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Supporting Environmental and Energy Decisions through an Open Software Structure

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Abstract: Public participation to environmental planning and management decisions, as suggested by local Agenda 21 processes, can be supported by software tools developed with a cyclic interaction with all the stakeholders and simple enough to be quickly operated by a large set of heterogeneous users. This also helps preventing their rapid aging and their excessive dependence on changing technologies. We experimented the development of such software tools using an Office type environment to store data, analyse, and geographically represent the effects of alternative decisions and html files to help utilizing the software and distributing the information over the Internet. Two different applications are reported in the paper. The first refers to air pollution control in a region in Northern Italy and tries to evaluate the health impacts and external costs of PM10 traffic and domestic heating emissions. The second deals with energy planning at provincial level and is specifically devoted to the exploration of renewable energies alternatives. Within both systems, some complex simulation/optimization model is needed to carry out a part of the analysis (e.g. to compute the PM10 mean concentration produced by a given emission scenario). These models, which are extremely data and computer intensive, were simulated off-line for a number of different scenarios and then embedded into the software tools with a nearest neighbour technique. While this approach certainly decrease the precision of the overall results, it allows an instantaneous analysis of different proposals during the public debates and allows for a straight addition of further scenarios even produced by different off-line models.

Keywords: Decision Support; Regional Planning; Agenda 2; Spreadsheet; Nearest Neighbor, Air pollution.

1. INTRODUCTION

Environmental awareness spreads more and more among citizens and public institutions and local governments have to find new tools for policy development that take into account various environmental aspects, allow a wider participation, and increase the transparency of the decisions. For instance, the local Agenda 21 process, recommended by Rio Conference, calls for a continuous involvement of all stakeholders in the development of a given territory as one possible answer to the NIMBY syndrome that risks to block any new project in countries where a minimum of public debate is allowed. The conclusions of the EU INTEGAIRE Project (www.integaire.org) state (p. 102) "Local groups need to be involved from the start when an action plan is being drawn up. Local authorities need...to look for innovative ways to engage stakeholders".

Decision support tools for these purposes should frame local environmental conditions and show how the situation may develop, following existing trends as well as new government actions. The way in which they are developed should also allow an easy and direct access to the information by (most of) the people involved, should prevent a rapid

aging through the possibility of an easy updating, and should support experimentation and testing of alternatives hypotheses by a (possibly large) set of different users.

We derived two basic consequences from these considerations.

First, the process of developing a software tool to support environmental policy decisions is a cyclic one. The developers and the users must work together to determine the aim and scope of the software product and to define the critical aspects of the inquired phenomena and agree on the simplification, or by-pass, of features that do not seem to be basic for the result. Even technical users often do not know exactly how the problem can be managed neither they can describe exhaustively how they would like to explore and control both the real system under consideration and the software that represents the system itself and the actions taken over it. Software development must thus be approached with a very flexible method that permits a continuous interaction and prototyping, as suggested by both software engineering and ergonomics (see for instance, Argent and Grayson [2001]). An important point that is worth underlining is that "the problem" to be solved is often unclear at the

beginning of a study and “the user” is also a fuzzy concept. Since the very beginning of the development of decision support systems (see, for instance, McKinney [2004] for a recent survey in the domain of water resources) one of their main feature unanimously recognized was the lack of structure of the problems their dealing with. Indeed, real problems do not have a structure themselves but we can easily formalize some of them because there is a wide agreement of the mathematical laws that interpret their evolution. For instance, many water or air pollution problems belong to this category and the development of a model may be guided by a set of widely accepted principles (see the recent paper by Jakeman et al., [2006]). Decision problems, on the contrary, do not belong to this category as soon as they reach the level of involving more than an individual. Whenever a decision must be taken by a council, as is the case of local government, the possibility of finding a consensus about a definite formulation almost invariably disappears. This is not only a consequence of the differences in points of view, it is inherent to the very nature of the decision problem: ideas, opinions, perceptions evolve during the study and the answers found always generate new questions. Using Denzer’s [2001] words, “reality shows that environmental information systems are never finished”.

The second consequence that emerges is that implementation software must be as simple and widely used as possible, renouncing to more efficient, application-specific programs, which are often dedicated to specialists, may require a considerable time to familiarise with, and may be too dependent on a rapidly evolving technology. Nowadays, the most common software environment is Office-like and most people is accustomed to navigate documents in a hypertextual way, like browsing the Internet through html files. This is why we propose a software structure based on these very simple and widely known components.

2. SOFTWARE STRUCTURE

After more than 25 years of development of decision support systems, a general agreement has been reached on their basic features and related software tools. For instance, according to a recent paper by Denzer [2005], the basic building blocks of a general environmental information and decision support system are: models, GIS, databases and tools based on AI and scenario techniques (called DSS in the above paper). Booty et al. [2001], describing the RAISON system (a long lasting project originated in 1985) add to these blocks uncertainty analysis and visualization tools.

Other categorizations can be used and have been used, but whatever definition is taken, the

developer is usually confronted with the problem of the trade-off between efficiency and generality. For instance, one may develop a database that can quickly answer a number of questions through a well designed interface, or ask the user to directly work with a general DBMS. Obviously, the first choice favours the efficiency and the second the generality. The first assumes that the interesting questions may be identified and remain the same for some time (when they change the interface must be modified), while the second let the user perform any data search (even if the speed in answering depends again by the design of the database).

Our proposal is based on the assumption that today all computer users can navigate a hypertext and all technical users can work with a spreadsheet. We can thus develop software systems which favour yet another dimension: openness and portability. They can be easily updated, do not require specific training, and may grow with the user’s interests and needs. Clearly, the user should be well aware of the problem they deal with and learn the logical structure they implement, but this is true for any application, even a WYSIWYG word processor.

On the other side, complex decision problems, such as those of a regional authority, need sometimes sophisticated simulation or optimization models. Such models however cannot be used in real-time since they involve a large amount of data preparation and a much longer execution time. Fortunately, the application of such models to a specific situation does not require all their power and generality. For instance, a river pollution model can be used with a specific hydraulic regime or a traffic model with a fixed network. We thus propose to run off-line such models by the field experts and then translate their results into a set of simplified relations which links the variables under investigation (those on which the authority has some decision power) with the relevant outcomes. The simplest input-output relation that can be embedded into the decision support software is a set of input-output scenarios among which the system automatically selects with a nearest neighbour logic. A more sophisticated alternative is to fit a neural network on the model results and use it to interpret the dynamics of the real world system. These approaches represent a strong simplification from a technical viewpoint, but one has to bear in mind the final purpose of the software system: to allow an informed debate, and highlight the different consequences of alternative decisions. Some approximation is worth paying in exchange of a quick and clear answer.

The structure we propose is thus made of:

- a database with the relevant past information on the problem under study;
- a set of spreadsheets which allow to easily analyse alternative decision scenarios, and containing the simplified input-output relations describing the physical system;

- a hypertext detailing hypotheses and procedures to access the database and use the spreadsheets. It may also include a kind of searchable “data” dictionary, that not only presents metadata information, but also clarifies the meaning of all the intermediate results present in the spreadsheets. The hypertext can be made available over the Internet in order to enhance the level of participation and allowing each stakeholder to test his/her alternatives and evaluate their effects in different ways.

3. SOFTWARE IMPLEMENTATION

Given the above premises, the software implementation is straightforward and simply requires an Office-like environment plus a standard browser as shown in Figure 1.

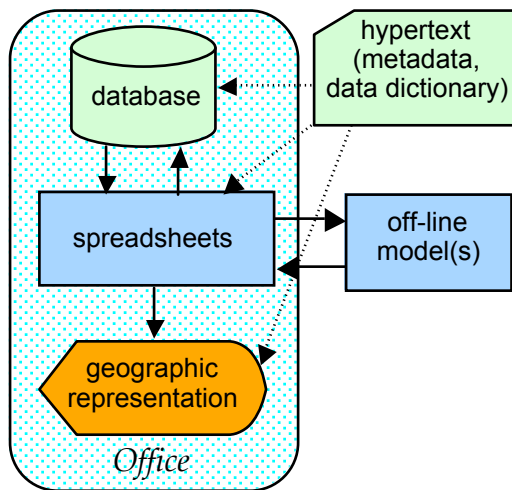


Figure 1. Components of the software implementation.

The geographic representation is often essential to understand and analyse environmental decisions, but in the type of problems we have dealt with does not necessarily need to be a real GIS system. Most of the time it is simply one of the many types of graphs that the user may want to see and does not require to be georeferenced. Clearly, the use of a complete GIS software may be welcome, if this can be easily linked with the spreadsheets and does not require a specific skill to be utilized.

Since we have been using the Microsoft Office® suite for the development of the applications described in the following sections, we have decided to present spatial information with MapPoint®, that can be connected to the spreadsheet results in a transparent way.

The hypertext starts with an overall scheme of the systems that allows the identification of the type of data available and of the flow of information, so

that the user can jump to any part of the system and analyse or modify it.

The overall system does not have a specific user interface. Clearly, a number of graphs and plots are built into the spreadsheets, but any other type of graph of any other variable can be drawn on the fly by using the standard graph wizard. The same is true for the geographical representation: the user must simply write the desired column of values in a given position and the variable spatial distribution is immediately displayed.

It is evident that this approach frees the software developer from the need to identify precisely the user requirements, something that, as already pointed out, is hard to define, differs among the stakeholders and varies in time.

Indeed, the users can jump to any point of the system and modify formulas and values. Again, a certain number of variables, which are thought to constitute the key values of the decision, are suitably emphasised to help modify them in a coherent way, but any other change is still possible: the system is completely open.

In practice, the modification of some of the spreadsheets may be regulated by access rights. For instance, only a limited number of scenario variables may be left free for general distribution of the software, but technical offices may be allowed to test and suggest any modification.

4. CASE STUDIES

Both case studies described in the following refer to local governments at different levels in Northern Italy. Their common feature is that the authority in charge can assume decisions only on the whole territory and cannot impose specific plans to each municipality. This implies that the municipality is the minimum territorial unit and a finer resolution is useless. This also means that the database can, at least in part, be structured as tables having the municipality name as a keyword followed by a (usually long) set of attributes. Results can also be presented with the same resolution or with other standard aggregation (e.g. provincial level).

4.1 External Costs of PM10 Pollution at Regional Level

The purpose of this project was to support the decisions about traffic restrictions and domestic heating improvements by evaluating the expected reduction of external costs of air pollution.

The PM10 External Costs System covers the entire Lombardy region (more than 1500 municipalities and 8 million inhabitants) and is dedicated to local authorities as well as to technical staff of various offices in the local government. Its structure is shown in Figure 2 where ovals stand for the user's main choices.

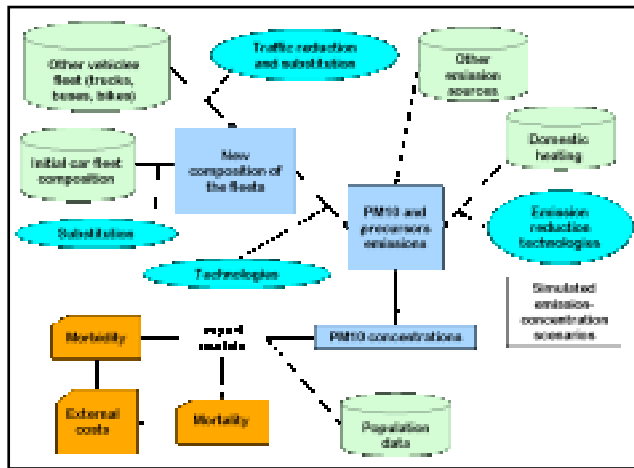


Figure 2. Structure of the PM10 External Costs System of the Lombardy region.

The software follows the ideas proposed by the EU ExternE project (www.externe.info), a long run research effort to evaluate the economic impact of air polluting activities in Europe.

The major problem in dealing with PM10 is that the majority of it is secondary pollution [de Leeuw, 2002] and its concentration is above the standard for most of the year in many crowded areas of the region.

The logical flow of the system starts from scenario hypotheses about the composition of the vehicle fleet and the domestic heating systems, computes the emissions, converts emissions into mean concentrations, then computes the impacts of such concentrations to human morbidity and mortality, and finally transforms these values into external costs.

4.1.1 Database

The main source of data for the project is the regional emission inventory INEMAR [Caserini et al., 2002], which contains emission values for many pollutants for each municipality and is periodically updated. The second most important source is the National Institute of Statistics (www.istat.it) from which all the population characteristics (numbers, age distribution, health conditions,...) have been extracted. Other smaller tables refer to the COPERT III vehicle emissions and ExternE exposure indexes and cost evaluation.

4.1.2 Spreadsheets

Various spreadsheets are used to perform each step of the evaluation procedure: based on the user's scenario assumptions, the new vehicle and heating emissions are evaluated, they are distributed among the 1500 municipalities and added to the

other non-regulated sources to obtain a user emission scenario. This is translated into concentrations using a nearest neighbor method in another sheet where the input and output of different runs of the off-line simulation model are stored. The metric used is a standardized distance of PM10 and precursor (SO₂, NO_x, NH₃) emissions defined by the user from the scenario simulated with the off-line model. Combining estimated concentration values with the distribution of population (classes and activities) and exposure indexes, another sheet computes health effects for each municipality and finally external costs are evaluated. The plots of several aggregated variables are presented in the output sheet, together with the possibility of selecting them for a detailed spatial representation as shown in Figure 3.

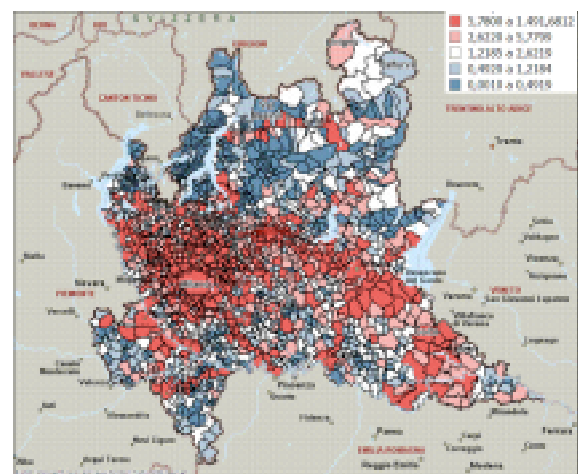


Figure 3. Direct visualization of spatial variables: primary PM10 traffic emissions.

4.1.3 Off-line air pollution simulation

The AriaRegional model suite (www.aria-net.it), used off-line to compute the mean annual concentrations following a given emission pattern, is based on a sophisticated eulerian three-dimensional model, derived from STEM. It requires a hourly description of emission values and chemical speciation, of the regional meteorology as well as of the boundary conditions. This means that each simulation requires a considerable effort and several hours (or even days) of computer time.

It has been run for a limited number of emission conditions, but the suggested open structure allows to freely add new outputs to improve the precision whenever they are available.

4.1.4 Hypertext

The online hypertext works as a help file for using the software, contains all the original documents from which parameters and functions have been

extracted, and a searchable data and results dictionary. This allows to find out among the several tens of thousands of numbers managed by the system those of interest and possibly modify them or use them for additional graphic output. Presently, there are no plans for general distribution to the public.

4.2 Choosing an Energy Plan for Provincial Development

The purpose of the Environmental-Energy-Plan (EEP) of the province of Cremona in Northern Italy is to outline the local energy budget, analyse energy resources (one of the most important indicator of economic trend), evaluate related environmental aspects (indicators of life quality) and define the sectors where the local government can intervene to foster sustainable development. The project has been carried out following the Local Agenda21 process: all the stakeholders (from energy experts, to representatives of local organizations to interested private citizens) have been involved since the beginning, during the Agenda 21 forums and the software was used by a variety of people to support discussions and reach a consensus on the development plans. It is being also used to monitor the development and execution of the selected plan, targeting the emissions of the Kyoto Protocol.

4.2.1 Database

The database, enriched during all the procedure, contains the information about local energy and environmental resources as well as many other related topics (land morphology, hydrography and meteorology, environmental indexes, such as concentrations of pollutants, demographic indexes, forestry and agricultural asset, descriptors of productive activities as numbers of farms, factories and tertiary activities, road network, vehicle fleets, traffic, and fuel consumption). All the data have been documented including metadata such as data provider and storage date.

4.2.2 Spreadsheets

The spreadsheets calculates and represents all the aspects of the plan retrieving information from the database and managing it according to the logical scheme shown in Figure 4, which is also part of the user interface. It shows data tables, calculation sheets (rectangular blocks), and the parameters necessary to define an energy scenario (again represented by ovals). The main output of the system are the energy and CO₂ emission balances till 2020. The deficit of energy production, and the distance from the target of emission are also computed (Figure 5).

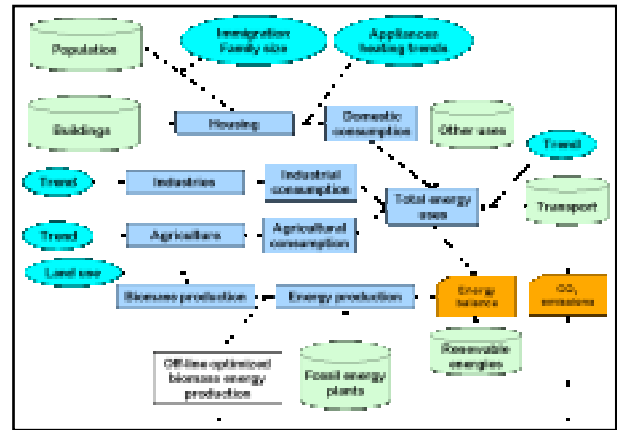


Figure 4. Structure of the Environmental-Energy Plan of the Cremona province.

The spreadsheets can be browsed to obtain intermediate information or to add new indexes. For instance, one of the users added the calculation of the ecological footprint of each scenario.

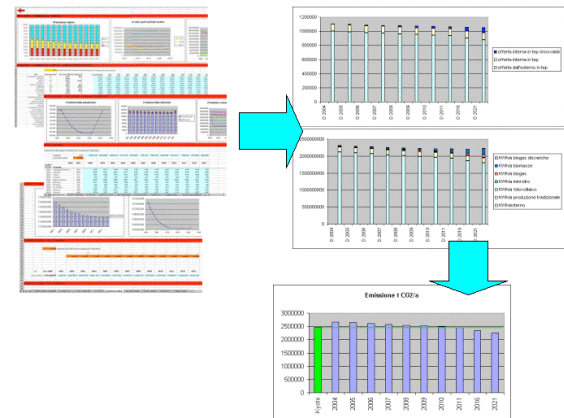


Figure 5. Spreadsheet calculation: distance from the Kyoto emission target.

4.2.3 External optimal plant location model

The exploitation of biomass potential, one of the key development issues identified by the provincial government, requires the solution of an optimal plant location problem. This has been formulated as a mixed integer linear programming problem [Fiorese et al., 2005], considering biomass cultivation and transportation costs and pollution, and has been solved off-line for different hypotheses on biomass availability. In particular, different assumptions on the area dedicated to short rotation forestry (SRF), typically poplars, have been analyzed. These solutions have then been plugged into the overall system, in such a way that, for each scenario defined by the user, the closest solution obtained off-line is used.

4.2.4 Hypertext

The EEP support tool is complemented by the hypertext containing laws, system and data descriptions, selected scenarios, and approved conclusions, directly available on-line to disseminate the information (Figure 6). This mechanism has proved very useful to encourage public awareness and participation. It can be accessed from <http://www.provincia.cremona.it/Agenda21>, and has been distributed as CD-ROM.

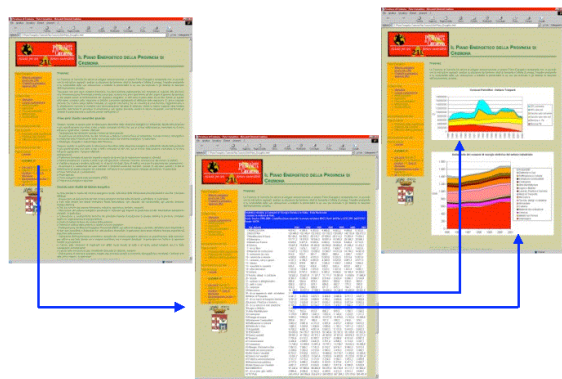


Figure 6. Online hypertext for data and result presentation.

5. CONCLUDING REMARKS

Today, searching the web for “environmental decision support systems” one can find several thousand occurrences. It is a clear sign the this topic has been consistently growing in the past couple of decades. However, only very few systems may count more than one application and are spread over a relative wide audience. Looking for “spreadsheet” or “databases”, the number of occurrences is several orders of magnitude higher. This is why we propose to develop open, light systems based on this widely diffused knowledge which minimize learning time and let the user “see” into the software and modify it in a familiar way. We think they can contribute to reduce the “confusion of languages” between modellers and managers recently pointed out by Loucks and van Beek [2006, p. 54].

Clearly, spreadsheets need to be complemented with more sophisticated models, but these can be run off-line and their results embedded into the system, possibly decreasing its precision, but adding the ability to answer quickly to all the questions that may be raised during an open discussion. Indeed, extending a famous maxim by Geoffrion [1976], we can say that the purpose of decision support tools is “insight, not numbers”. This approach has been recently implemented to support environmental and energy decisions at different levels in Italy.

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