2
M16	Implementation of Lanes of High Occupancy on Lisbon major roadways	7	3	3
M13a	Incentive to retrofitting of buses	4	8	4
M9	Parking regulations enforcement increase	3	10	5
M8	Introduction of alternate license plates	12	1	6
M6a	Retrofit plan for Buses	6	9	7
M18a	Retrofit plan for taxis	11	4	8
M17a	Taxi fleet renewal	5	12	9
M14a	Buses renewal	1	15	10
M7	Installation of particle filters systems in buses	13	7	11
M10	Introduction of a Low Emission Zones in the city of Lisbon	14	6	12
M11a	Conversion of TCR vehicles to LPG	9	13	13
M11a	Conversion of TCR vehicles to LNG	10	14	14
M15a	Retrofit of vehicles for solid waste collection	15	11	15
M12	Circulation tax in downtown areas	16	1	16

## The TAPM Air Quality Model

The Air Pollution Model (TAPM), from CSIRO<sup>10</sup>, was installed in CCDR-LVT by *Universidade de Aveiro* as an aid to air quality assessment and management<sup>11</sup>. TAPM can be used to predict three-dimensional meteorology and air pollution concentrations. It comprehends a prognostic meteorological model and an air pollution concentration components, coupled together. This model predicts the air flows to local-scale air pollution, such as sea breezes and terrain induced flows, against a background of larger-scale meteorology provided by synoptic analyses.

The meteorology component of TAPM is solved by an incompressible, non-hydrostatic, primitive equation model with a terrain-following vertical coordinate for three-dimensional simulations. The momentum equations are solved for the horizontal wind components, the incompressible continuity equation for vertical velocity, and scalar equations for potential virtual temperature and specific humidity of water vapour, cloud water/ice, rain water and snow. The Exner pressure function is split into hydrostatic and non-hydrostatic components, and a Poisson equation is solved for the non-hydrostatic component. Explicit cloud microphysical processes are included. The turbulence terms in these equations were determined by solving equations for turbulence kinetic energy and eddy dissipation rate, and then using these values in representing the vertical fluxes by a gradient diffusion approach, including a counter-gradient term for heat flux. A vegetative canopy, soil scheme, and urban scheme are used at the surface, while radiative fluxes, both at the surface and at upper levels, are also included<sup>10</sup>.

Concerning the air pollution component of TAPM, it consists of four modules:

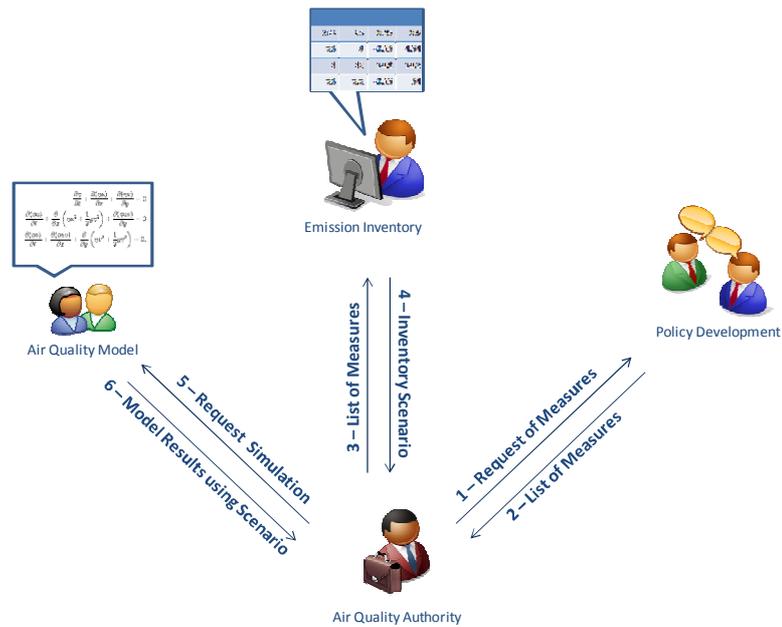
- (1) The Eulerian Grid Module (EGM) solves prognostic equations for the mean and variance of concentration, and for the cross-correlation of concentration and virtual potential temperature.
- (2) The Lagrangian Particle Module (LPM) used to represent near-source dispersion more accurately.
- (3) The Plume Rise Module is used to account for plume momentum and buoyancy effects for point sources.
- (4) The Building Wake Module allows plume rise and dispersion to include wake effects on meteorology and turbulence.

TAPM includes gas-phase photochemical reactions based on the Generic Reaction Set, gas- and aqueous-phase chemical reactions for sulfur dioxide and particles, and a dust mode for total suspended particles (PM<sub>2.5</sub>, PM<sub>10</sub>, PM<sub>20</sub> and PM<sub>30</sub>). Wet and dry deposition effects are also included.

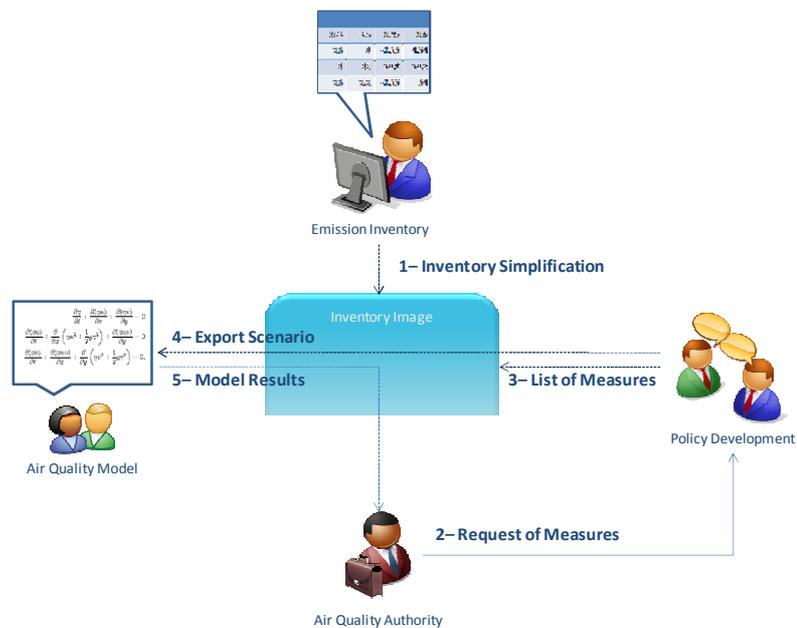
Details about the adaptation of TAPM to the LTV region were presented in other report<sup>11</sup>.

## System Development: Mirror Image of the Inventory

The air emission inventory of the RLTV region is developed in an Excel environment, using the advantage that this tool has in terms of flexibility, incorporation of very useful – but integrated and easy to use – analytical tools, such as graphics, statistical analysis, simple database analysis and queries. Nevertheless, this same flexibility of Excel gives too much freedom to the inventory experts, which may create additional complexity and make the model more difficult or cumbersome to be understood by others. Therefore, it is not feasible to expect that the policy experts have the patience and time to be deeply involved in the understanding of the original inventory. Work of both teams – the inventory team and the policy team – together every day, although representing the ideal solution, is clearly not practical – particular when these teams are external to the administrative body and operate physically apart.



**Figure 11.** Teams involved in Air Quality Management. The baseline scenario



**Figure 12.** Teams involved in Air Quality Management. Scenario enhanced by SIMULAIR

SIMULAIR system was designed to:

- Create a mirror image of the Inventory. It does not cover all information and complexity included in the inventory, but reflects a simplified image of the inventory reality;
- Focus on variables that most probably the policy team wants to change and test;
- Provide a pathway between the inventory and the air quality model, minimizing the dependency of the policy team in the other teams for simple changes. SIMULAIR it is however, not intended to replace either the inventory system neither the air quality model.

In operational terms, the goals established in SIMULAR development, were that it should be:

- Simple to navigate. A simple tree structure must be used, avoiding complex links and the probability of being lost in the site;
- Easy to use and fast to learn. It should be as intuitive as possible and should assume that the policy developers team is interested in having a fast feed-back to questions about measures, and has not the time or resources to invest in a long training period. Also, the user needs not to be an expert in GIS;
- Unambiguous commands and navigation links, keeping the user always aware of the changes that it is testing in the system;
- Test or scenario driven. The user should not change original inventory data, but maintain record of changes, and be able to know which info it has changed and how;
- Able to operate changes in single sources or in bundle of sources grouped together;
- Appealing interface.

Two key concepts were used to improve the system:

- Multipliers. Original information in the inventory, concerning activity data, emission factors and emissions is stored in the system and always visible to the operator. He has the possibility of changing values of variables directly, or applying multipliers while retaining the original values;
- The environment where the operator is acting is defined by (1) the “Inventory” representing an instance of the space domain and time domain that the inventory is referring, including reference year; (2) Scenario, comprehending all changes in multipliers and variables, particular for a given exercise. Information for a particular operator and for a given measure may be recorded individually.

The air emission inventory available at CCDR-LVT consists of a set of Excel spreadsheets, for each specific sector. Information for each spreadsheet is collected in a standard form sent to TAPM model. After analysis of the information in the inventory and TAPM model requests, the information that is stored into SIMULAIR was chosen by selection of the variables that the user may want to change during policy modeling, but also taking care of the easiness that such change in variables could be reflected in emission estimates. The following table summarizes the select variables, for each source type. The user may also, for point sources and line sources, change the location of these emission sources.

**Table 2.** Mirror System of the Inventory. Selection of information data from the inventory visible to SIMULAIR

Source	Manipulable data	Notes
Point Sources	ID, Name and Activity code (EAC code)	The number of Large Point Source data is larger than the large point sources used as input to TAPM. Every individual unit may include more than one stack. The relation between flow variables in the stack is automatically updated by the system.
	Coordinates	
	Stack parameters: H, D, V, VF, T	
	Activity Data	
	Emission Factors	
Line sources	Emissions	Each road is made of several sub-link segments, according to changes in flow, velocity or traffic composition. User may change the fleet in absolute terms or per cent, SIMULAIR checking for 100 per cent. EF for each individual vehicle type is automatically estimated from velocity and average vehicle fleet. Velocity may vary according to vehicle type
	ID, road name and sub-link ID	
	Coordinates	
	Total Vehicle flow	
	Composition of fleet: Heavy Vehicles, Passenger Cars, Light Duty Vehicles, 2 wheelers	
	Velocity	
Area sources	EF per pollutant and vehicle type	Area boundaries are administrative boundaries and cannot be changed by the user.
	ID, Name and Activity code (EAC code)	
	Activity Data	
	Emission Factors	
	Emissions	

## System Development

GIS offer capabilities to collect, interpret and publish spatial information. Although being the appropriate tool for environmental scenario management, it has important drawbacks mostly resulting from the complexity of use and cost associated with proprietary systems. A huge investment in training and system maintenance has to be considered if generic proprietary tools like ESRI ArcGIS or Intergraph Geomedia are to be used.

On the other end of the spectrum there are internet mapping technologies which were developed in the last decade. In the first years of development, internet mapping was only used for map viewing purposes. This scenario has changed latter due to the important developments in spatial database and web services technologies, along with a substantial effort in interoperability standards development lead by the Open GeoSpatial Consortium. OGC developed specifications that made possible complex spatial analysis to be conducted on the WWW. The OGC has been publishing several spatial data interoperability standards in the form of web services. The Web Map Service implementation<sup>12</sup> is very commonly found in several proprietary and open source systems. Its popularity is mostly due to its simplicity and immediate availability in any browser platform.

A Web Map Service is a web service that produces maps in several raster formats (PNG, GIF, JPEG) and in vector format (SVG, WebCGM) that may come simultaneously from multiple remote and heterogeneous sources. If several solutions implement WMS, it will be guaranteed that they will work together. The WMS is basically a web service that can provide information about the types of maps that

the server can produce (GetCapabilities), information about the map content (GetFeatureInfo) and the actual map as a picture or set of pictures (GetMap).

A second development strategy was the use of Open Source Software Systems. From the open source definition<sup>13</sup> it implies free redistribution (with or without licensing fees charged) of the isolated component or included in a bundle with the full source code, allowing modifications and derived work. The adherence to the open source movement is justified by the need to provide an extensible system, making it possible to add new users or to develop new functionality as the system evolves. Proprietary software uses the paradigm “one solution fits all”, making a huge percentage of the available functions barely used. A system like the one presented here should be designed to evolve gradually, with ease of use as a major concern together with a clear evolutionary path.

The Open Source Geospatial Foundation<sup>14</sup> has been created to support and build open source geospatial software. Their goal is “to encourage the use and collaborative development of community-led projects”. There is already an interesting list of contributions with several packages with different degrees of maturity.

Open source web mapping systems are clearly the best solutions for the problem in hand as it gives the developer access to all the basic functionality, maintained and developed by the user community and following the interoperability standards.

### **Selection of tools**

The evaluation of web mapping open source software should address several issues namely documentation, development team knowledge and references, modularity, extensibility, size of the user community, references and case studies. The open source GIS space is populated with several products that fill completely the needs for this project.

The system architecture followed in this project, presented in next figure, is based entirely on open source web mapping components, chosen after evaluation of the above criteria:

- University of Minnesota Map Server for mapping functionality<sup>15</sup>
- PostGIS as a spatial database engine<sup>16</sup>
- OpenLayers for displaying map data in web browsers<sup>17</sup>

### ***UMN\_Mapserver***

MapServer is basically a web map server built to support the development of web mapping applications. It is very fast and reliable in the production and display of geographic data in vector and raster format, capable of reading data from the major GIS applications and of connecting to spatial databases (e.g. PostGIS). It was originally developed at the University of Minnesota and it is maintained by a large group of developers.

Map server has built-in functionality with a significant importance to this project namely the support of industry standard data formats and spatial databases and the support of popular Open Geospatial Consortium (OGC) standards including WMS. Other features include on-the-fly feature classification, sophisticated rule-based labeling, on-the-fly projection for both raster and vector data and a wide variety of spatial and attribute-based queries.

In SIMULAIR the UMN MapServer was used to serve aerial photographs (using tile cache) and vector information stored in a PostGIS database. The native presentation layer was substituted by Open Layers and the information exchanged between MapServer and OpenLayers was based on the built-in WMS functionality.

**PostGIS<sup>18</sup>**

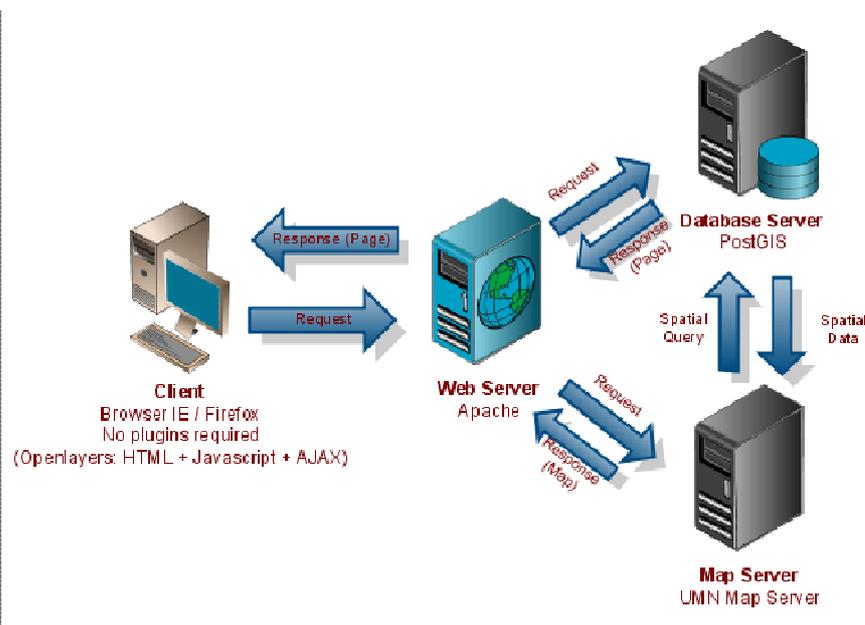
PostGIS is based on PostgreSQL object-relational database used to extend the database engine to incorporate GIS objects. It supports several optimization methods such as R-Tree spatial indexes, and functions for analysis and processing of GIS objects. This allows that all the system advanced spatial queries can be executed by the database engine, making it possible to deliver complex systems with open source web mapping tools.

**OpenLayers<sup>19</sup>**

OpenLayers is an open source AJAX toolkit for combining data from any source using a bit layering technique. The juxtaposition of pieces of information is a client visualization paradigm completely open and without imposing limitations to the sources. It does not depend on the server technology and can display a set of vector data, such as points, with aerial photographs as backdrop maps from different sources.

**System Definition**

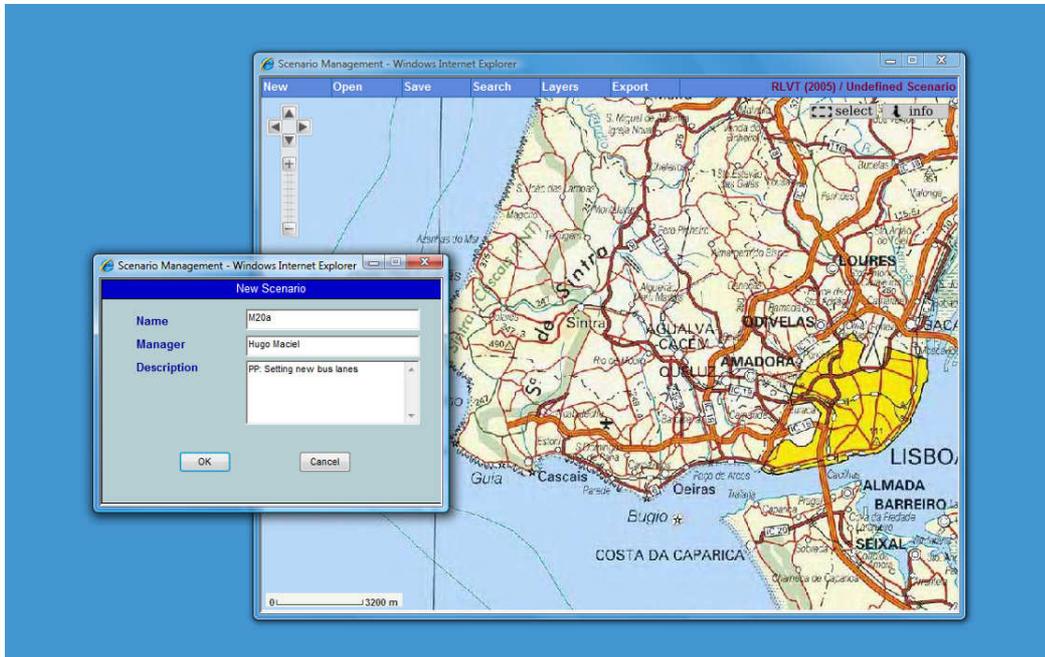
The system architecture integrates several open source components, using the OGC WMS (Web Map Service) to guarantee the complete independence of the presentation layer.



**Figure 13.** Overall System Architecture

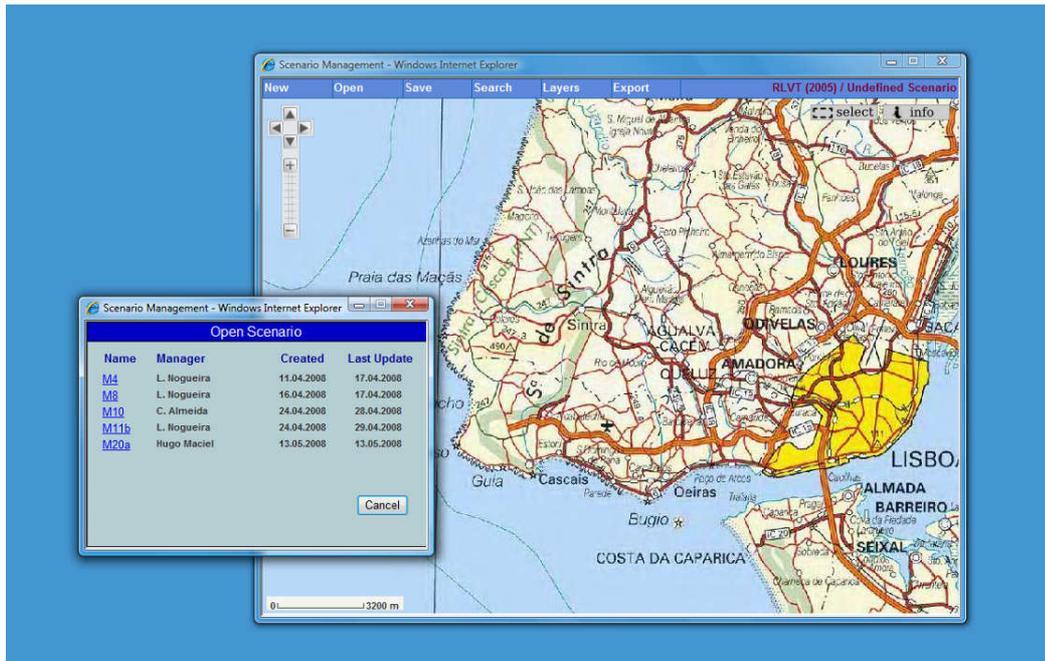
## Toolkit interface

After opening a given inventory the user can define new scenarios or open existing ones. In the case the user opts to create a new scenario a new popup window is used to input the name, the associated manager and a brief description of the scenario.



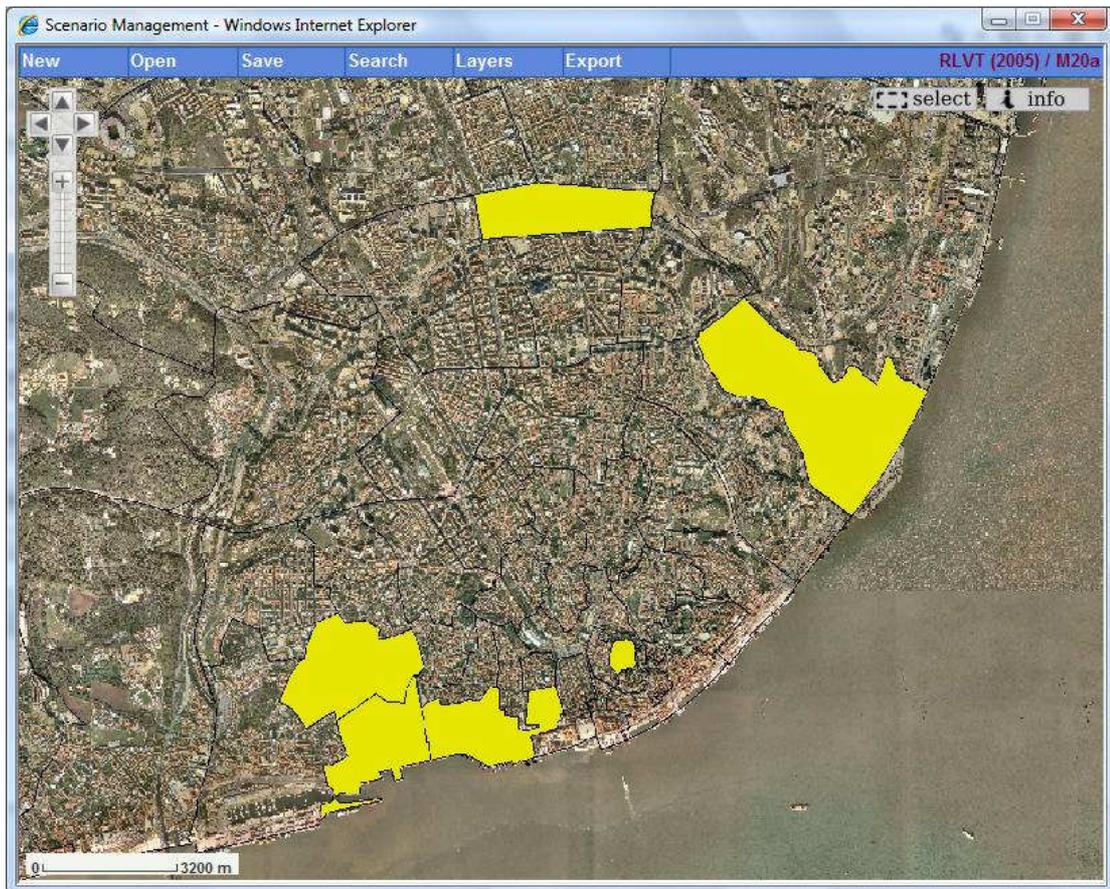
**Figure 14.** New scenario for a given inventory

Alternatively the user can open existing scenarios from a pre-existing list. In this case additional information such as date of creation and date of last update are given to the user.



**Figure 15.** Open scenario from list

The design of the scenario management toolkit had the objective to follow very closely the typical procedures of the working environment. A very simple window with a map background and tools to access system functions was designed.



**Figure 16.** Interface components of the scenario toolkit interface

On the top of the window a one-level menu is presented with the main system functions:

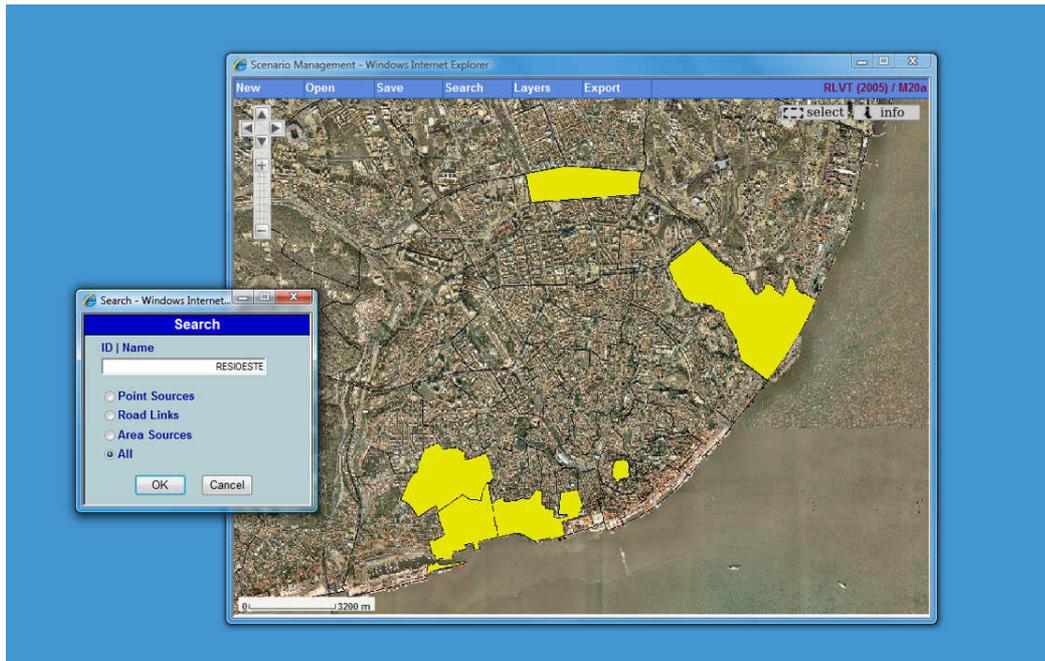
- New Scenario, Open Scenario and Save Scenario
- Search and change layers
- Export scenario to TAPM model

The top right of the window presents the inventory/scenario being currently under edition.

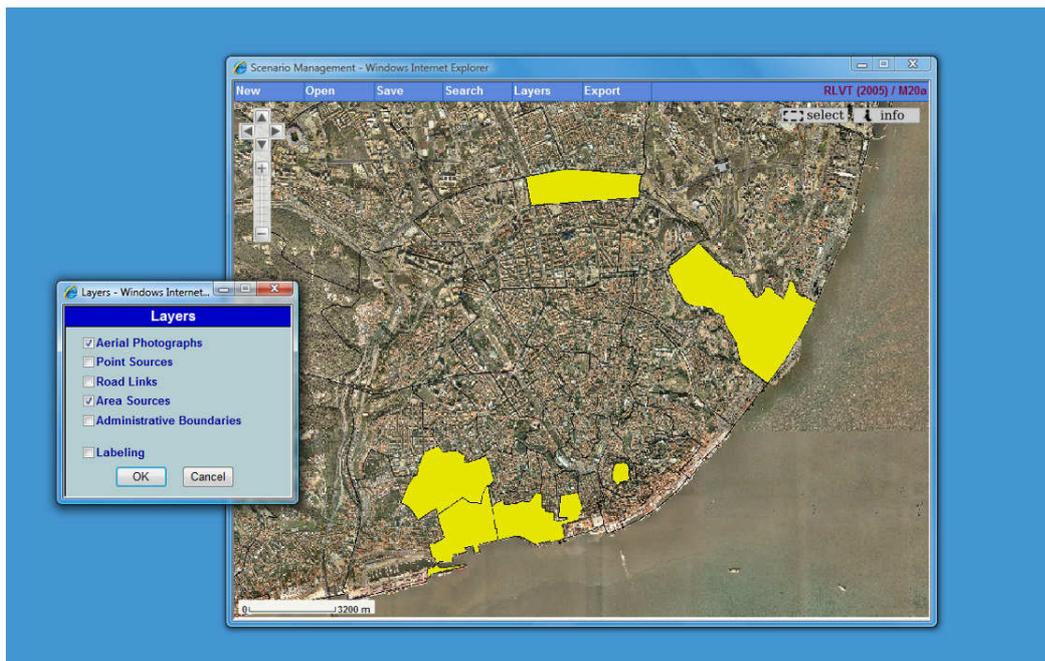
The inside window space is used to accommodate the map navigation and query functions:

- Zoom and pan (left). This actions can be made directly on the map - double-click to zoom in and drag to pan – or using the top left tools on the map.
- Select objects. Toggles to select mode allowing the user to directly select the objects on the map (points, lines and polygons).
- Get info. For the selected objects, from a query or from direct manipulation of the map, opens a new form with the object attributes. If the user as edit permission over the scenario, the attributes of the objects can be changed either one by one or all together.

Search and Layer selection are straightforward.

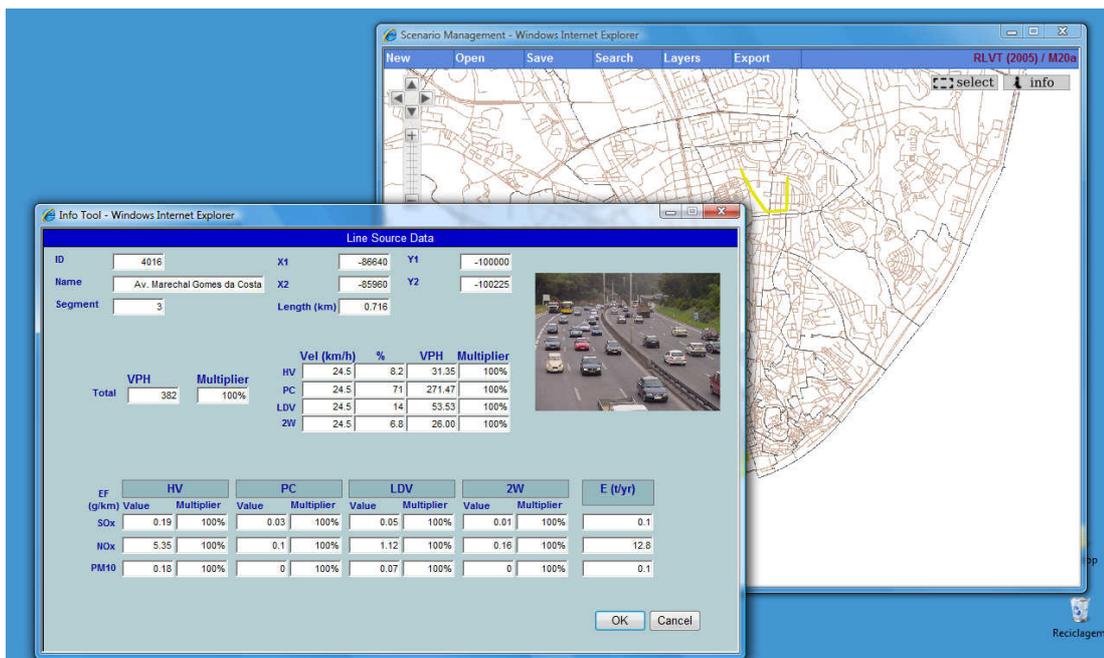


**Figure 17.** Function for search in layers



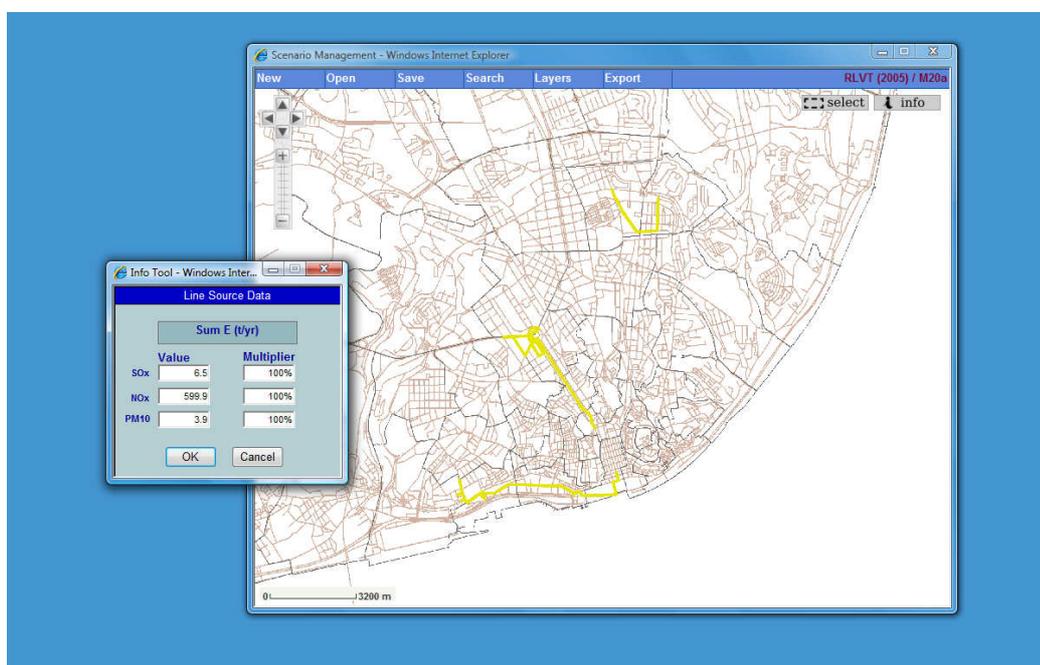
**Figure 18.** Change working layers

The system includes very detailed forms to access information about individual objects data. The changes on the fields are stored in the database for each scenario, maintaining always a backup of the original data. Below an example for line source data is depicted.



**Figure 19.** Editing line source data (one object selected)

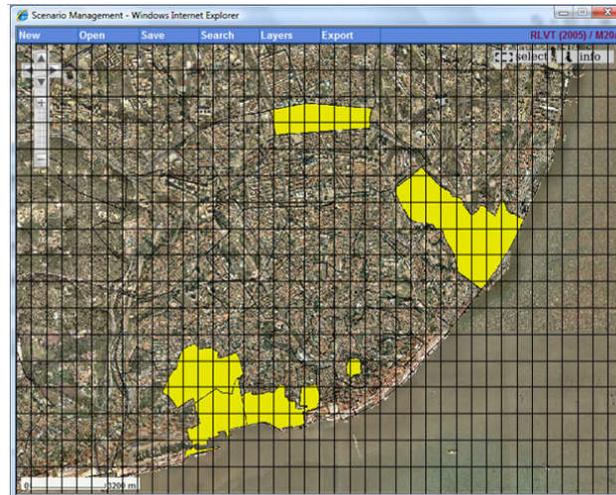
When several objects are selected - accordance to the example presented below a set of line objects - the user can only change emission parameter values, directly or with a multiplier. The same principle applies to other types of sources (point sources and area sources).



**Figure 20.** Editing attributes for several roads simultaneously

The final step of the scenario management is the export of the scenario data to a set of files that will be read by the TAPM model. This operation involves a rasterization of the output and further conversion to an ascii file. It corresponds to the superposition of a regular grid on top of the map and

spatial analysis queries are run directly on the PostGIS server. The contribution of each source is added proportionally to the percentage of the source covered by the grid. In the case of point sources simple point in polygon is needed. For area and line sources more complex spatial clipping has to be computed.



**Figure 21.** Illustration of the export to TAPM process

## CONCLUSIONS

Considering the occurrence of air quality problems in recent years in restricted places in the urban area of Lisbon and the legal obligation to implement Plans and Programs it may be helpful to facilitate the linkage between the main actors involved in the process, i.e. the policy team that will be responsible for the plan; the air quality modellers that translate the effects of measures in emissions into air quality standards and, finally, the air inventory team. For that purpose a system was proposed that could produce an image of the inventory that the policy developers could manipulate easily and at will.

After consultation with the policy team, and being aware of the needs of the air quality model, a innovative system was proposed based on open source Web GIS. Using a limited amount of resources, this project was able to develop a simple inventory model that has good prospects of being sufficient to help the analysis of policy measures and to evaluate consequences with appropriate spatial disaggregation.

Results show that an inventory model can be simple, flexible, easy to use and learn and relying on open source software products, while maintaining the desirable robustness and interface attractiveness. Key for the achievements of this tool was the previous thorough analysis of the needs of the system to be developed and what the ultimate users really want and what they seek to avoid, i.e. to develop a system oriented to match both the needs of the policy developers and air quality modellers and not the capabilities of inventory producers.

Although this system was developed as a proposal pilot product for the Region of Lisbon and Tagus Valley, the simple and general structure that was defined clearly allows the generalization of this new system for other areas of suitable dimension and similar inventories of detailed disaggregation.

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## **KEY WORDS**

Emission Inventory Model

Policies and Measures

Open Source GIS

Web mapping

PostGIS

Map Server

Lisbon