

AN INTERACTIVE INTERNET MODEL FOR SUPPORT OF DECISION MAKING CONCERNING LOW AND INTERMEDIATE NUCLEAR WASTE REPOSITORY SITES

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ABSTRACT

This paper presents an attempt to contribute towards finding the solution for one of the most persistent problems in the nuclear history of Slovenia; finding a site for repository for low and intermediate radioactive waste, which has been in the temporary store since the beginning of Krsko nuclear power plant operation in 1982. The first process of site selection ended with fierce opposition of local public in all five locations, which were identified by a comprehensive, scientifically sound procedure. The analyses following the failed procedure identified the technocratic process and exclusion of the public as the main reasons for the failure. The new procedure is therefore conceived as an open process, combining expert evaluation with public participation. One of the elements of this process is an interactive web-based model to support the choice of site for low and intermediate level radioactive waste repository.

The objectives include: informing the public about the problem and the decision making process, improving the transparency of the decision making process, establishing communication between the public and Agency for radioactive waste, enabling the incorporation of people's opinions and values in decision making process, achieving higher trust and commitment on the side of the public for the process and their support for the proposed sites.

The following paper deals with the first phase of the project, which includes theoretical conceptualization of the model and its implementation on the web. In the second phase the model will be put to use, the results will be collected, evaluated and used in the process of site selection.

The model simulates a part of the evaluation and decision making process. It is a version of a multi criteria expert suitability assessment based on evaluation of spatial parameters in geo-information systems, slightly simplified in order to meet the requirements of the lay users and the restrictions of the internet technology. The model operates in two modes, allowing for exploration of the decision context and testing and evaluating the alternatives. There is still a need for further development of the model especially in terms of enabling feed-back with the aim to support a dynamic and communicative decision-making phase of the process.

INTRODUCTION

Locating new land-uses, especially if these are obnoxious, is becoming increasingly difficult task. Traditional, expert dominated approaches, based on rational planning and decision making paradigm [1], are not adequate in the post-modern, pluralistic, 'risk' society. Although the calls

for a stronger role of experts in the decision – making can still be heard, it can be argued that the problems are caused by too much rather than too little involvement of experts. The conflict is usually not of the cognitive nature, (misunderstanding about the facts), which can be resolved by better explanation, but rather the result of underlying value conflict (Fig. 1), which can not be solved within the technocratic decision-making process.

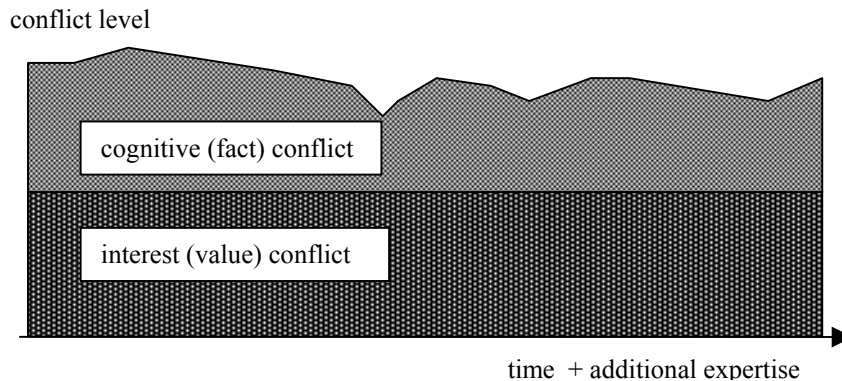


Fig. 1. Conflict level can not be reduced by applying additional expert knowledge because of the value conflict underlying fact conflict (from [2]).

Technocratic decision making processes can only work if there is an advanced agreement about the values as well as unconditional trust in selection criteria and method among all concerned parties (legitimacy of science and decision-makers). Another common delusion of the scientific community is that values can be researched and monitored similarly to other characteristics of environment. However, the values are the subject as well as the object of the planning process. Therefore they tend to change in the process of comparison and negotiating as well as influence this process.

The case of low and intermediate level radioactive waste (LILRW) repository in Slovenia is an instructive lesson to learn from as well as an opportunity to conceive approaches and methods to support the linkage between technocratic and political decision making to make best use of scientific knowledge as well as democratic potential. Main source of radioactive waste in Slovenia is Krsko nuclear power plant (NEK), along with smaller producers in science and medicine. The waste that is to be disposed of in the repository is now kept in two temporary stores, which are expected to be full by the end of 2010. Site selection process for the repository first started in 1989. The selection was supposed to be carried out in four steps. The results of every step were to be revised by a commission and presented to public. The screening process in the first step eliminated about 99% of Slovenian territory from further consideration based on criteria such as geology, national parks, settlements, drinking water reserves, flooding and seismic sensitive areas. The second step involved additional comparative criteria (mainly land use and water management criteria) to determine 36 potentially suitable areas. Third step included criteria of individual houses, ecological conditions; transport possibilities and hazards, climate and economy, and resulted in five most suitable locations. The issue of “social acceptance” was postponed until the fourth step, which was never accomplished. Strong resistance of the local communities stopped the whole process in 1993.

The first site selection procedure for radioactive waste disposal failed despite all the invested effort and commitment of the best expertise. The process was based on the assumption that the issues are far too scientific to be understood by lay public and that all the effort has to be made to reach the perfect decision and consensus among the 'initiated' experts in order to preserve the public trust. However, in the failed process the main barriers were not the technical or safety questions, but the problem of communication and achievement of the public acceptance about the decision. Unfit and unsuccessful past attempts contributed additional unease and distrust to the generally negative public attitude and reduced the credibility of experts as well as of those responsible for the project implementation.

The responsible national body (Agency RAO) later prepared a new site selection process, based on critical assessment of previous events. Special concern is devoted to the question of public relations and communication. It is acknowledged that the location for the LILRW repository is not a problem with a single 'right' answer, which only needs to be calculated. The decision about the location is a common, public affair^a, and should be reached in a cooperative manner. Since this aspect has been largely neglected in the past, several innovative approaches and methods had to be devised. The interactive suitability modeling, presented in this paper, is a part of this decision-support toolbox.

The main aims of the model are:

- to establish a two-way communication between the public and Agency for radioactive waste,
- to obtain additional knowledge about public opinions and attitudes related to LILRW issues,
- to inform the public about the LILRW repository issues and procedures,
- to improve transparency of the process, resulting in higher level of trust and legitimacy as well as support for proposed solutions.

Participative Technology

Communication technologies, such as the world wide web (www), combined with other information technology solutions (decision support systems, geo-information systems), are improving the opportunities for interactive approaches by enabling two-way communication and reaching wide audience. The technology that is intended to support public involvement in the decision making processes is called 'participative technology' and in the field of spatial planning it usually includes GIS and www. Use of internet can attenuate some of the draw-backs of more traditional participatory settings: first of all it enables direct and exhaustive information flows without mediators between the responsible agency and the public. There are also no restrictions for participation in terms of time or space. Every user is equal and the level of influence does not depend on his/her social role or style of communication. Also, adaptation of sophisticated tools such as GIS evaluation models, for the use of the general public, has an additional benefit of demystification of technology and scientific knowledge. Of course the technology by itself does not necessarily improve participation: computerization in general focused the research to acquisition and processing of the so-called objective, scientific/technical knowledge about physical reality, while informal, intuitive knowledge has been increasingly excluded from such formalized processing. Opportunities to participate are conditioned by accessibility of technology and some level of knowledge. There is also no control of the population that is included: the sample is usually biased towards younger, male, educated and better situated part of the society. There is and always will be a digital divide, excluding part of the population from e-society.

An extensive body of research in participative technologies as well as some applied models developed in the last decade. Cases include the specific area of RW repositories [3,4]. The researchers propose three main parts of the process that a comprehensive participation tool must be able to support: exploration of the decision-making context, testing and evaluating the alternatives and choice of the solution [5].

Conceptual Model

Besides the requirement to support all three main parts of the process, the model has to observe the following conditions:

- to fit into the framework of the location choice process,
- to meet the requirements and constraints of the GIS and web technology,
- to comply with the users' skills.

There are four main parts of the model: introductory pages, exploration mode, evaluation mode and feedback.

Exploration of the Decision-Making Context

This functionality is enabled by the introductory page as well as by the exploration operating mode of the model. The introductory page contains the information about the LILRW repository issues and the site-choice process in traditional (text and pictures) format. Since the model is meant as a complementary tool to other communication channels, we expect the users to be at least partly familiar with the problem. Therefore the information is kept short but informative. Links to the sites with in-depth information are also available. Additionally, the option to explore the context more in-depth is offered by the 'exploration' operating mode of the model. This mode enables the user to browse through digital map data-base and to verify the site characteristics of a chosen location. Despite certain simplifications the model tried to retain and represent major characteristics of the process and the key criteria influencing the choice. The following thematic maps are available:

- Natural characteristics (hydro-geological suitability)
- Transport distance
- Mineral resources
- Agricultural land
- Water resources
- Forests
- Natural values
- Cultural heritage
- Landscapes
- Natural recreation areas
- Settlements

If the user locates a specific site on the map by a mouse-click, the model returns the information about the site characteristics. Each characteristic is accompanied by a short explanation concerning the implication of the characteristic for the suitability for LILRW repository. Most of these maps also show restrictions for use that were proclaimed by a formal document. If the user

considers the site suitable for the repository he/she can 'vote' for the site by submitting the geo-location to the common database.

Testing and Evaluating the Alternatives

This functionality is offered by the second, 'evaluation' mode, which enables suitability evaluation of the whole Slovene area. The model is a slightly simplified version of a multicriteria GIS suitability evaluation, which is one part of the site-choice process, usually executed by a multidisciplinary group of experts. This evaluation method is based on the assumption that space is heterogeneous regarding suitability (e.g. safety, price, environmental impacts) for the LILRW repository^b. It applies a set of criteria and logical decision rules to obtain a suitability function, which describes each spatial unit (500 by 500 m cell) according to its suitability for LILRW repository. The elements of the evaluation process, which were used as a base for our model, were developed and proposed by several previous studies, concerning LILRW repository siting [e.g. 6, 7]. Despite certain simplifications the model retains the major characteristics of the process and the key criteria influencing choice. The decision criteria were grouped according to three main decision aspects:

- Safety considerations,
- Protection of natural resources,
- Protection of natural and cultural values/heritage.

The evaluation criteria were described by a set of indicators, describing spatial characteristics and represented by a set of thematic digital maps in raster format. The set includes only the indicators that make sense on the strategic (national) level, thus excluding infrastructure buffers, land ownership and similar. The indicators, which cannot be shown on the map, as well as those requiring complex modelling (impacts on regional and urban development) and intuitive, personal criteria (identity, tradition...) are excluded as well. The list of indicators is in Table I.

Table I. List of criteria used for the suitability evaluation.

group of criteria / criterion	categories
1. SAFETY CONCERNS	
1.1. Natural characteristics	Less suitable according to the hydrogeological evaluation study
1.2. Transport distance	Distance from Krško power plant >100 km, 100-30, < 30km
2. PROTECTION OF NATURAL RESOURCES	
2.1. Mineral resources	Existing mine or strategic potential
2.2. Agricultural land	Best agricultural land
2.3. Water resources	Stream (with 500m buffer) Drinking water recharge area (central area) Drinking water recharge area (buffer area)
3. PROTECTION OF NATURAL AND CULTURAL VALUES/HERITAGE	
3.1 Forests	Protective forest
3.2 Natural values	National park Regional and landscape park Forest reserve Natural monument (with 500m buffer) Ecologically important area
3.3 Cultural heritage	Cultural monument (with 500m buffer) Cultural heritage area
3.4 Landscapes	Landscape of national importance

3.5 Natural recreation areas	Forest with special purpose
3.6 Settlements	Settlement

The user can choose indicators from the set as well as adjust their weights and furthermore devise a personalised set of criteria by ascribing a suitability score for each indicator value. Suitability is assessed on a 4-class qualitative scale: suitable, conditionally suitable, less suitable, not suitable. By choosing the last option, the user excludes areas with concerned spatial characteristic (i.e. aquifer recharge areas) from further consideration. The model then ascribes corresponding numerical value (0 for not suitable, 0.50 for less suitable, 0.75 for conditionally suitable, and 1 for suitable) to each cell of the grid and calculates the suitability function. Total suitability is calculated as a multi-product of all variables in each cell of a grid. The function seems appropriate, since all the used criteria are of restrictive type, i.e. they potentially reduce the acceptable level of suitability. It is also understandable and transparent. The final suitability values are normalized and divided in the same 4 suitability classes. The result is shown as a suitability map, where the national territory is divided in areas according to suitability classes (not suitable, low, medium and suitable). If the user is satisfied with the result the model parameters can be submitted in the common knowledge –base.

Decision-Making

The decision making phase requires communication between the stakeholders, exchange of attitudes and ideas, as well as feed back on conflicts and potential compromises, supported by argumentation. This is essentially a dynamic and often also an intuitive process and is therefore least amenable for technology. However it can be supported by information tools, mainly by providing communication platforms, interactivity, fast processing of new data and quick feed-backs. In our model, this phase is represented by the feedback option, where the users can submit their results. These parameters and evaluations will be collected by the Agency and used as a guideline for further decision making. The result will be a collection of individual, subjective opinions. Clearly, the model cannot be used as a simple voting machine, but it can provide valuable information for calibration and verification of the expert models, thus showing, which environmental values people are especially willing to protect. We also expect the results to show how much consensus or conflict there is between different value systems. These (potentially) differing value maps could be used as a common language between lay people and experts and the basis for a constructive and creative problem solving process. The use of the model is anonymous (i.e. no registration is required). However, when the user wants to submit the results, then he has to fill in some of the basic demographic data, such as age, sex and education, as well as region of residence, which may later be analyzed to search for patterns in the evaluation parameters. Since the project is still in a testing phase, the exact technology of data processing hasn't yet been resolved.

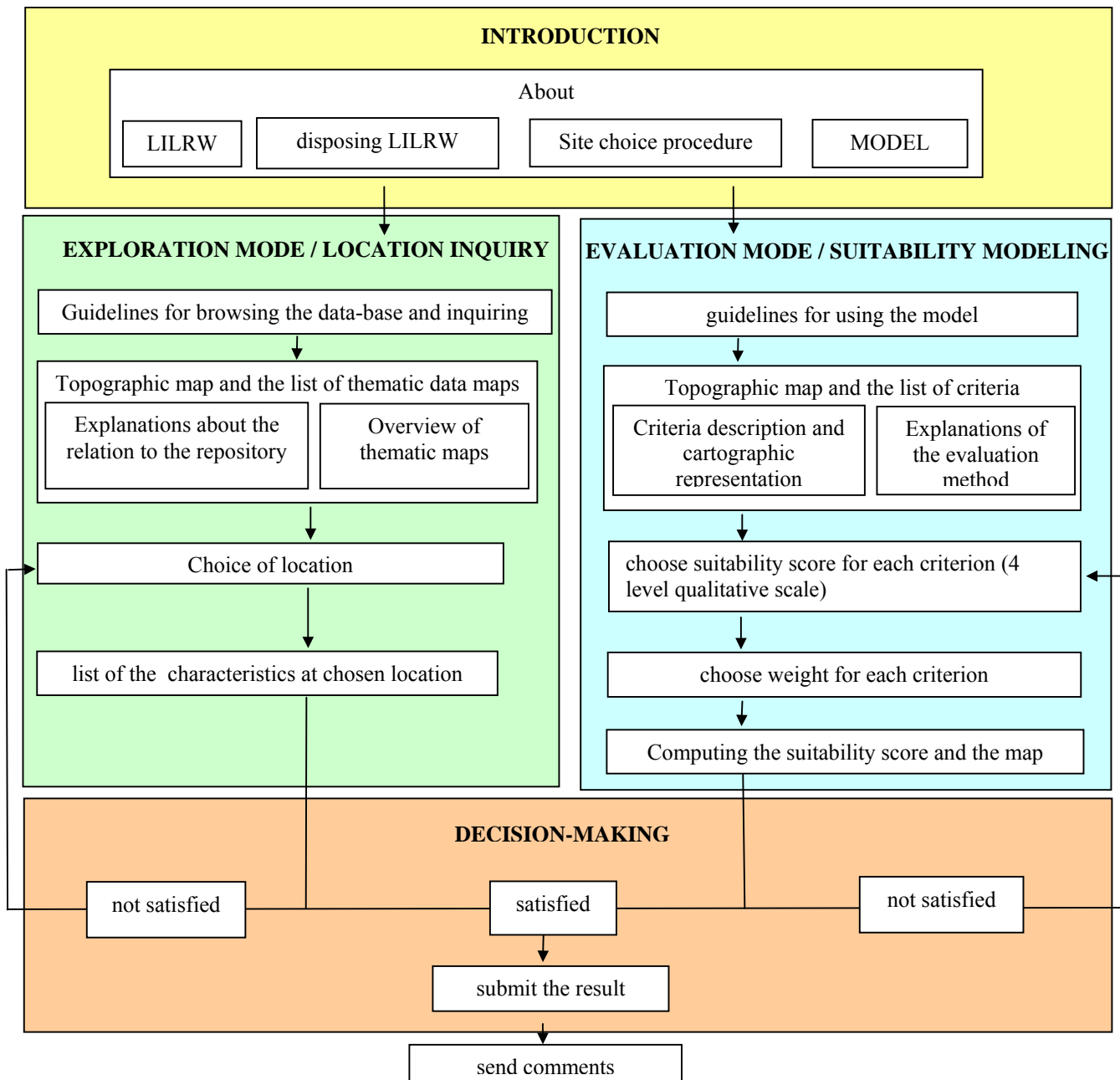


Fig. 2. The scheme of the model.

Technical Description of the Model and Used Software

A lot of professional GIS (Geographic Information System) software products were available on the market at the time of the project. GIS software products mostly distinguish themselves by different types of functions they have and consequently their price. Our aim was to find a product at acceptable price that could easily be used on the internet. Our data maps were made using professional GIS software. The price of these products is usually too high for the limited project budget, so we searched for software among so called OpenSource programs. OpenSource programs can be developed, used and distributed for free, as long as the user agrees with the licence. The difference between OpenSource and professional products are in the functionality of the programs. OpenSource programs many times lack some functions, or have poorly designed functions. On the other hand their free accessibility makes them worth considering when working on a tight budget. We decided to use MapServer, which is an OpenSource development environment for building spatially enabled Internet applications. The software is maintained by a growing number of developers (nearing 20) from around the world and is supported by a diverse group of organisations funding enhancements. MapServer is not a full-featured GIS system, nor does it aspire to be one. It does, however, provide enough core functionality to support a wide variety of web applications. Also, MapServer will run where most commercial systems won't or can't. MapServer system includes MapScript, which allows the use of popular scripting languages and development of applications that integrate disparate data. If the data has a spatial component, which can be accessed via one's favorite scripting environment then it can be mapped. For example, by using a database module it is possible to integrate data from just about any database vendor with traditional GIS data in a single map graphics or web page.

Exploration of the Decision-Making Context

In the first part of the process the user can pinpoint the possible repository site's location and receive data about the conditions on that location. The user can also select or deselect the layers, which represent various relevant data. With this function the user can for example visualize the possible protected areas.

In this mode we only used MapServer. The user can select various layers from all the relevant, collected data and has possibilities to zoom in, zoom out, zoom all and re-center the map, select all the layers at once, deselect all the layers at once and to pinpoint the location on the map. The user accesses explanatory data by clicking on the name of the layer which he or she wants to see. The supporting programs were written in JavaScript language and HTML dynamics and we also used ROSA Applet. Rosa2000 is a Java applet that allows one to improve server-side web applications by adding some simple features on the client-side. It was originally designed with WebMapping applications in mind, but is generic enough to be used in any type of application. The ROSA Applet is being used for additional functionality with map browsing commands.

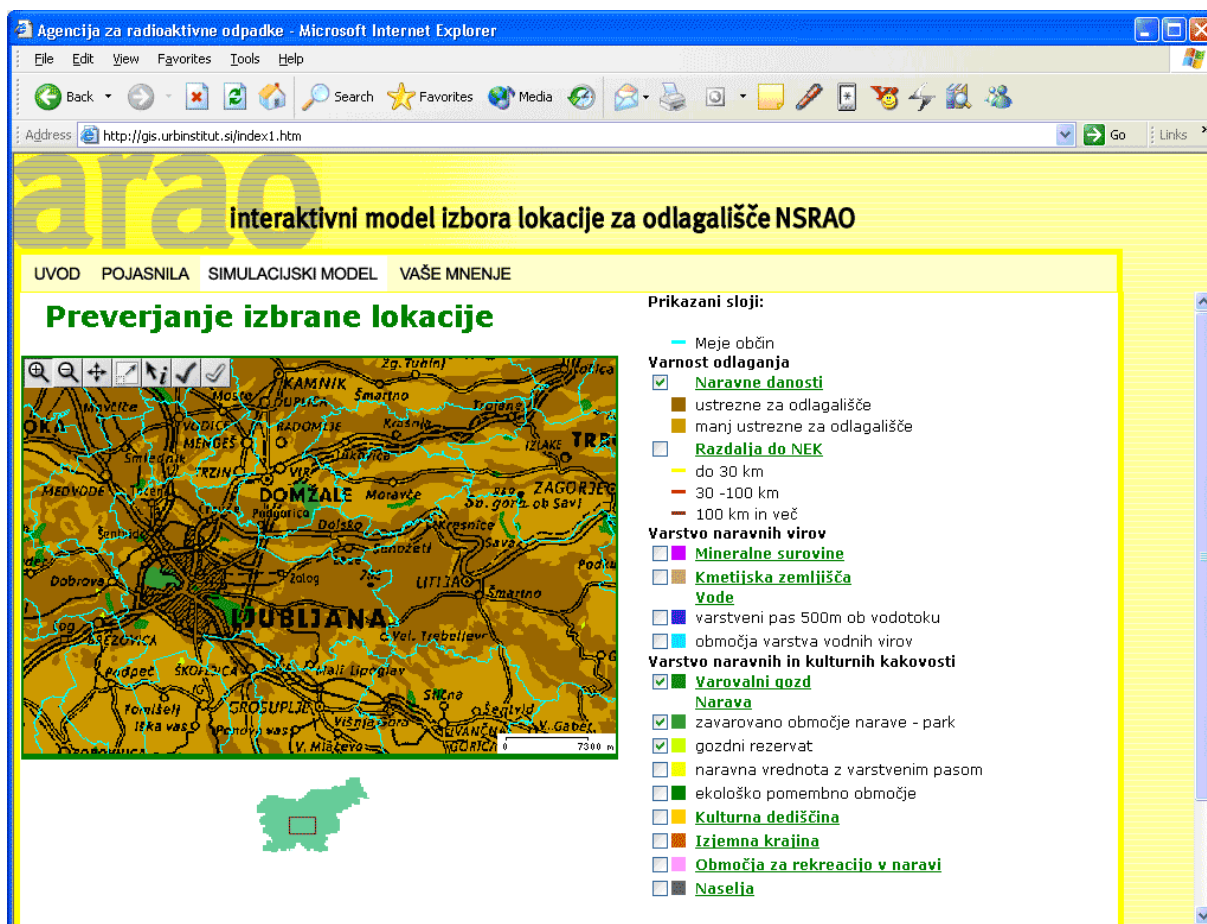


Fig. 3. Picture of a web page for pinpointing the location of the possible repository site with data layers on the right and visualization of selected layers on the left.

Testing and Evaluating the Alternatives

In the second part of the process the user can design the evaluation function by choosing the weight of each indicator and adjusting the suitability scores for the values. The outcome is shown on the map. Thus the first screen seen by users is the screen with the empty form and map. The user can select desired indicators simply by clicking one of the four radio buttons next to each layer. The radio buttons have four choices (not suitable, low, medium and suitable). The far right input cell is used for weight adjustment. Every layer has detailed explanatory information, which can be accessed by clicking on the name of the layer. When the user sets all the parameters, calculation of the model can begin by clicking the 'calculate' button. The program needs about 2 to 3 minutes to calculate the map. Afterwards the map is returned from the web server and displayed on the user's screen. The user can decide to repeat calculation of the map with new parameters or to submit the results.

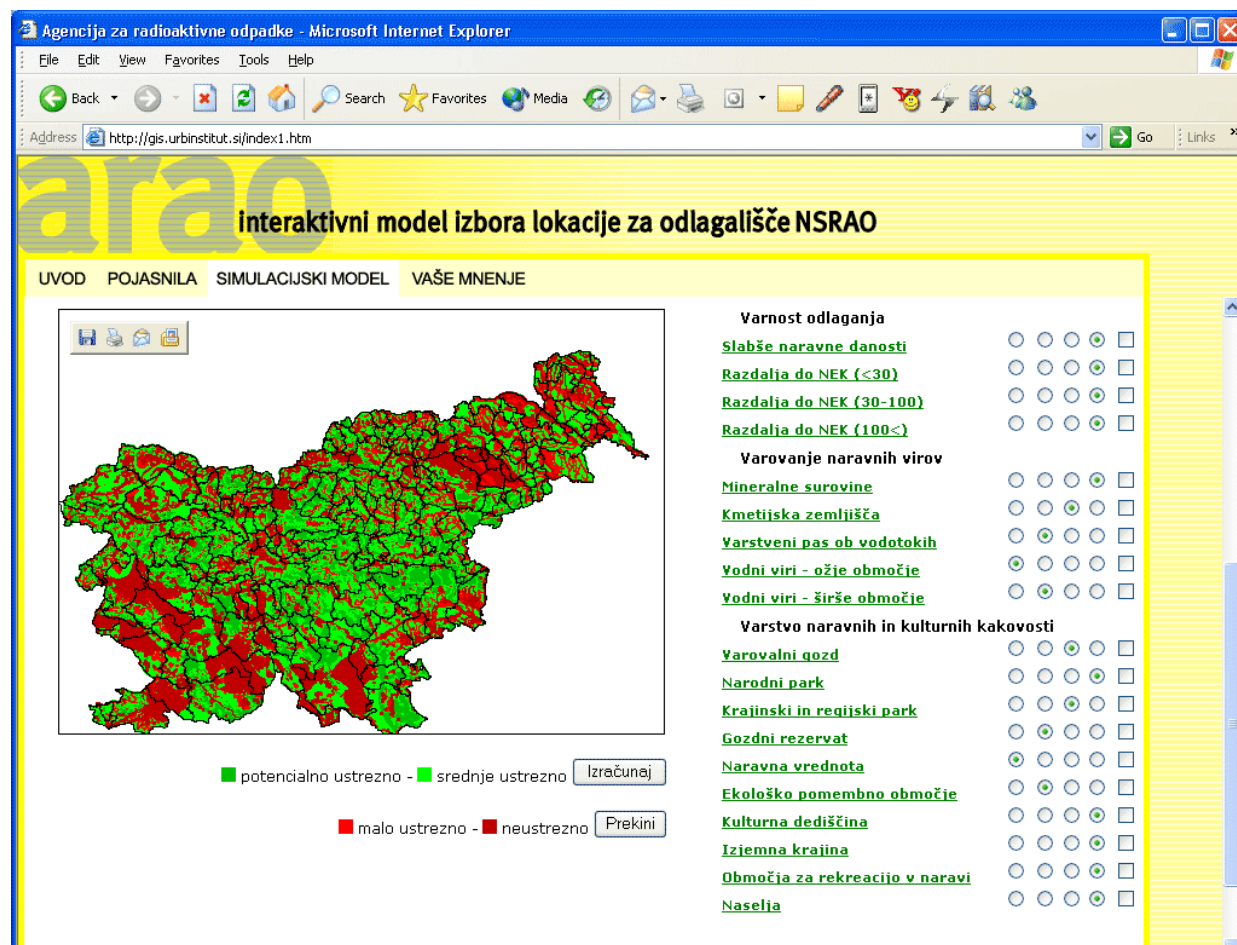


Fig. 4. The screen capture shows the map, which has been calculated from the selected criteria (on the right). The suitability is shown in colour scale from dark green (most suitable locations) to dark red (not suitable) for the LILRW repository.

In the second part, the supporting programs were also written in JavaScript language and dynamic HTML. We also used ROSA Applet. Because of the calculations we also used ASP (Active Server Pages). This is the scripting environment for the used web server. ASP enables combining HTML scripts and reusable ActiveX server components to create dynamic web pages.

Some pre-processing of the data was needed for the calculations. The map of Slovenia was divided into a grid of cells of 500 by 500 meters. Data from the layers was then transformed to the grid format and stored in a Microsoft Access database system. The ASP script reads the data entered by the user, and calculates the result for each cell in the Access database. The new values for the cells are then reclassified into 4 suitability scores and written directly into a point shape. The shape is then sent to a user's computer as a new map, which appears on the user's web page.

Decision-Making

For support of the decision making part of the process the web pages allow the user to submit the preferred site's location from the first (exploratory) operation mode and the parameters of the model from the second operating mode (evaluation). Users can also send suggestions and questions regarding the modelling and/or site selection process. All the submitted locations and model parameters can be stored for further analysis in a relational database for later processing by statistical software.

CONCLUSIONS

Failed attempt to locate radioactive waste disposal in Slovenia has roused the need for the changed approaches in location choice process. The closed, expert-dominated approach proved inadequate; therefore the new one was started that is more open to public. The presented model offers the responsible agency a tool to obtain information about the value systems related to the possibility to dispose RW in Slovenian territory. The use of the tool itself should improve the transparency of the process and therefore also legitimacy and acceptability of proposed solutions.

Several trade-offs had to be made while conceiving and implementing the model between accuracy and comprehensiveness of the model and its suitability for the users and technology. Some innovative solutions had to be found to make an originally rather complex GIS tool operate in a simplified version, which nonetheless does not distort the process and/or the results. The first two parts of participation support: exploration of the decision-making context and testing and evaluating the alternatives, have been designated and implemented on the web. However we did not - at this stage - adequately resolve the support of the third (decision-making) stage. Further effort is still needed mainly in the result processing and feed-back. We expect that the processing of the results will bring new insights as well as achieve the communication purpose of the project.

As any tool, computer software needs to be put to use to be properly evaluated and improved. This model is now at a stage of verification in the expert community and has not yet been put to public use. We hope that the tool will soon reach the audience it was intended to address. The fear that its use would heat-up discussion and revive opposition, because of possible misinterpretations of the model results, should not stop the responsible authorities from starting communication.

FOOTNOTES

^a Public opinion polls reveal that public trust in issues concerning the disposing of radioactive waste is prevalingly devoted to »environmental groups«. According to the polls, public also thinks that the ultimate solution concerning waste disposal should not be left to the experts, but should be taken by all citizens in a referendum (Public opinion poll, Agency RAO <http://www.sigov.si/arao/index.htm>).

^b The study "Location choice for LIRW repository and its relation to the spatial planning process" [8] considered alternative assumptions according to the relative importance of spatial (physical) characteristics for location choice: (1) The repository can be anywhere, (2) The repository can (in principle) be anywhere, but there are better and worse locations; (3) The

repository cannot be anywhere, all locations are unacceptable; (4) The repository cannot be anywhere, all locations are unacceptable, locations can be ranked according to their suitability

REFERENCES

1. J. T. Lyle, "Design for human ecosystems. New York", Van Nostrand Reinhold (1985).
2. N. J. Obermeyer, Spatial conflict in the information age.
<http://www.geo.wvu.edu/i19/papers/monmonier.html> (1998).
3. S. Carver, M. Blake, I. Turton, O. Duke-Williams, »Where to dispose of Britain's nuclear waste: Open spatial decision-making on the Internet«.
<http://www.geog.leeds.ac.uk/mce/mce-home.htm> (1996).
4. S. Carver, "Open spatial decision making: Evaluating the potential of the WWW" Innovations in GIS 4. Z. Kemp (ed.). London, Taylor & Francis: 267-278 (1997).
5. S. Carver, A. Evans, R. Kingston, I. Turton, [GIS on the WWW: improving public participation in environmental decision making](#), Paper presented at the European Association for the Study of Science and Technology Conference, Lisbon, Portugal.
<http://www.geog.leeds.ac.uk/papers/98-4/>(1998).
6. J. Marušič, M. Golobič, "Presentation of multi-criteria approach – combination of models". An assessment of different methods for LILRW location choice (in Slovenian) Workshop, Brdo pri Kranju. Ljubljana: Agencija RAO, pp. 23-41. (1998)
7. M. Golobic, Simulation model of regional and urban development impacts: an approach for transparent and communicative LILRW disposal siting process. In: The 8th International Conference on Radioactive Waste Management and Environmental Remediation: proceedings: ICEM'01. Bruges: ASME, (2001).
8. V. Stefanovic, M. Golobic, J. Koblar, M. Vodnik, "Location choice for LIRW repository and its relation to the spatial planning process" (in Slovenian), Urban planning institute of the Republic of Slovenia, Ljubljana (1998).