Benefits and limits of GIS for managing heterogeneous environmental data in sustainable urban design: example of the ADEQUA project

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SUMMARY
Sustainable urban development requires a reconfiguration of the traditional processes towards a new approach that raises the question of the integration of environmental data in the design, as well as the evaluation of urban projects. This new approach implies to manage heterogeneous parameters and to improve concertation processes. Therefore, the place of the Geographical Information Systems (GIS) in such a process has to be questioned.
In the first section, this paper explores the issue of the sustainability indicators. The results of a survey are presented and discussed. This survey of urban research stackeholders highlighted their various waitings for GIS tools, and the complexity of the set of problems. The description of benefits and limits of GIS in this context is discussed in the second section.

KEYWORDS: *GIS, Sustainable urban indicators, environmental analysis*

INTRODUCTION

Cities have an important role to play as regards to sustainable development. Indeed, these territories are subjected to evolutions which may seriously compromise the economic, ecological and social balance. However, a sustainable approach of the urban development requires a reconfiguration of the traditional approaches based on single criterion. It thus directs planning towards an approach based on the joint and concerted analysis of heterogeneous parameters in which the environmental impacts and quality of life of the future residents play an important role. This new approach raises the question of the integration of the environmental data in the evaluation of the urban projects. It also results in wondering which can be the place of the Geographical Information Systems (GIS). Indeed, if the potential of these systems has been demonstrated in many territorial planning projects, there benefits in urban design at the district scale remain to be assessed. In this paper, we present a research that adresses the complexity of urban sustainability indicators as well as their integration into a GIS. This research project is called ADEQUA "Aménagement Durable d'un QUArtier" (Cherqui, Mora & al, 2004).

We will detail, in a first section, the question of the sustainability indicators. We will present then the results of the ADEQUA research project and will conclude this paper by the description of interests and limits of GIS in such problematics.

SUSTAINABILITY INDICATORS IN URBAN PLANNING

An indicator is a value derived from parameters, providing information on a phenomenon. It is a quantitative value which allows the characterization of an evolutionary situation, in order to evaluate and compare the different stages of this situation. Obvioulsy, an indicator presents a model of reality, not reality itself. Such a model needs to be informed by qualitative data and comments.

Needs for an approach based on multiple indicators

Formerly endorsed by the operational research, monocriterian approaches have shown their inadequacy for the planning problems (Molines, 2003). Although these approaches do not postulate that "in the real world" only one indicator is concerned, they limit the decision-making support by presenting explicitly only one criterion (Bouyssou, 1993). The sustainable development is based upon the balance of environmental, social and economic constraints. It requires the integration of complex and multiple indicators which may be antagonist. The indicators, vector of communication, also increase the information and the awareness of each stakeholder such as city planner, prime contractor, social representatives or ordinary citizen. In this way, indicators take part in the mission of transparency, popularization and dialogue preached by sustainable planning approaches. Finally the characterization of an urban project by a set of indicators synthesizes its strong points and limits. It allows the decision makers to base their decision on actual points.

The Aalborg Charter (1994), the Lisbon Action Plan (1996), the European Sustainable Cities Report (1996) and the Communication titled "Sustainable urban development in the EU: a framework for action" (1998) successively pointed out the need for using indicators of sustainability of the urban systems, in order to assess the initial state, to observe and follow the progress achieved, or to work out the policies (Dufrasnes & Achard, 2004). However, by looking further into the assessment of a project, integration of multiple indicators of sustainability also involves a serious complexification of the analysis. On the one hand, this approach requires a preliminary reflexion on the indicators to be set up. On the other hand, it implies to work out new methodologies for creating and aggregating these indicators.

Several research projects have proposed various lists of indicators to achieve urban sustainable development. Dufrasnes and Achard (2004) propose a state of the art of the national and international researches (e.g. European project E-Co-housing, HQE2R Project, Urban Development Strategy…). However few research projects tackle the problems of creation and aggregation of these indicators. The question of quantitative approach of sustainability in construction project at the district level has not been explored either.

To fill this gap, the ADEQUA Project addresses the issue of the sustainable urban development at the district level. It aims at providing a methodological guide of sustainable planning which will assist stakeholders during a planning project. It gives a detailed attention to the indicators that describe the environmental characteristics of public spaces and built envelopes.

Indicators of sustainability in urban design: the ADEQUA project

The sustainable development of a district requires the evaluation of differents kinds of objectives, themselves defined by various sets of indicators. These indicators are assessed using various methods such as solar simulations, thermal analysis, sonic simulations or observations... The quantification of these indicators may come from computer simulations, data bases or human experiment. Within the framework of the ADEQUA project, eight objectives were defined (Cherqui & al 2005, Figure 1).

Each objective is evaluated according to various indicators. The multiplicity of these indicators reflects the variety of the stated objectives. The indicators will be useful for many purposes such as measuring the consumed primary energy as well as thermal, acoustic or visual comfort of a site or a building, the volume of waste produced or the change in the ecological value of the site.

Within the ADEQUA project, a survey has been done to evaluate stakeholders' requirements in terms of data and indicators. The results of this survey highlight several characteristics of the urban planning projects. They confirm the complexity of the problem and outline the framework of a future operational GIS. The intervention of the partners varies according to the themes studied, the type of urban project as well as the step of the project developement.

Goals	Stakes
Preserve the resources	Limit the impacts on the natural resources.
Preserve the ecosystem	Respect the fauna, the flora, the air, the water and the ground in place and minimize the risks for this environment.
Improve environments' quality	Improve environments' quality inside and outside buildings.
Preserve health and manage the risks	Offer conditions ensuring the health of the users and control both industrial and natural risks.
Take into account culturage heritage	Respect, preserve and develop the culturage heritage of a district.
Support local development	Encourage the local development of the district from economic, cultural, educational or social points of view.
Increase social life	Offer to the users of the district a pleasant framework of life by encouraging social cohesion.
Develop the place of the district in the city	Ensure the social and material connection between the district and the remainder of the city.

Figure 1: Goals and stakes

Social and operational approaches are combined with technical ones in the ADEQUA project. This project combines general solutions at the beginning of the urban design (analysis of the initial state, sketches of projects) with more particular approaches at the end of the design. The first steps are generally centered on the analysis of the site and on its relationships with the surrounding environment. The buildings are then materialized in the form of blocks and only their main characteristics are informed. The final steps involve the design of the buildings in their quasi final form. Indicators become then very precise.

The needs of data and analysis tools vary according to the type of urban project: operation of rehabilitation, creation of new districts, urban renewal for instance. Various indicators are required according to the different topics apprehended such as quality of life, environment, resources preservation, as well as the objects they are related to: block, building, frontage, level, roof... Some indicators characterize phenomena that are external to the site. Therefore, urban projects imply to work at multiple scales. Furthermore, some indicators like bioclimatic ones vary according to time and place. Last but not least, the various presentation and formats of data compexify the process of integration.

CONTRIBUTION AND LIMITS OF GIS FOR THE IMPLEMENTATION OF SUSTAINABLE INDICATORS

GIS at the various stages of the urban projects

Installation or rehabilitation district projects are generally subdivided in four stages:

- urban diagnosis and programming;
- design and evaluation;
- consultation-communication;
- follow-up and observatory.

GIS, with their capacities of management, seizure, analysis and visualization, supports stakeholders in each one of these stages.

Urban diagnosis - programming

The diagnosis is required to assess the site, its potentialities and constraints and its relations with the overall city. The site is studied on the environmental and the socio-economic levels. This study strongly varies according to the type of project such as the construction of a new district or the rehabilitation of old buildings. The first sketch of scenarios is carried out and analyzed. This phase is characterized by the use of overall indicators and the need for integrating concepts of flow and data coming from the rest of the city. In this phase of programming, the entities do not need a very accurate digitalization. It is particulary true for the "buildings" which are, at the beginning of the studies, simple blocks dedicated to multiple modifications. To carry out zoning tests, the data structure must be flexible and not very constraining. At this early stage of the project, the system does not need to be based on a rigorous conceptual model. This stage requires a flexible and multiscalar GIS which facilitates digitalization, analysis and modification of simplified scenarios. This tool must also allow the consultation of other data sources (other GIS, alphanumeric database, satellite images...).

Simple 2D spatial analysis can be performed such as the sum of builted area, the lenght of perdestrian raods or the number of bus stop at less of 500 meters of the building.

Design and evaluation

At the beginning of the design step, scenarios evolve quickly. The sketches carried out in the preceding phase are refined. Indicators coming from expert-softwares are integrated to assess the sustainability of sketches. Indicators have sometimes voluminal and temporal dimensions which are important to preserve. The 3D GIS potentialities serve this purpose.

The data base must be structured in order to ensure the permanence of the system, to facilitate the interoperability and to allow the automatic generation of entities. The evaluation process can begin with the system developed during the diagnosis step. However when the project is stabilized it is necessary to use a more rigorous data model. This will facilitate the integration of the indicators, which will allow possible connection with a non geographical DBMS and will authorize the automatic generation of ‘under-entities’ such as the frontage or the level for the entity "building". It also plays a part of supervisor centralized of the data. It reduces the redundancies and facilitates the updates (Laurini & Milleret-Raffort, 1993).

A Database model has been developed during the ADEQUA project (Figure 2). This model has been created to answer as best as possible stakeholders needs in terms of entity and indicators. This model is organized around a part "building" and a part "external spaces". The total entity is the overall site.

A building is described by its cadastral footprint, its frontages, its various levels, the walls of these levels (by distinguishing the external walls and the shared walls) and the possible characteristic elements affixed on the walls (Figure 3). In order to increase the environmental assessment, each part of the building corresponded to an entity which has its own indicators. For example, sunshine exposure or sound level indicators are attributed to the “frontage” entity and the energy consumption to the “level” entity (Musy, Siret & al, 2004). The buildings’ part of the model has been explained more specifically elsewhere (Siret, Musy & al, 2004).

Entities are imbricates the ones with the others in a hierarchical way (district - > block - > parcel - > building...). On the one hand, this organisation allows to inform the whole of the territory and to perform spatial analysis. The number of entities is important besause this precision is necessary to the good repartition of the indicators. For example, the difference between “mineralized spaces” and “vegetalized spaces” can be used to inform more accurately vegetalized spaces (deciduous species proportion, sunshine factor...) in order to characterize some indicators. Difference between “roads” and “rails” is necessary to assess noise impact. On the other hand, this entity distinction avoids

weighing down the database unnecessarily. Many analyses can be carried out. These analyses can overlay indicators coming from various softwares. For example we can calculate the total of uncomfortable areas in winter (aera wich receive less than 2 hours of sunshine and wich are very windy).

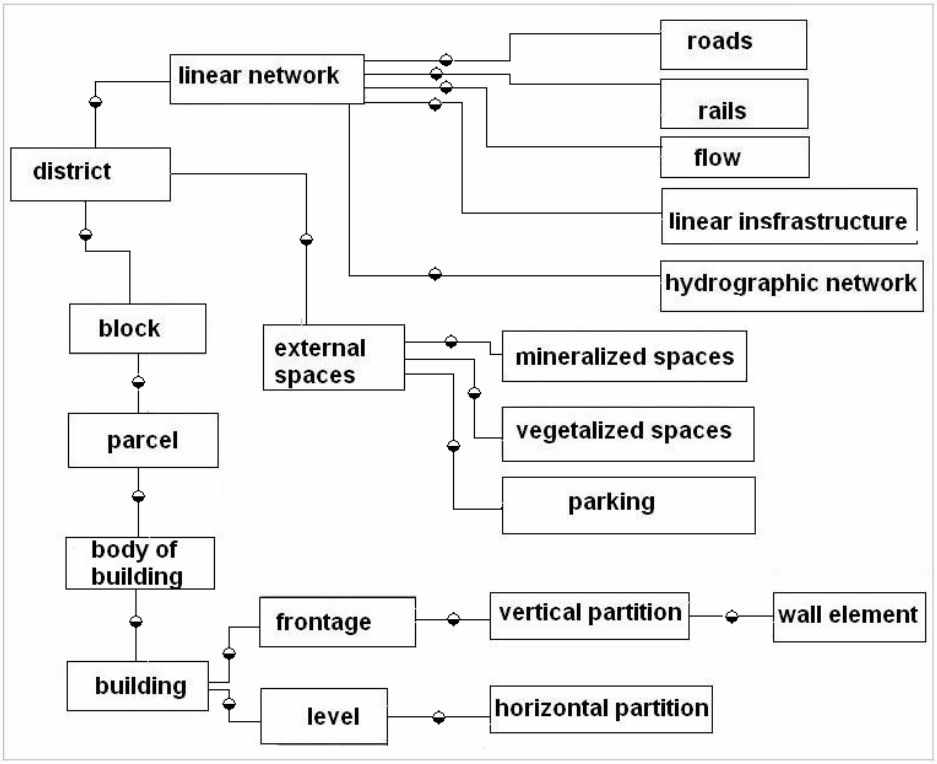

Figure 2: The data conceptual model

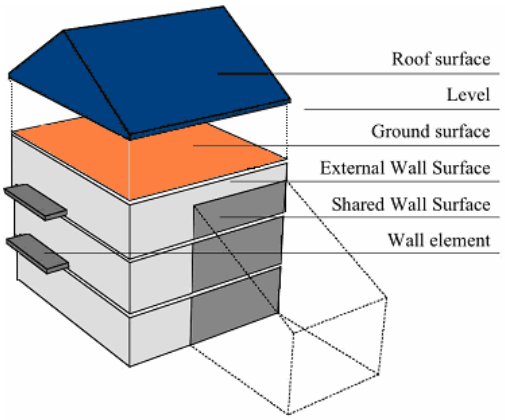

Figure 3: Entities representing a typical building within the GIS data model

Consultation-communication

This step requires visualizations to facilitate the dialogue between stakeholder and the decision-makers. These visualizations must emphasize the main characteristics of the project. They must underline its strength as well as its weakness. Speaking visualizations, illustrating a popularized and synthetic message, will be privileged. This step implies the use of technical indicators to take the heat out of the debates. However, if the use of overall indicators is privileged, it is necessary, to ensure the transparency of the project, to be able to reach original indicators (Figure 4).

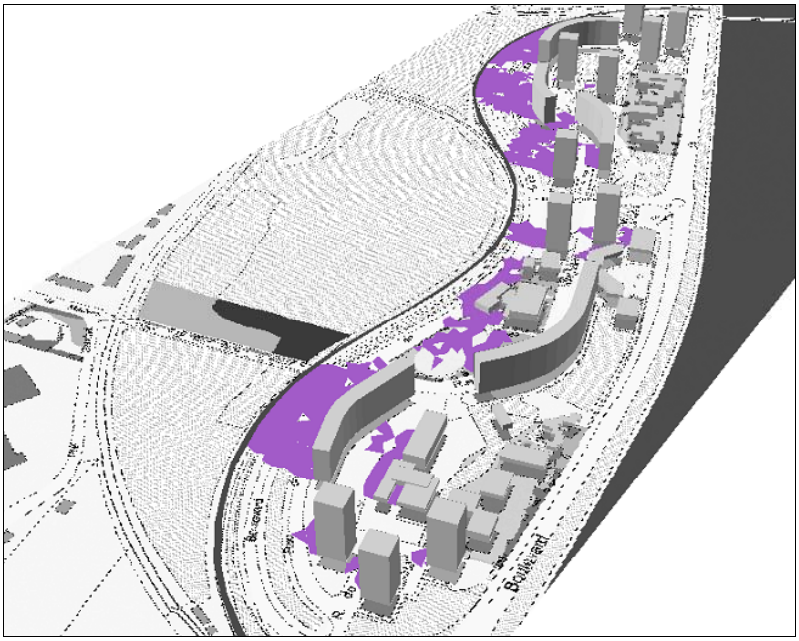

Figure 4 : Example of synthetized map: areas of discomfort in external space (crossing of wind and solar indicators)

Follow-up and observatory

This step can be done before and after comparisons and can be used to check the accuracy of the analysis as well as the recommendations emerging from the previous stages. This step requires recording the history of the project. With this stage, the indicators must be thematic and all-encompassing. Considering the stakes defined at the beginning of the design, one or two agregated indicators may be sufficient.

Contributions and limits of GIS in a sustainable urban planning context

Contributions of GIS are very important. First, GIS give a geographical dimension to the project including a broader territory approach and a multiscalar approach. The spatial analyses tools of the GIS increase the level of understanding of the overall project. The ability of integrating indicators from different expert-softwares provide the material for a sustainable assessment of the project and authorizes an analysis of the area which takes into account the various facets of the problem.

Secondly, GIS ensure the perenniality of the information system by structuring the data and linking them with DBMS software.

By offering the support of the third dimension, essential dimension in the urban context, GIS increase the environmental analysis value. The third dimension enables 3D spatial analyses which are important in this context, for example for visibility analyses. It also provides visualizations adapted to the general public and to the urban field wich is dominatied by the role of volumes and verticality (in order to analyse, for example, the environmental impacts on the buildings frontages).

Finaly, GIS can also be considered as a federator tool of the indicators produced by expert-softwares. They allow joining together all the capacities of analyses mobilized in the project. In the ADEQUA project, several expert software are monopolized to simulate indicators. For example, sunshine exposure comes from SOLENE, energy consumption from COMFIE and sound level from SOUNDPLAN. The GIS provide the data input necessary to some software (like footprint buildings and masks for SOLENE). GIS can be used to centralize, combine, amalyze and visualize the indicators produced by these software.

Beyond these potentialities GIS, in their current configuration, do not answer all the requirements of urban sustainable development project. Several limits may be pointed out:

- Weakness of the functionalities of 3D spatial analysis. It is very difficult to carry out analyses of impacts on the frontages of the buildings. However, these analyses are essential with the comprehension of urban environments (propagation and impact of the noise or wind). Currently these impacts assessment require over simplifications.
- Rigidity of the data base. The database structure cannot easily be transformed during the project. Additional information generally requires a complete modification of the database.
- Difficulties of producing alternatives comparisons. GIS can produce many indicators, but do not allow to synthesize these results in order to compare various scenarios between them . These comparisons must be done "manually" by the researchers or by using a multicriterion analysis software (Molines, 2003).
- Interfacing with the CAD and simulation softwares. Interchange formats between GIS and other tools are not really common. Additional developments are necessary to improve interoperability.

CONCLUSION

The assistance brought by GIS in sustainable urban planning projects is strong. In the one hand, GIS allow the management and the combination of heterogenous urban indicators resulting from observations or from physical simulations. In the other hand, GIS improve public participation and the decision making process. By producing an environmental information which is complete and apprehensive by everyone, GIS facilitate the dialogue between stakeholders. In this way, GIS play a capital role in the processes of communication and dialogue as regards to urban development (Laurini, 2001).

However, new methods and techniques must be developed to better take into account the spatio-temporal character of the information which characterizes environmental analysis. New methods should also be developed to analyze 3D information more effectively. Our research center started to develop tools going in this direction (Ramos et al, 2004).

BIBLIOGRAPHY

Bouyssou, D. 1993 “Décision Multicritère ou aide multicritère?”, Newsletter of the European Working Group “Multicriteria Aid for Decisions”, Series 2, 2, Spring, 1-2.

Cherqui F., Mora L., Wurtz E., Allard F., Method to assess sustainable design of a district, 21st International Conference Passive and Low Energy Architecture, Eindhoven, The Netherlands, 2004 p.813

Cherqui, F., Popovici, E., Mora, L. Peuportier, B., Wurtz, E., 2005, Projet ADEQUA, rapport d'avancement n°1, 44p

Dufrasnes E., Achard G., 2004, Note d'étape ADEQUA N°1 : Constitution d'un jeu d'indicateurs d'aménagement durable: 55p.

European council of Town Planners, Vision for Cities in the 21st century , The New Charter of Athens 2003, Lisbonn, les 20 et 21 novembre 2003. http://www.ceu-ectp.org/e/athens/, 2003

Laurini R., Milleret-Raffort F. 1993, Les bases de données en géomatique, Paris, Hermès, Collection Géomatique, 340 p.

Laurini R., 2001 Information Systems for Urban Planning, London, Taylor & Francis, pp 349.

Molines, N., 2003, Méthodes et outils pour la planification des grandes infrastructures linéaire et leur évaluation environnementale, thèse de géographie, Université de St Etienne, CRENAM, 330p. + annexes

Musy, M., Siret D., 2004, Ramos F., Groleau D., A 3D GIG for environmental diagnosis of urban frontages, UDMS, Urban Data Management Symposium, Chiogga, Italie, 27-29 October 2004, 8p.

Ramos F., Siret D. and M. Musy, 2004, A3D GIS for managing building rehabilitation process, Geoinformatics 2004, 12th Int. Conf. on Geoinformatics, University of Gävle, Sweden, 7-9 June 2004, 7p.