SOFTWARE TOOLSET FOR SUSTAINABLE DECISIONMAKING

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Abstract - The goal is to have as many systematic and comprehensive tools and resources pertinent to sustainable decision making readily accessible through Internet, including a set of criteria over which to assess policy alternatives, technological alternatives, project proposals, or the consequences of past decisions or the performance of past programs. A subset of tools has already been implemented, including a spatial decision support system for sustainable industrial siting, decision aid for holistic technology assessment and selection, and a software toolkit to help and cheapen a technology foresight exercise. The current plans call for the development of the integrated tool for multicriteria assessment of the extent and dynamics of sustainability, including identification of the most important indicators promoting or impeding progress toward sustainable development.

INTRODUCTION

The strategic approach adopted in the formulation of the Work Programme of ICS-UNIDO (International Centre for Science and High Technology under aegis of United Nations Industrial Development Organisation) is to privilege a policy of sustainable development, which takes into account both the endogenous industrial capacity of developing and emerging countries as well as environmental issues. Achieving more sustainable development is also the motto of most politicians in these countries. However, making political choices converge to sustainable development requires a pragmatic approach to assess sustainability, based on good science and adequate information. Despite of the fact that the concept of the sustainability is very complex and still rather ambiguous, scientists should find the way to assess it (Vranes and Pizzio, 2000). To start with, it is clear that the process of development requires making of decisions, selecting from among several possible alternative development paths the line of action that will return the most perceived benefits. For the development to be sustainable, all the decisions directing its path should be made with sustainability in mind. That means that a guiding principle and an objective for the sustainable decision process is that the decisions must be taken which meet the needs of the present without compromising the ability of future generations to meet their own needs. To help this process the ICS-UNIDO has started development of the pragmatic set of sustainable decisionmaking aids, using Bellagio Principles (earthwatch.unep.net/indicators.html) as the priciple guidelines for undertaking and improving assessment of progress toward sustainable development. Apart from the above mentioned principle of adequate scope (time horizon long enough to capture human and ecosystem time scales), the Bellagio principles especially pivotal to the project are the following:

- *HOLISTIC PERSPECTIVE; Assessment of progress toward sustainable development should consider the well-being of social, ecological, and economic sub-systems and take into account both positive and negative consequences of human activity, in a* *way that reflects the costs and benefits for human and ecological systems, in monetary and non-monetary terms.* In ICS-UNIDO toolset, both those that already operational and those yet to be implemented, a holistic perspective has been adopted as a must, and multicriteria assessment is performed using both operational research and artificial intelligence technique.

- *PRACTICAL FOCUS; Assessment of progress toward sustainable development should be based on a limited number of indicators or indicator combinations and their standardized measurements to permit comparison.* ICS-UNIDO software assessment tools define an initial set of default indicators and the algorithms for their aggregations, while the users are allowed to modify (add, change, delete) this initial settings easily, according to their preferences.

- *OPENNESS; Assessment of progress toward sustainable development should make the methods and data that are used accessible to all, stating explicitly all judgments, assumptions, and uncertainties in data and interpretations;* Our tools are easily accessible, through Internet, for all our target beneficiaries and other authenticated users. All the recommendations are explained and justified, and the alternative ranked according to the criteria defined by the user.

- *BROAD PARTICIPATION; Assessment of progress toward sustainable development should obtain broad representation of key grass-roots, professional, technical and social groups, and ensure the participation of decision-makers to secure a firm link to adopted policies and resulting action.* All sort of stakeholders are encouraged to use ICS-UNIDO decision aid, which helps them to aggregate their perspectives and reach consensus over sometimes contradictory criteria and preferences.

- *ONGOING ASSESSMENT; Assessment of progress toward sustainable development should be iterative, adaptive, and responsive to change and uncertainty because systems are complex and change frequently and promote development of collective learning and feedback to decision-making.* Internet accessible software assumes that the assessment should be repetitive and cyclic process and not the "one-off" thing, and allows an easy reevaluation of its recommendations and rankings of alternative solutions in case of new findings or changed circumstances.

It is the ICS-UNIDO ambition to provide a complete set of tools to support almost every important decisionmaking step on the route towards sustainability, and to allow various sorts of stakeholders from beneficiaries countries to take their share of decisions according to the good principles of sustainable decisionmaking and environmental management. Environmental management is 'the organizational structure, responsibilities, practices, procedures, processes and resources for determining and implementing environmental policy' (British Standards Institute, quoted in Richard Welford (1996), p. 36.). It is even more important for developing countries and countries with economy in transition, that have just started considering the environmental management and sustainability principles in establishing their policies, that all the crucial decisions are made well and that decision-makers use the best information, methods and tools available. For development to be sustainable they need to make the decisions that do not have long-term negative impacts, and to assess both impacts and benefits prior to undertaking policy implementation actions. Therefore, the ICS-UNIDO has decided to provide its beneficiaries from developing countries with a comprehensive, computer-based decision making aid readily accessible through Internet.

For ICS-UNIDO, the Internet represents a key tool for providing inexpensive, "recipient focused" on-line services to beneficiary institutions and individuals from developing countries and the wider community. Also, governments, and organizations in developing countries have realized the benefits and opportunities that the Internet presents for social and economic development, increasing organizational and national competitiveness. As a result, the Internet developments in third world countries have accelerated significantly in the past few years. More and more developing countries are connecting to the Internet with the hope that it will help reduce the isolation experienced by these countries and facilitate their economic developments. Of course, the poor infrastructure presents serious barriers to rollout of the Internet in many developing countries. Consequently, many international aid financed networking initiatives are under way. World Bank, UNDP, ISF, USAID are among the most active supporters of such initiatives. Moreover, the latest developments in data communications technology (particularly wireless technology) makes it possible to bypass the existing poor infrastructure and have more faster and reliable Internet connection.

Therefore, the ICS has begun developing an Internet available repositories of the best available technologies, economically viable and environmentally respectful (BATEV) and decision aid for evaluation of those technologies (DEBATER) to help its users from the developing countries to acquire and assess various available technologies taking into account all relevant aspects. A holistic assessment of technology requires a full multicriteria exploration of the technical, economic, ethical, social, environmental and political impact that can result from the application of technology or technological systems. Internet accessible, multiparadigm decision support system brings together artificial intelligence, operations research, engineering, economics, and public policy concepts to help its user make sustainable technology investment decisions (see Vranes, 1995). It integrates knowledge and data from a variety of sources to facilitate users conducting multicriteria analyses of technology alternatives and to justify appropriate investments. With DSS, users in developing countries are able to make rational choices among technology alternatives by using their specific subset of criteria and their relative measures of importance, among a huge set of criteria concerning technical performance, economical feasibility, environmental soundness, socio-economic impact, etc.

Of course, since predictions of impacts, especially in the long term, can ever only be approximate, decisions need to be revisited and revised as their consequences are revealed in practice. However, even in the case that "end-of-pipe" solution is still necessary, with the decision making system it would be easier to select the best remediation technology, depending on user specific criteria, site characteristics, type of contaminant, level of contamination etc. ICS decision aid for remediation technology selection (DARTS) is fully operational and will be presented in more detail in the following sections.

Another service that will be presented in more detail is a provision of a software tool assisting in technology foresight exercise. The technology foresight process seeks to identify those technologies that will be key to national and-or regional sustainable development in the longer term and to make recommendations to address the opportunities and challenges associated with these technologies (see Ascher, W.,1978). International experience demonstrates that technology foresight is rather complicated and time and resources demanding. Therefore, the technology foresight exercise of one type or another has been undertaken mostly by the leading industrial countries, while the developing and transition economy countries were left aside of the process. To remedy this situation, the ICS-UNIDO has opted for the development of a software tool, which will help its target beneficiaries to perform the exercise in more cost effective and less time consuming manner.

Also, for sustainable industrial development, the need of the hour is judicious, reasonable and planned use of the finite resources of land, according to the natural environmental properties (Ostwald 2002). To cater to this need, ICS is using geographic information systems, remote sensing and spatial decision support systems techniques to help proper siting of newly planned industries & industrial estates, especially in developing and transition economy countries, where the process of sustainable industrialization is still in its initial stage. We will start with detailed presentation of this tool and proceed with the description of the rest of the software toolset mentioned briefly in this introductory section.

DECISION AID FOR SUSTAINABLE INDUSTRIAL SITING

In developing and transition economy countries, the siting of industries appears to follow a random pattern that does not consider the available infrastructures, the allocation of water resources and the prevention of pollution of water, soil and air. Strategic plans have to be developed in order to improve the plant allocation within industrial areas in such a way to optimize the land use, the transportation system, the water use and the waste treatment. Therefore, ICS suggests the use of Spatial Decision Support System (geographic information system enhanced with multicriteria analysis) as a proven tool for achieving sustainable industrial siting. Site selection based on environmental criteria (proximity to protected forests, national parks, water sources, etc.) with the objective of minimizing adverse environmental impacts is, therefore, a vital prerequisite. Of course, other important criteria (proximity to main industrial sites, to main roads, residential areas, etc.) are simultaneously taken into account. A real world example of Spatial Decision Support Systems and multi-objective land allocation will be presented..

This case study describes the planning process for the coastal area of Tunisia (the Gulf of Tunis) using the GIS technology to integrate data from the variety of sources, particularly satellite images. It highlights the importance of GIS, remote sensing and decision-support systems as tools for institutional co-operation and illustrates the many advantages of GIS over conventional approaches to urban mapping, environmental management, sustainable industrial siting and vegetation monitoring. The Tunisian coastal zone, as many coastal countries of the Mediterranean Basin, is subject to increasing pressure from a wide variety of activities such as recreational and tourism projects, industry and urban settlement. Coastal managers are faced with the challenge of balancing these pressures. The aim of the work was the creation of a suitability map showing the industrial sensitivity of the coastal zone of the Gulf of Tunis, Tunisia. It consists of landscape evaluation for industrial siting and includes a GIS tool developed using GRASS geographic information software. In a multi-criteria evaluation, an attempt is made to combine a set of criteria to achieve a single composite basis for a decision according to a specific objective.

In the present study a decision needs to be made about which areas are the most suitable for industrial settlement. The concept consists of inserting interactive effects of several contributing factors and constraints that may contribute in enhancing or decreasing industrial susceptibility. The factors are raster images: proximity to main industrial zones, proximity to main residential areas, proximity to main roads, proximity to water sources, proximity to forest and protected areas, proximity to barren lands. The constraint, on the other hand, is a raster image that excluded certain areas from consideration (reserved lands: sea, lakes, rivers, urbanized settlements and industrialized zones). Through the multi-criteria evaluation, these criteria images were combined to form a single suitability map from which the final choice will be made. The output consists of a certain number of categories, each reflecting its susceptibility to the installation of new industries. The suitability map resulting from the multi-criteria evaluation shows different classes for which the degree of susceptibility to accept new industrial plants vary from extremely prone areas to weakly prone (see Figure 1) based on:

- Its proximity to existing industrial zone in which the probability of finding existing infrastructure and organized industrial system is high;
- Its proximity to residential and commercial sites that represent a first necessity for any social activity and in particular industrial activities according to the high number of workers in this domain;
- Its proximity to main roads and its good connection with the market. Access to transportation is thus an important consideration
- Its natural location (coast, rivers, lakes, slope, etc…) that can represent an environmental delimitation.

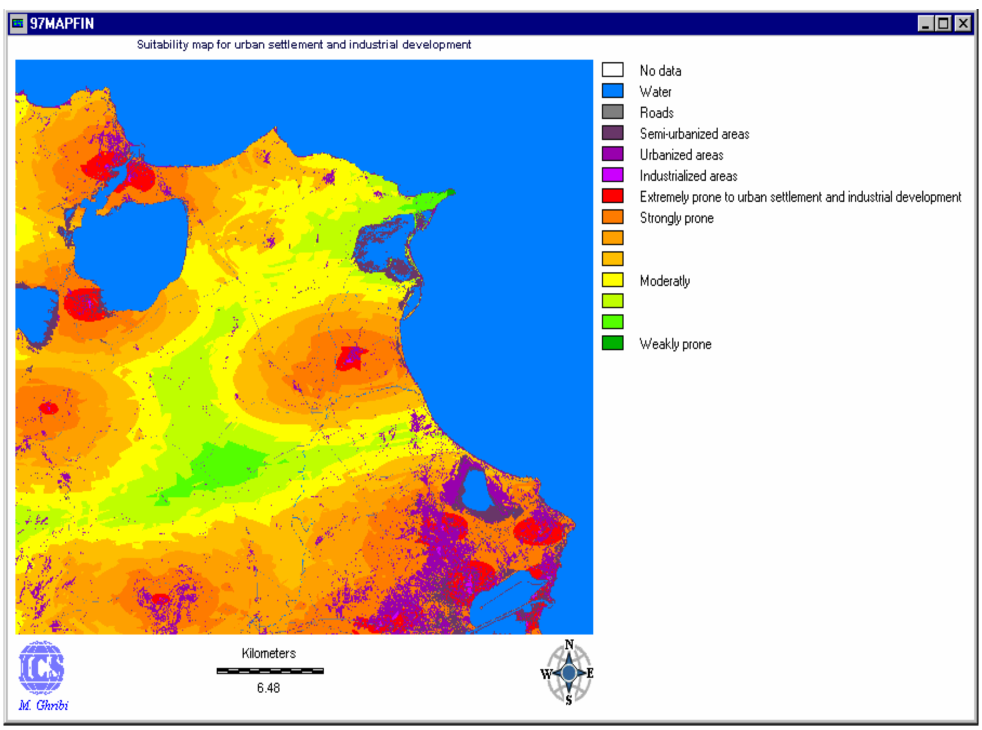

Figure 1. An example of a suitability map

TEHNOLOGY ASSESSMENT AND SELECTION

Having chosen a proper site for a new plant, the best technological process of production should be selected. It is also of crucial importance for developing countries and those with economy in transition and rather constrained budgets, that technology selection decisions are made well and that decision-makers use the best information, methods and tools available. Existing tools and techniques often focus on particular areas of concern or meet specific needs of targeted stakeholders (investors, technologists, policy makers, environmentalists, etc.). By capitalizing on the synergism, our software tool, called DEBATER (Decision-aid for Evaluation of Best Available Technologies, Ecologically Respectful) offers the opportunities for interaction between perspectives and for incorporation of the environmental considerations and sustainable development concepts into the decision-making tools for broader application. In a good 'sustainability approach' technical, social, and environmental goals are treated together with economic goals as a core of the holistic technology sustainability assessment. DEBATER enables technology selection decisions that do not have long-term negative impacts, and help all sorts of stakeholders to assess both impacts and benefits prior to undertaking technology implementation actions.

In the sphere of ICS competence and coverage (i.e. pure and applied chemistry, earth, environmental and marine science and technology, and high technology and new materials), a multitude of emerging technologies have become available in recent years. Magazines dedicated to discussion of these technologies have sprung up, many retail catalogs are available, and technology assessment conferences take place throughout the year. However, despite the abundance of information, investors in developing countries often rely on marketing data, trial and error, and anecdotal information to make technology-purchasing decisions. Therefore, it has become obvious, that a more informed and analytically sound basis for decision making is essential. Having quantifiable justification and objective assessment of technical performance, economic viability and environmental soundness, investors may more readily gain approval and allocate scarce funds for technology purchases. Of course, a serious impediment investors in developing countries may face in conducting technology assessments is that measuring the benefits of technologies in monetary terms is rather difficult. It is relatively straightforward to determine purchase costs, annual operating costs, and other costs of technology ownership. However, translating gains such as improved efficiency, reduced environmental hazards and prevented fatalities—corresponding to new technology introduction—into monetary terms is more difficult. Therefore, ICS' aim is to provide its beneficiaries from developing countries (scientists, developers, investors, environmentalists, policy makers, regulators) with an independent, objective and credible assessment of products and technologies, taking into account normalized and aggregated technical, economic and environmental criteria. This is fully in line with the ICS' intention to become a leader in practicing and encouraging delivery of technological services to developing countries in innovative and inexpensive ways. There is a good evidence that Internet available technology repository and technology evaluation and selection aid can improve the cost and quality of ICS services through:

- *Building competitive advantage of ICS* by linking emerging information technologies to the ICS mission (it is obvious that the technology transfer organizations that can successfully deploy information tools will have a competitive advantage over organization that do not).

Having an up-to-date information on available technologies (BATEV), and the DSS that makes the most effective use of this information (DEBATER), is too integral to the strategic success of a technology transfer organization to be overlooked as a major planning issue. It is therefore integrated into an organization's overall management and planning system. This will be particularly important for the future when organizations will operate in a networked information environments

- *ICS' overall service process improvement* (improved technology transfer, improved training courses preparation, unified technology repositories across the ICS sectors, unified criteria for technology assessment and selection, etc.). When high quality information is made readily accessible to the various decision makers, and when the decision makers both in-house and in the recipient countries are helped with DSS, the decisions are more effective and consequently the ICS is better positioned to deliver quality services to its partners and target beneficiaries from developing countries and achieve its mission and goals.

- *Facilitating rapid development of project feasibility study* (through automated assessment of economic and technical feasibility and environmental soundness) for joint projects with counterparts from developing countries and countries with economies in transition; With BATEV and DEBATER, ICS and partner technologists will be able to better and faster identify and assess promising projects, and prepare final project documents to be submitted for funding

- *Reducing effort and rework*, by capturing and preservation of in-house skills and expertise, re-applying and disseminating the same knowledge (captured in DEBATER's knowledge base) and data (stored in BATEV data base) unlimited number of times, while also reducing redeployment of the ICS staff, which is an unavoidable drawback of the conventional technology transfer activities

- *Ensuring increased satisfaction of ICS' services recipients* in developing countries, since much more of them (unlimited number actually) could be served, supported and trained, instead of a limited number of the "lucky ones" chosen to attend the conventional training courses at the ICS premises or elsewhere. A wide spectrum of target beneficiaries (scientists, developers, policy makers, small and midsize entrepreneurs and other stakeholders) from developing countries will be able understand true cost of the introduction of new technology, prepare for environmental standards, cut environmental costs and reduce waste, and to make informed and objective technology selection.

The recipients from the developing countries also benefit directly by the expansion of learning opportunities, by the possibility to acquire new knowledge from their homes and companies, providing that they have access to Internet, which is rather common nowadays, even in the developing countries.

Software tools

The first major outcome of the DSS development is a set of databases on the **B**est **A**vailable **T**echnologies, **E**conomically **V**iable (BATEV). Since this is a rich and up-to-date technology repository, it could be used independently from the decision making system for some technology transfer, dissemination, and training, awareness raising and other purposes. The decision making system, although using BATEV as a basis, will have a lot of other software modules, making its architecture much more complex than a simple data base management system .

The goal of BATEV is to ensure that project managers and site stakeholders are aware of the full-range of technology options, available to them to assess, either by themselves or using DEBATER, and characterize their applicability to their particular problem at hand and to choose the right technology, at the right time, at the right site, at the right cost.

ICS is constantly reviewing the latest technologies, in order that it can help its target beneficiaries to select the most appropriate technology for a particular area, and to foster the development of feasibility studies according to specific criteria selected by BATEV users.

Technologies from the candidate list are selected for the inclusion into BATEV repository if they meet one or more of the following criteria:

- Good technical performance
- Maturity
- System expansion possibility and upgrade reliability
- Economic prosperity
- Market success
- Competitiveness
- Job creation and economic growth
- Improved cost efficiency
- Credible environmental performance

The technical performance data supplied by the vendor could reflect real differences in capability, or could simply be a result of different perceptions as to the best technical path. Therefore, ICS will provide independent auditing and, if necessary, provide the "real-world" measurements to check the viability of the technical performance declared by technology developers and product vendors.

The decision support system operating on top of BATEV repository is called DEBATER (Decision-aid for Evaluation of Best Available Technologies, Economically and Environmentally Reputable). The name (although naturally induced from the first letters of its functionality descriptors), suggests that the automated decision support system only takes part in the debate on the issue, i.e. the evaluation and selection of the best available technology, taking into account its technical performance, economical viability, and environmental soundness. The final decision, of course, is up to the human decision maker.

This way we will also fight the fear and prejudice concerning the artificial intelligence and decision support systems, being thought of as a potential jeopardy for human decision makers, leaving them jobless. The DEBATER will debate the issue with its users and make its recommendation (together with the ranked alternatives). Its users will be allowed to interactively interfere the decision making process, to change the decision elements or even the decision as a whole (preferring one of the ranked alternatives suggested by DEBATER).

DEBATER helps ICS' beneficiary institutions and individuals from the development countries and countries with economy in transition to make smart technology decision. It offers technology evaluation, comparative analysis of technology alternatives and selection of the best available, environmentally and economically viable technology, and helps its user to make the most of their technology investments. Our decision support system in multi-vendor, multitechnology environment provides its users with well balanced recommendations based on their own choice of criteria and their relative measures of importance.

DEBATER factors human experts' experience into decisionmaking in a fashion that is friendly as well as powerful and that gives its users confidence in their decisions. Owing to its intrinsic intelligence and richness of the underlying databases, it can be far more useful and reliable than any information and recommendation source otherwise available to us. It does not tire or become cranky. It does not bluff but instead tell its user the limitation of its knowledge and estimate the uncertainty of its conclusions. It processes and distills the experience of many experts and applies it to the particular problem at hand without bias. It tells us upon our demand what assumptions it is making and what its line of reasoning is. In short, DSS add breadth and depth to human reasoning and decision process.

Since DEBATER is interactive (not fully automated), user actively interfaces the decision process, not only to obtain the explanations for the system recommendations but also to choose the most feasible alternative according to some subjective criteria and intuition (if needed) or to change some partial decision elements. The main reason to keep the system open for the user is the unstructured nature of the technology selection process and frequent need for human intuition and judgement, not easily described in any artificial intelligence formalism. A human possess unique knowledge and inside information that is not easy to include in any quantitative method.

With DEBATER, ICS's target beneficiaries are able to make rational choices among technology alternatives by using their specific choice of measures and criteria, among those included in the technology overview.

System architecture

DEBATER is a multiparadigm, multicriteria decisionmaking system (Linstone 1984, 1999) that consists of the following major modules :

- *The intelligence module* establishes a sort of user's profile, in order to configure the system according to the type of user, his/her level of competence, etc.

- *The user interface* represents an entry point for the user to interfere the decisionmaking process and tailor the analysis to satisfy his/her specific needs

- *Technology repositories* (Several databases containing up-to-date information on mature, innovative and alternative technologies comprise the foundation of the model)

- *The knowledge base* contains all sorts of experts' knowledge that can help the decisionmaking process (experiential heuristics, constraints, hypotheses, etc.)

- *The analysis engine* calculates costs, benefits, fatalities, and other measures of interest based on relationships developed from the underlying database, and makes a multicriteria analysis according to the set of criteria and their relative importance chosen by the user. PROMETHEE multicriteria analysis method has been chosen as the most appropriate (Brans, 1985, 1994).

- *The report generator* (output consists of financial and other operational results, recommendations and ranked alternatives, presented to the user in both numerical and graphical formats).

The relationships between these modules are depicted in Fig. 2.

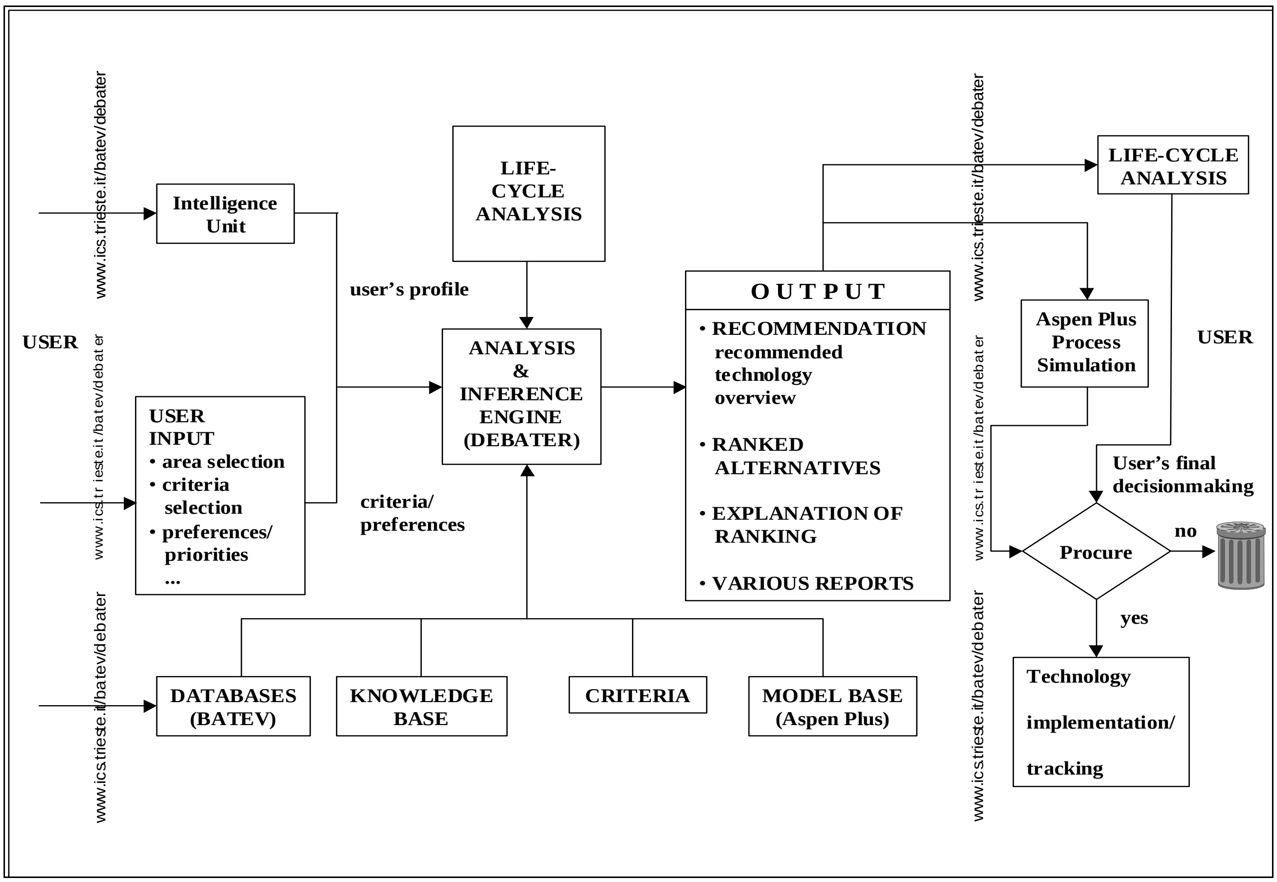

Fig. 2 DSS architecture

DEBATER makes quantitative and qualitative comparative analysis of various technology alternatives and provides its user with the technology recommendations and ranked alternatives, like a human debater in the real debate on technology selection. The user then takes that information and weights it against other factors (such as political environment, and other external variables not easily formalized and processed by automated decisionmaking system) to make a final technology purchasing decision.

As an example of DEBATER instantiation, the DARTS software, enabling comparative analysis of available soil clean-up options, depending on pollutant type and user's specific choice of criteria and their weights, will be described in more detail in the following section.

DECISION AID FOR REMEDIATION TECHNOLOGY SELECTION

Soil remediation is a difficult, time-consuming and expensive operation. A variety of mature and emerging soil remediation technologies is available and future trends in the remediation industry will include continued competition among environmental service companies and technology developers, which will definitely result in further increase in the cleanup options. Consequently, the demand has developed for a decision support system that could help the decisionmakers to select the most appropriate technology for the specific contaminated site, before the costly remedial actions are taken. Therefore, we have developed DARTS (Decision Aid for Remediation Technology Selection), that works closely with human decisionmakers involved (site owners, local community representatives, environmentalists, regulators, etc.) to assess the available technologies and select the preferred remedial options. The selection is based on technical, financial, environmental, and social criteria. These criteria are ranked by all involved parties to determine their relative importance for a particular project.

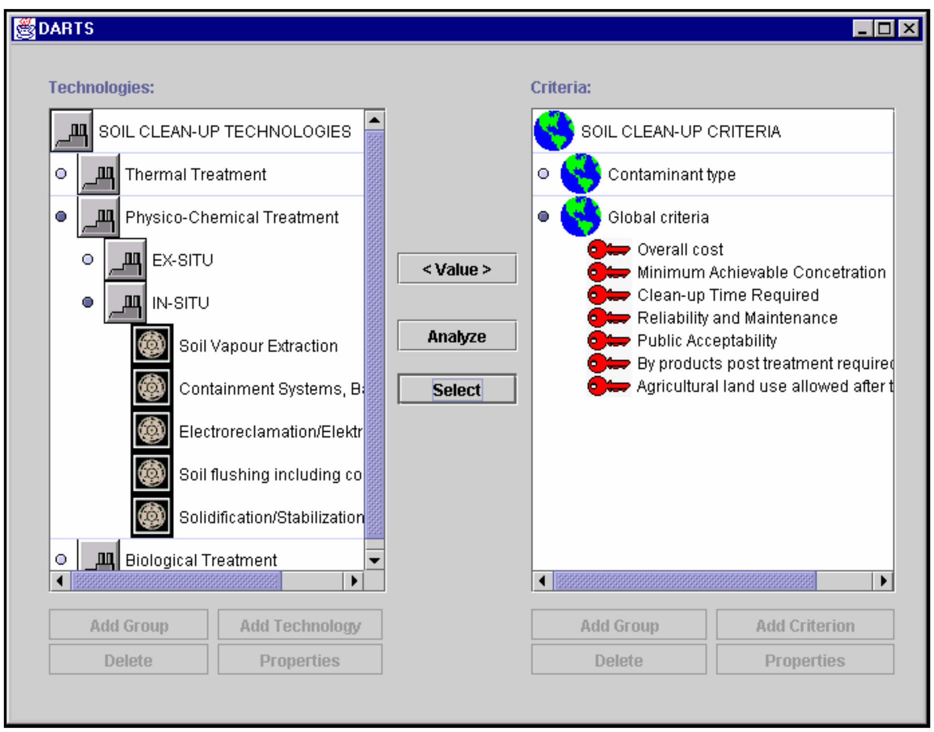

Figure 3. DARTS screen shot

The DARTS presents its users with a variety of configuration and input parameters from which to choose. Several are mandatory (such as identifying technologies to be evaluated), but there are many that the user can choose to leave blank or use the supplied default values. This way, the user decides how to tailor the analysis to satisfy his/her specific needs.

The application's main window (Fig. 3) consists of the current state of the configuration, and a few dialogs for data entry purposes. It is connected to the database that contains previously entered information on available technologies and selection criteria. During an interactive session with DARTS, the user usually selects the technologies to be simultaneously evaluated and compared with each another, selects contaminant(s) that are present at the specific site, and technology assessment criteria and their relative preferences. If interested, DARTS user could go deeper into the implementation details and configuration parameters, and change even indicator aggregation algorithms or a shape of preference function. Once, the configuration has been set and preferences defined, systems comes up with the recommendation of the best available remediation technology for the combination of contaminants present in the polluted soil, together with the ranked alternative solutions.

A laboratory prototype has been developed as a JAVA application, using the Symantec Visual Café dbDE development environment. Internet accessible version of DARTS is currently under construction. When completed, it will help the authenticated users all around world to solve their soil clean-up problems. The client-server architecture adopted for Internet version, assumes that all the analysis and data-base administration is done at the server side, while a light client (i.e. a distant user) needs only a standard Web browser and proper authorization to access and use the DARTS.

TECHNOLOGY FORESIGHT

Technology foresight is presented as a set of methods to foster collaboration in multidisciplinary analyses of long-term scientific and socio-economic developments in order to identify technologies which may have future economic and/or a broader societal significance. This type of knowledge is crucial in making sustainable decisions especially those concerning national priorities for allocating resources to research, industrial development and education - in both public and private contexts. Given the strong background in technology transfer to developing countries at the ICS-UNIDO, we have decided to undertake the development of a software package supporting technology foresight exercises, and also representing a valuable tool for increasing the chance that less developed countries undertake this resource consuming exercise, crucial for more effectively exploiting their potential. The main aims of any technology foresight exercise are (Ascher 1978, Martin 1996):

- to search for the direction of technological growth in certain countries and/or regions from a long-term sustainability viewpoint
- to identify the emerging generic technologies and the underpinning areas of strategic research likely to yield the greatest economic, environmental and social benefits
- to contribute to the development of scientific and technological policies that promote sustainable development
- to develop a strategic and coherent view of the challenges, threats and development opportunities associated with each technological sector, etc.

Prior to designing our e-collaboration tool for technology foresight, we have undertaken an extensive analysis of available forecasting methodologies, comparing their respective advantages and disadvantages, and frequency of application in exercises already undertaken and published. Based upon this extensive research we have also realized that technology foresight is a process, rather than a set of techniques, that involves consultation and interaction between the scientific community, industry and policymakers, and is not a “one-off”, but is iterative to take account of feedback and new developments. Therefore, our objectives are:

- To provide a platform for multiparadigm approach to technology foresight, to facilitate integration of various complementary methodologies (i.e. expert panels, Delphi, scenario, etc.). The combination of multiple paradigms supplies a firm foundation for addressing complex technology foresight problems more objectively.

- To take advantage of networked society and emerging information technologies providing a firm foundation for e-collaboration, and make a software tool to aid the technology foresight exercise

- To avoid the limitation of conventional methods. For instance, "paper and pencil" Delphis are usually limited by the "top-down/bottom-up" dichotomy, rather than allowing more complete parallel entry to any aspect of the problem. In our computerized environment, using the CyberDELPHI e-collaboration tool, individuals could be free to tackle any aspect of the problem according to personal preferences (Breiner et. al.1994).

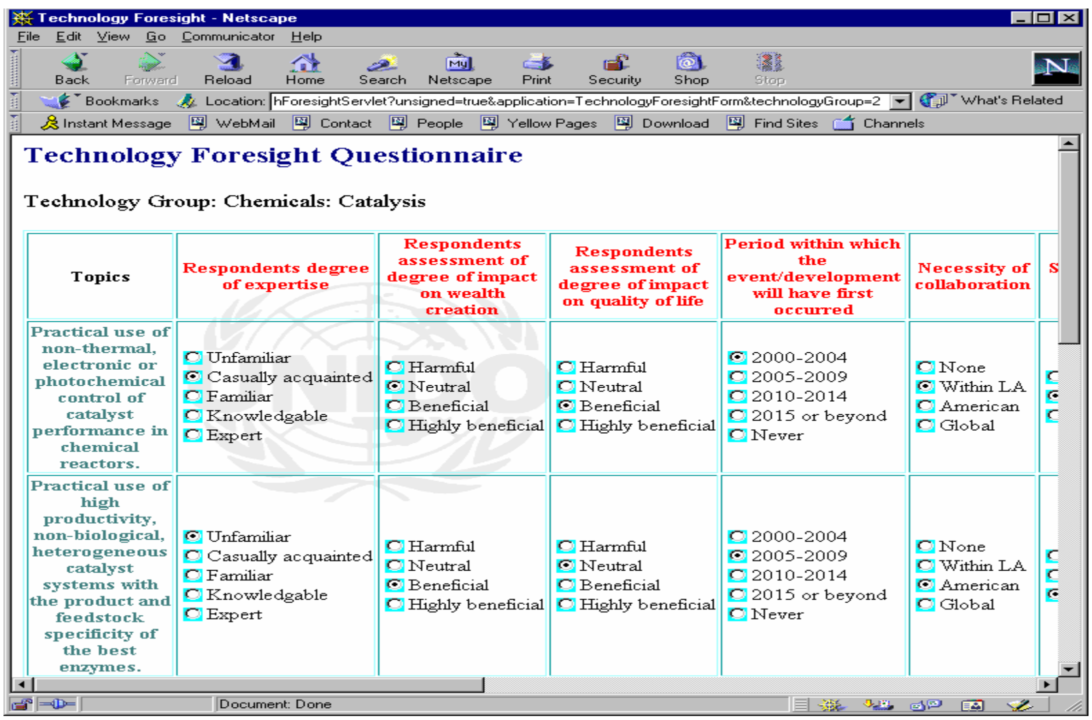

Figure 4. Screen shot from CyberDelphi questionnaire

Our multiparadigm software tool enables a holistic forecasting exercise, combining some good aspects of various foresight paradigms based on both panel activities (scenarios, recommendations, policy proposals, etc.) and a large scale “via-net” Delphi survey accomplished using our

CyberDelphi software. Following a brain-storming process (assisted by BATEV technology repository, and DEBATER intelligent decision support system for technology assessment) in which potential future opportunities for scientific and technological advances are identified, panels engage in an extensive and collaborative consultation process, using the CyberDELPI survey software.

The CyberDELPHI implementation is very useful in reducing the time required to evaluate the experts' responses and also helps to encourage the experts to give as much detail as possible. This reduces considerably the resources needed to implement a traditional Delphi study (e.g. time and money), and could also yield better results. Not only could the survey be done by computerized Internet accessible questionnaire, but a software program could serve as a surrogate mediator and facilitator, or provide a decision support to human mediator (Turoff 1989). Here, the technology of Intelligent Group Decision Support Systems is utilized, which further adds to the innovative nature of our Foresight exercise. The final results of the CyberDELPHI sequence are forecasts, measures of expert disagreement and summaries of critical argument related to each issue. The chief shortcoming of the Delphi method arose precisely out of the inevitability of reaching consensus views, since they were based on the opinions of a broad range of scientists. Earlier applications of Delphi were aimed at building a consensus but more recently it has been recognised that the reasons for dissent given by those who do not subscribe to the consensus are also worthy of note. Therefore, where the divergence is big, it could be wise not to try to reach consensus at any cost, but to exercise another very popular foresight technique, i.e. scenario development, in the areas of greatest disagreement, since scenarios could bring coherent pictures of alternative futures.

As the biggest divergence in experts' opinions are expected in the areas containing elements of surprise or novelty in possible future directions, good forecasting in this areas demands creativity, insight and intuition of experts, the elements that could best be captured using the scenario development foresight technique. Scenarios encompass qualitative perspectives and the potential for sharp discontinuities and sometimes paradoxical conditions and options, that other techniques exclude. Critical to a good scenario development is the exact identification of these critical uncertainties, representing possible discontinuities, or step changes, which could have a major impact on the sector. The scenario could also display the interactions among several trends and events in order to provide an holistic picture of the future and depict a situation in a way readily understandable by the non-specialist in the subject area. Therefore, the option has been left open for panels to include scenario development into multiparadigm technology foresight exercise supported by the software toolkit. The whole system has been described in more detailed elsewhere (Vranes, Opacic and Pizzio 2001)

CONCLUSIONS

Sustainable development requires innovative solutions for improving our welfare that are derived from practices and technologies that satisfy our functional needs, and work harmoniously with environment and across diverse groups of stakeholders. ICS-UNIDO mission in this regard is to advance the understanding, development and application of technologies, methods and tools in order to strengthen the sustainable decision making process at policy/regulatory level, related to the formulation and implementation of national or sub-national (area-wide) policies, strategies and action plans for sustainable industrial development. ICS-UNIDO seeks to address the problem by integrating and transferring to developing and transition economy countries the tools of decision domain to help them plan their sustainable development.

The aim of the proposed toolset for sustainable decision making is to help various stakeholders to choose the most suitable site for newly planned industrial estates, to conceive products and technologies which support a sustainable development and meet general technical, economic, social and environmental demands as well as their specific requirements and preferences. It enables technology selection decisions that do not have long-term negative impacts, and helps all sorts of stakeholders to assess both impacts and benefits prior to undertaking technology implementation actions. In the nearest future, the tool will also essentially comprise an analysis of return on capital investment and on potential long-term sources of funding mobilized by the implementing agents themselves in order to financially sustain the selected projects.

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