

MULTICRITERIA ANALYSIS AND SUSTAINABLE DEVELOPMENT IN THE FIELD OF URBAN INFRASTRUCTURE

Marcel Miramond¹, Pascal Le Gauffre², Sylvie Barraud³

ABSTRACT

The purpose of this paper is to provide an overview of the results of research proposed by the Civil Engineering Research Unit of INSA Lyon in response to a call for submissions made in 2003 by the French Research Ministry as a part of an interdisciplinary program: Sustainable Urban Development. The main focus of that bid was on the question: under what conditions the various elements of Sustainable Urban development can be actually integrated.

The hypothesis defended by our research team is that decision aid and more particularly multicriteria analysis can contribute to the integration of those diverse elements by finding a consensus between the different aspects of sustainability (i.e. social, cultural, economic and environmental factors). The field of investigation considered in this work is that of urban infrastructures (energy, waste, water & sewage, transport, green/blue).

The first part of the paper tries to show that the general concepts of sustainable development and those of decision aid results are in a very close relationship and the paper subsequently moves on to a practical approach which, through the analysis of a set of case studies, supports the relevance of the hypothesis.

These previous results underline the theoretical and potentially practical convergence of multicriteria decision support tools with the transdisciplinary aspect of sustainable development.

Another dimension has been considered: the social aspect of the decision making process particularly relative to technicians' and scientists' positions as regards stakeholders. Through some case studies focused on using multicriteria decision support tools for problem stating, knowledge management, dialog and integration of social stakes, the paper tries to demonstrate the efficiency of these tools when dealing with social and ethical matters.

The last part of the paper presents a different way of contributing to the integration of the diverse components of sustainability. It is the PETUS (Practical Evaluation Tools for Urban Sustainability) a project funded by the European commission. PETUS is

¹ Professor, URGC – INSA Lyon (Civil Engineering Research Unit – INSA Lyon) - 34 avenue des Arts, Batiment J.-C.-A. Coulomb, 69621 Villeurbanne CEDEX, France.

Phone +33 4 72 43 82 09, FAX +33 4 72 43 85 21, marcel.miramond@insa-lyon.

² Assistant Professor, URGC – INSA Lyon (Civil Engineering Research Unit – INSA Lyon) - 34 avenue des Arts, Batiment J.-C.-A. Coulomb, 69621 Villeurbanne CEDEX, France.

Phone +33 4 72 43 88 58, FAX +33 4 72 43 85 21, pascal.le-gauffre@insa-lyon.fr

³ Assistant Professor, URGC – INSA Lyon (Civil Engineering Research Unit – INSA Lyon) - 34 avenue des Arts, Batiment J.-C.-A. Coulomb, 69621 Villeurbanne CEDEX, France.

Phone +33 4 72 43 83 88, FAX +33 4 72 43 85 21, sylvie.barraud@insa-lyon.fr

developing a framework that can be used to analyse and improve the sustainability of urban infrastructure projects. It is hoped to provide information to guide actors at all levels of decision making towards the use of the most appropriate procedures.

In conclusion, this communication gives a critical perception of potential uses and limits of these different approaches and tools and proposes reflections for future improvements and developments.

KEYWORDS

multicriteria analysis, urban sustainability, infrastructures, decision making, framework

CONTEXTS AND OBJECTIVES

If the fields of civil engineering in general and urban infrastructures in particular have, with that of decision aids, multiplied their meeting-points in the last few years, the question of integration has never been asked with such relevance as today.

Indeed, the civil engineering community in all its diversity but also through its identity finds itself confronted with considerable stakes concerning sustainable development. Questions of impact, life-cycles, capitalization of knowledge and know-how, the safety-first principle, the concomitant notions of flexibility and reversibility lead to the taking into account of decision criteria prone to scientific uncertainty, incomplete data, a lack of historical perspective.

These various stakes redefine the decision process in the urban field and question the existing and future methods and tools for decision aid concerning their capacity to take into account and integrate various and necessarily partially conflicting realities.

Sustainable development is indeed often presented as a more advanced will to integrate economic, environmental and social preoccupations not to mention the technical dimension which concerns us more particularly.

If it is difficult to know under what conditions the various dimensions of sustainable development can be integrated, the question of the contribution, the role but also, of course, the limitations of decision aids should be formulated.

The hypothesis defended here is that decision aids and more particularly multicriteria analysis can contribute to the taking into account of these various dimensions. The suggested field of investigation is that of urban infrastructures (energy, waste, water and effluents, transport, parks).

Three approaches are studied. They have in common the mobilisation of and recourse to in- the-field case studies:

The first concerns the potential contribution of multicriteria decision aid on two planes

- that of aid in the evaluation of a project or the comparison of a proposition compared to a reference solution or again aid in the adaptation or improvement of a project.
- that of aid in the comparison of alternatives or variant solutions in a project.

The second deals with multicriteria analysis in problem stating, problem conception and governance.

The last is relative to the role of case studies as auxiliaries in the elaboration of satisfactory solutions with reference to sustainable development.

First, however, the meaning and content of the expression « multicriteria decision aid » needs to be clarified.

MULTICRITERIA DECISION AID

Multicriteria decision aid aims at providing methods and tools for the resolution of a complex, multiple component problem.

Whatever the qualities of projects and action proposals concerning sustainable urban infrastructures, knowing how to evaluate and choose between different solutions in a conflictual multicriteria context is, and will remain, a burning question. Indeed, the problems posed are always unique in their combination of objectives, available means and partners concerned. In other words, they are context-dependent.

Adopting a multicriteria paradigm means accepting that the decision taken will be a compromise between several conflicting objectives.

Multicriteria decision aid helps to establish priorities between the competing propositions. Its object is to provide the means to appreciate the respective merits of the alternatives.

But with a view to ranking different kinds of action, a delicate and often critical problem has to be faced: how can the role of each criterion for a given choice be correctly evaluated and how can it be given an appropriate weighting?

Among the methods available today, two tendencies can be distinguished: the additive-compensatory (index methods) and the non compensatory (outranking methods). The latter will be retained hereafter as it is better adapted to the reality of the situations encountered and the questions raised concerning sustainability. The methods mainly concerned are Electre, Naïade, Macbeth (Maystre, 1994, 1999), (Munda, 1995), (Bana e Costa et al., 1999), (Rogers et al., 2002), (Brunner et al., 2004).

These outranking methods are the most frequently quoted in the case studies observed. The method proceeds by comparing actions in pairs, the result being expressed by an outranking relation capable of distinguishing between indifference, preference or incomparability. For each criterion an indifference and a preference threshold enable uncertainty to be taken into account. Each criterion has a veto threshold. Fuzzy outranking relations enable a degree of credibility of outranking hypotheses to be introduced. A process then enables a direct and indirect ranking to be obtained. The direct ranking consists in extracting from the list the preferred action and repeating the operation with the remainder. The indirect ranking process begins by extracting the least satisfactory action. The advantage of these two rankings is the way they reveal actions which cannot be compared with others (which is crucial to the problems being treated here). A two-dimensional graph can be used to represent the two rankings (Simos, 1990). Each action is a point on the graph. Stable actions are near the diagonal and the incomparable actions are far from it. The closer to the upper right-hand corner a point is, the better its ranking (it should be noted that the principles of outranking could also serve to compare a proposition to a reference solution or in the search to adapt or improve a solution).

The results obtained must be completed by sensitivity and robustness analyses. The sensitivity analysis examines the stability of the results in relation to the variation in the various parameters and serves as a basis for the robustness analysis. The preceding graph can serve as a visual support for these analyses. In particular, the positions obtained by an action consecutive to the weighting process can be studied. The more compact the point cluster is, the greater the consensus. By comparing the positions of the various associated clusters, a better idea of the final ranking is reached.

The weighting expresses the relative importance attributed to each criterion. It is always a difficult choice. If there are several techniques for establishing the weighting, the important role of sociological aspects must not be overlooked (of course, the same could be said of the choice of criteria). Electre-type methods are in fact used to help to state problems in a decision-making process and are aid tools in multicriteria negotiation. They are above all tools of communication between the people doing the studies and the people taking the decisions.

Although the word 'governance' changes meanings according to the context in which it is used, here it means a collective decision process with no authority position being affirmed by any of the actors (Brodhag, 2000). Sustainable urban development is necessarily multicriteria and resolutely multi-actor.

If evaluation tools with objective economic, environmental and social criteria and the definition of points of reference enabling comparisons to be made are necessary, they are not sufficient. In a complex situation, tools for facilitating negotiation, revealing preferences, making the stakes clear to the participants, identifying weaknesses and gaps should be at the heart of the decision-making process.

The hypothesis defended here is that multicriteria decision aid can be one of those tools. Specific case studies will be discussed to enrich this point of view.

CASE STUDIES

In order to discuss the above-mentioned hypothesis which is central to this work a number of case studies were analysed through bibliographical research but also through direct contact with the participants. Twenty-seven case studies were listed, fourteen of which were the object of more detailed study.

These studies were chosen for various reasons. They were situated in an urban framework, they were carried out with reference to a specific problem and / or objective of sustainable development, multicriteria methods were used and useful information relative to the hypothesis can be extracted from them (advantages, drawbacks, limits).

For each study, as far as possible, a similar descriptive process is used. This includes the situation and the context, the participants, the alternatives, the multicriteria method used, the criteria and their weighting, the evaluation, the ranking, the conclusions of the study, the documentary resources and the contacts made.

Only a few elements of a sub-group of case-studies will be considered here to illustrate the discussion, first putting the accent on situations of comparison between alternatives, and then insisting more particularly on problem stating and governance.

THE CHOICE OF TWO SITES, ONE FOR A LANDFILL, THE OTHER FOR AN INCINERATOR, IN THE PROVINCE OF TURIN, ITALY, 2000-2001

According to Norese et al. (2001), the provincial programme divided the province of Turin into three zones. Each had to have an incinerator and a landfill to treat its waste on its own territory. The zone concerned was the south-eastern one which has 1,300,000 inhabitants living in 51 communes including Turin. The problem was to find two sites, one for the incinerator and one for the landfill. Thirteen sites were preselected for the incinerator and nine for the landfill. In order to evaluate the respective merits of each site, a list of thirteen criteria was defined for the incinerator and fourteen for the landfill. A series of different weightings was proposed for each case. The Electre 3 method was chosen to rank the sites. Subsequently more in-depth study of the best sites (two for the incinerator and four for the landfill) was carried out, particularly concerning the environmental impact.

This relatively classic case study including the use of an outranking method can be considered exemplary in its application.

A commission of forty-five members (administration, management, representatives of associations) was created at the outset and met thirty-five times in sixteen months. Its role was decisive. It chose the criteria and the alternatives and the various weighting processes. It became the coordinator of all the work and technical studies carried out by the various experts employed. Some meetings underlined the problems of communication and misunderstanding between the experts and the representatives of the communes. The multicriteria approach enabled a space for communication to be established and provided the basis for a common language to express needs and explain the results of the studies. For example, the choice of the method and how it worked was explained along with its ability to take into account the imprecision and uncertainty of the data. After the application of the weighting process, the discrepancies between particular expectations were represented with a Simos graph. Every participant was able to adopt a position relative to the virtual compromise the method presented. This compromise was judged to be relevant, particularly because it enabled doubts and worries to be made explicit and thus facilitated progression towards collective positions and decisions.

DECISION AID FOR DISTRICT ENERGY PLANNING, NYON, SWITZERLAND

In a Localized District Plan (LDP), an energy concept should set up elements enabling all those involved in the decision process to have at their disposal a common reference concerning energy.

The energy concept of an LDP is the evaluation of the characteristics of this plan, the possibilities of technical equipment and its use in the service of future customers with the final aim of reaching efficient and realistic objectives. It must take into account the specificities of the site and the interactions of the project with the environment and ensure that the solutions chosen are complementary and coherent.

In this case study, the energy planning method was applied to a 150,000 m² district to be built in the town of Nyon (near Geneva). The energy service of Geneva carried it out, in collaboration with communal decision-makers.

It is important to point out that the relevance of such an approach concerns the logic of creating synergies between civil engineering, architecture and energy professionals, but

also the strategic and political will to take into account the principles of sustainability in programmes of action in the public service.

By decision of the Mayor, a work group was set up with representatives of the services concerned.

The combination of the preferences of the decision makers and the performances of the scenarios was carried out with a computer application of Electre 3 (Ouzilou, 2000).

Seven scenarios were studied (according to their mode of providing energy) using fourteen criteria. A sensitivity study was carried out with fifteen simulations using in particular various weighting systems. In this case the final provisional ranking turned out to be very convincing making the decision easier. It should be noted that the solution chosen, the best one according to the process used, was not the best from an exclusively environmental point of view.

The process was facilitated by the legislation, but also by the fact that the director of the energy service of the Geneva canton had worked on a thesis about methods of multicriteria analysis.

COMBINING PARTICIPATIVE AND INSTITUTIONAL APPROACHES WITH MULTICRITERIA EVALUATION. AN EMPIRICAL STUDY FOR WATER ISSUES IN TROINA, SICILY.

The following study was carried out in response to the problem of under-exploitation of the plentiful water resources in the town of Troina in Sicily (De Marchi et al., 2000). In order to help the local authorities to solve this problem, a pluridisciplinary team was set up with the aim of understanding the origins of the problem and facilitating alternative actions to solve it.

The study followed the following steps:

- Multicriteria evaluation used as a tool for understanding the structure of the problem posed and exploring its qualitative dimension.
- An institutional analysis aimed at understanding the power structure and influences at play among the various actors concerned by the problem.
- An in-the-field study based on detailed interviews of key actors and a survey carried out amongst the inhabitants.

It should be noted that the main interest of this study was not to find a solution to a precisely formulated problem, but rather to understand a conflictual and frankly sterile situation concerning the various actors.

The first task was to identify the most representative actors most likely to contribute relevant elements for discussion. Then the (eight) alternatives and the (eight) criteria chosen to evaluate and discuss them were developed in the group on the basis of institutional analysis. With the Naïade method two rankings were obtained, the first from the performance matrix, the second relative to the various actors. These first two rankings enabled the team to appreciate the amplitude of the disagreements between the various interest groups and the power play which guided them.

According to the authors of the study, the adaptability and flexibility of the decision aid process are prerequisites to the setting up of an efficient and durable discussion. Indeed as each actor can revise his judgments at leisure, nuance them, confirm them or reject them (on the basis of supplementary information he has received meanwhile), a progressive

clarification of the situation can be witnessed (value systems in play, converging interests of certain groups...). As they have the feeling that their decisions can be « reversed » or modified, the actors find it easier to negotiate, using Naïade as a mere aid.

In order to consolidate the process and with a view to making the results legitimate, a public survey was carried out among the inhabitants.

As with other works by G. Munda (2004), this study shows the importance of the social dimension in setting up a multi-actor dialogue, especially when the actors in question have such diverging or contradictory interests. This example also illustrates our hypothesis that decision aid can be used as a tool for collaboration, for creating a dialogue and for problem-stating, and this is perhaps where it is the most relevant.

The idea put forward by the research team in charge of the Troina case is that multicriteria decision aid methods were useful tools in the setting up of a space for collaboration, especially if they were associated with methods used in the social sciences. Indeed, according to the authors, social multicriteria evaluation (SMCE), thanks to its high heuristic power, is a good alternative for the management of environmental problems and more generally problems linked to the setting up of sustainable urban development policies.

CROSS-READING ELEMENTS

Even if there is no really clear tendency, Switzerland, Italy, Canada and Scandinavia are places where the influence of multicriteria approaches is getting stronger in urban projects. As far as Switzerland is concerned, the existence of the EPFL (Ecole Polytechnique Fédérale de Lausanne) with its research laboratories on these subjects certainly has its importance. It can also be noted that Swiss legislation recommends a multicriteria approach in answering invitations to tender on the public market. Concerning Italy, the school effect is probably also present. As for Canada and Scandinavia, environmental protection is an automatic approach in this context.

Water and waste are privileged fields of application. These subjects are of course highly important but once again the existence of the EPFL certainly plays a role here. Energy questions are also very frequent.

Concerning multicriteria methods, whatever the country or field, outranking (low compensation) methods are recommended. The preference for those which tolerate vagueness is certainly linked to their ability to take into account the uncertainty of data and evaluation models as well as the subjectivity of some indicators of sustainability.

To continue with methods, even if the aim expressed by the users is to select one of the alternatives, there is a desire to obtain a justified ranking. After the first phase, detailed discussion and analysis of the best two or three alternatives is often witnessed.

Beyond the mere results most authors underline the importance of the preparatory work in the success of the process. If problems of communication and comprehension among elected representatives, experts or citizens are obviously inevitable, especially concerning sustainability, multicriteria decision aid can be used as a space for discussion between these groups while enabling a common language to evolve.

These case studies also showed the limits of the approach. This is particularly apparent when multicriteria analysis is used fairly late in the process when the final decision is all

but made. It is also the case when the demands of the various actors lead to numerous impossibilities of comparison. These situations where a decision cannot be reached can nevertheless be seen as affording an opportunity. Indeed, the process itself can be called into question, revealing omissions or dysfunctioning. The debate thus opened enables the problem to be restated, new criteria and other alternatives to be put forward, new points of view to be considered while sharpening awareness of the strengths and weaknesses of the model.

Besides, although these case studies refer to the field, they remain at least in part academic in their connotations. If the authors of case studies are convinced of the positive contribution of multicriteria analysis for sustainable urban infrastructure projects, it is in part because they are specialists in decision aid. Professionals in the field of urban development have a more nuanced view. Indeed, while it is feasible and relatively easy to mobilize the various actors and points of view concerned, it is much more difficult to find the time required by these approaches.

Lastly, capitalization is problematic. Case studies are always different. Even when the same field is concerned (e.g. waste), the same problem (e.g. the choice of a site) and the same method (e.g. Electre), the models constructed are different. Dependency on context is fundamental. Problem stating always has to start at square one.

APPLICATION PROBLEMS

The hypothesis defended here seems to have a certain relevance but a certain number of problems exist.

In fact, the most frequent problems we have revealed are practical ones which appear when decision aid methods are set up within the framework of sustainable urban development.

First the problems linked to the very basis of multicriteria methods: indeed, all these methods use mathematical concepts which are not necessarily easy to understand. Outranking methods are not intuitively accessible to people without the necessary background. Compensatory methods such as the weighted sum are familiar to everyone and their use comes fairly naturally. This may cause a block when other ways of apprehending problems are to be considered.

J. Pictet and D. Bollinger (1999) give an explanation for this. Indeed, they attribute the natural recourse to the weighted sum to the school system and its obsession with grading and average marks as the only system of evaluation. It would be “interesting to see the impact of a no-grades system in school on the way pupils later, as adults, consider the adjudication of public markets”.

A comparison between Swiss and French practice gives another example of these kinds of “school effects” and how they work. Indeed Swiss professionals, many of whom went to the EPFL, one of the pioneers in multicriteria decision aid, naturally use this type of tool in the decision-making process.

However, before going any further, one might ask if this quasi-cultural block relative to outranking methods is not actually a rejection of sustainability itself.

Indeed, even if, as has been shown, a sustainability approach is quite well accepted, it remains that its concrete application in the field of urban infrastructures involves a kind

of “revolution” in people’s practice, a revolution that not all professionals in this field are about to adhere to. By proposing a new way of dealing with problems (combining the three approaches: economic, environmental and social), sustainability introduces a clean break with the former habits of the actors involved, whether they be decision-makers, technicians or whatever. Sustainability thus meets with quite natural resistance which is linked to its social acceptability. The message concerning sustainability is well accepted by a growing number of people, but at the same time its application is problematic. The same kind of thing can be seen with multicriteria decision aid, which remains marginal for similar reasons of social acceptability.

Getting people to accept sustainability in every-day practice is finally a major question which multicriteria decision aid, not as a tool for finding solutions, but as a tool for stating problems, could help to answer.

Indeed, by creating a framework for dialogue and collaboration between the various actors, multicriteria decision aid, as a concrete operational tool, would enable these “cultural barriers” to be lifted and sustainability to be applied first at a local project level, then on a more global urban infrastructure scale.

A COMPLEMENTARY APPROACH

The preceding considerations have shown the potential of multicriteria analysis in contributing to a better integration of the various aspects of sustainability in the field of urban infrastructures. Aid in problem stating, governance, comparing alternatives or project variations, seems to be accepted. Except that this supposes that the variations and alternatives are authentic options. In questions of sustainable urban development, the professionals are not necessarily convinced. They may even have reservations, as has just been shown. The question of the time to be devoted to studies along with the difficulty of capitalizing knowledge and know-how in this field contribute to this distancing.

The importance of project leaders is primordial, and they all witness to the difficulties they have to face in communicating at all levels concerning sustainability.

Here are the conclusions of a study we carried out in 2002-2003 on sustainable development practices (Alfakih et al. 2004):

“For the moment it still seems difficult to constitute a corpus of knowledge which has been capitalized or transmitted in a structured way in the fields of sustainable development in urban infrastructures. However, the creation of a bank of examples, practices and case studies in an organized framework enriched with commentaries and references would certainly be a useful contribution, and may be the best way to move forward.”

The European project PETUS (*Practical Evaluation Tools for Urban Sustainability*) is based on these conclusions. The PETUS project is a 3-year research project (2003-2005) funded by the European Commission as part of the 5th Framework Programme Energy, Environment and Sustainable Development, key action “City of Tomorrow & Cultural Heritage” including eight European partners.

The case studies concerned here are different in nature from the preceding ones. It is no longer a case of examples of the setting up of a multicriteria analysis approach but of reputable or significant projects taking into account sustainability in urban infrastructures.

Now it is a question of case studies being used to help develop satisfactory solutions with reference to sustainability.

The Practical Evaluation Tools for Urban Sustainability (PETUS, 2005) project is developing a framework that can be used to analyse and improve the sustainability of urban infrastructure projects and to explore the potential for transferring projects to other areas. It is hoped that the framework will provide clear and concise information on sustainability and also guide actors at all levels of decision-making towards the use of the most appropriate procedures. This on-line Informative Support System combines both a “static” database with a “dynamic” monitoring procedure to assist end users to make the concepts of sustainability more operational.

For each sector, energy, waste, water & sewage, transport, green/blue, and holistic (building / urban planning / land use), the PETUS database provides the following information:

- a sector definition related to sustainability stakes including discussions about indicators, benchmarks, cross sector links and proposing references,
- a set of case studies (app. 60 all sectors combined) to illustrate the incorporation of sustainability into real projects for end users to learn from,
- a set of tools, used within the case studies or that have been reviewed as part of a wider literature review,
- a set of important issues directly raised from case study analysis.

The PETUS monitoring procedure presents a checklist and a matrix to encourage action to be taken towards sustainability in a project, plan or programme, allowing end users to collect relevant information throughout the project/plan management.

PETUS has been tested within public and private sector organisations and modifications have been and will be made to the framework to ensure compatibility with current working practices and local conditions.

Some feedback conclusions of PETUS testing with end users are presented below:

- The first general impressions of PETUS DSS are often positive. Yet its practical implementation in every day work is not so easy: problems of language, time for its implementation etc. are raised.
- Through discussions, PETUS appears as a way of learning about sustainability and not of learning technical competence. As PETUS investigates a large area (several sectors, different space and time scales and economic, social and environmental items are investigated), it is not possible to propose a comprehensive technical database. PETUS rather provides approaches, discussions, context specific examples etc. related to sustainability.
- PETUS helps to enlarge vision of problems and projects (for instance between partners of an urban infrastructure project) in terms of impact assessment.

Here some examples of conclusions are presented but they are not exhaustive. The varied feedback from end users is displayed and discussed in the “Testing report” available on the PETUS project website (PETUS, 2005).

We hope that PETUS will provide feedback about sustainability experiences through its different parts.

This “indirect” feedback can have three purposes in relation to different types of PETUS end users:

- Experts interested in sustainable projects, examples, ideas in their own field of expertise. They need detailed case studies, which present a lot of information and different local contexts. These case studies should for example tackle questions of transferability, local context...
- Experts interested in projects, opportunities...in another sector than their own field of expertise. They know what is possibly sustainable in their own sector and would like to improve, enlarge their view, their way of thinking. These case studies should present them with opportunities, conflicts, benchmarks, propositions of new possibilities of collaboration between new actors that have to learn how to work together (multidisciplinary approach), propositions for new kinds of work organisation and management...
- Decision-makers. Case studies should here help end users to see what is possible in relation with decision making, what could be enhanced... It deals with policy, plans and programmes.
- A fourth category could be young technicians or engineers that need to learn easily and quickly elements of sustainable development (examples of sustainable urban projects). Case studies appear here as (professional) training.

Is the PETUS framework a Decision Support System (DSS) or an Informative Support System (ISS)?

The question is: does PETUS really support the decision-making process? We think that in the current situation, PETUS is more an Informative Support System than a real Decision Support System.

The success of PETUS to really support decisions made during an urban project depends on the framework appropriation and use by end users. Questions are: how will the PETUS matrix be used? How can the framework improve project management? Are there enough case studies to create inspiration and to present relevant projects transferability information? How to maintain information on PETUS? How will new tool descriptions and new relevant case studies be inserted in the future when the PETUS project is finished? Etc.

To conclude, we think that first if PETUS could be tested in several urban infrastructure projects throughout Europe where stakeholders have an interest in sustainability to check if it is really supporting (and improving) decision making through time, then if the PETUS framework can be improved with some slight modifications (specially on the guidance part), and finally if time is spent to explore how the matrix can be controlled and used, PETUS could be of real help and provide benefits for stakeholders involved in urban infrastructure projects related to sustainable development and become a real Decision Support System.

CONCLUSION

Let us come back to the initial hypothesis, that is, the positive contribution of multicriteria decision aid to a real taking into account of the various dimensions of sustainable development in the field of urban infrastructures.

This hypothesis seems to be relevant in the search for, and elaboration of, a consensus between the demands of sustainable development on the one hand and the various participants on the other.

However, a certain number of difficulties have been revealed. These concern a lack of information and understanding concerning the potential of non-compensatory, multicriteria methods, but it may be permitted to believe that team work between researchers and the professionals in the field could positively answer this need. The time to be devoted to studies remains a problem because, as we have seen, the success of this type of approach is closely linked to the quality of the problem-stating phase. But the most important problem is obviously the full adhesion of all the participants to the concepts of sustainability. A tool such as the PETUS system will certainly contribute to this adhesion.

Concerning sustainable development and multicriteria analysis, the limits are essentially cultural. Training, study procedures, research will enable those limits to be pushed back but an effort of communication and information about in-the-field case studies will also have to be made to facilitate a direct connection with the complexity of the real every-day world of those professionals involved in urban infrastructures. This is what we have tried to do in this article.

REFERENCES

- Alfakih, E., Miramond, M., Richard, F., Ruffier, J. (2004). Réalités du développement durable dans les pratiques urbaines : le cas des infrastructures urbaines. Compte rendu de fin d'opération d'une recherche financée par le ministère de la jeunesse, de l'éducation nationale et de la recherche. Décision d'aide n°01V0800. 130 p.
- Bana e Costa, CA, and Vansnick, JC. (1999). The MACBETH approach: basic ideas, software and an application. In *Advances in Decision Analysis*, Meskens, N, Roubens, M (eds). Kluwer Academic Publishers: Dordrecht, 131–157.
- Brodhag, C, (2000) Gouvernance et évaluation dans le cadre du développement durable. Colloque : Europe villes et territoires, Lille, 3 et 4 novembre 2000. (available at: <http://www.agora21.org/articles/brodhag00b.htm>).
- Brunner, N., and Starkl, M. (2004). Decision aid systems for evaluating sustainability: a critical survey. *Environmental impact assessment review*. 24(2004) 441-469.
- De Marchi, B., Funtowicz, S.O., Lo Cascio, S., Munda, G. (2000). Combining participative and institutional approaches with multicriteria evaluation. An empirical study for water issues in Troina, Sicily. *Ecological Economics* 34 (2000) 267-282.
- Maystre, L.-Y., Bollinger, D. (1999). *Aide à la négociation multicritère*, Presses Polytechniques et Universitaires Romandes, 192 pp.
- Maystre, L.-Y., Pictet, J., Simos, J. (1994). *Méthodes Multicritères ELECTRE*, Presses Polytechniques et Universitaires Romandes, 1994, 322p.
- Munda, G., (1995). Multicriteria Evaluation in a Fuzzy Environment. In: Contributions to Economics Series. Physica-Verlag, Heidelberg.
- Munda, G., (2004). “Social multi-criteria evaluation (SMCE)”: methodological foundations and operational consequences. *European Journal of Operational Research* 158 (3), 662–677.

- Norese, M.-F. (2002). Participative approach, Multicriteria Analysis and GIS support. 3rd *International Conf. on Decision Making in Urban & Civil Engineering*. London, Great Britain, November 6-8, 2002, 6 p in [CD-ROM] ed. by F. Khosrowshahi.
- Norese, M.-F., Toso, F. (2001). Group Decision and distributed technical support, 20 pp. (available at : www.lamp.polito.it/ssd/cv/ifors1.pdf).
- Ouzilou, O. (2000). Decision aid for district energy planning, Nyon, Switzerland. *Assises de l'Energie*. Dunkerque 19-20 novembre 2000. 9 p. (available at: <http://www.ville-ge.ch/geneve/energie/documents/dunkerque 2000.pdf>).
- PETUS (2005). *Practical Evaluation Tools for Urban sustainability*. (available at : <http://www.petus.eu.com>).
- Pictet, J., Bollinger, D. (2003). *Adjuger un marché au mieux-disant, Analyse multicritère, pratique et droit des marchés publics*, Presses Polytechniques et Universitaires Romandes, 250 pp.
- Rogers, M., Bruen, M., Maystre, L.-Y. (2002). *Electre and Decision Support: Methods and applications in Engineering and Infrastructure Investment*, Kluwer Academic Publishers, 208 pp.
- Simos, J. (1990). *Évaluer l'impact sur l'environnement*. Presses Polytechniques et Universitaires Romandes, Lausanne.