Determination of environmental criteria for estimation of land development using GIS

Uporaba GIS-a za določitev naravnih kriterijev možnosti okoljskega razvoja

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Abstract: It is well known that GIS techniques are very useful in the environmental control and planning operation. According to actual environmental low in Slovenia all main human impacts on the environment have to be revised and independently checked. The processes of revising and checking are manly made by hand review and subjected to the subjective evaluation. In many cases the revisers are subjected to criticism that their decisions were not strict and correct enough. For these reasons it is necessary to use independent tools. GIS techniques are one of the possibilities, which can make the decisions and evaluations of the verified human impact on the environment much faster and not as subjectively evaluated by revisers. For using the GIS techniques the data needs to be stored in GIS formats. Even though this does not present a huge problem any more, the data organization and data description can be. Especially, if taken into consideration that some GIS analysis can be performed only if the data stored in GIS have the inputs we need in further analysis process. We will show that the data, nowadays available, can be analysed using low cost GIS software and that environmental impacts can be verified and evaluated using elementary GIS analysis techniques. We will also show that in order to be able to use GIS techniques in the revising phase, the project designers have to take into account that their work will be analysed using GIS techniques; if this is not the case, than the GIS techniques can not be used straight away and some additional work has to be done on the data description and especially on the topology. For the case study site the "third development axis" was selected. The third development axis is a future highway which will stretch from the northern border of the Republic of Austria via Koroška and Savinjska region to the motorway A1 Koper-Šentilj.

Izvleček: Zelo dobro je poznano, da so GIS orodja zelo uporabna pri planiranju in nadzoru stanja v okolju. V skladu z okoljsko zakonodajo morajo biti vsi

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večji posegi v prostor pregledani in ocenjeni. Večinoma so postopki revizije in pregledovanja izvedeni ročno in zato podvrženi subjektivni oceni. V veliko primerov so revidenti podvrženi kritikam, češ da niso bili dovolj strokovni in natančni. Zaradi tega je nujna uporaba orodij odločanja, ki so čim bolj neodvisna. Med njimi so gotovo GIS orodja, ki omogočajo relativno neodvisno in hitro izdelavo ocen vplivov posegov v prostor. Za uporabo GIS orodij pa morajo biti podatki shranjeni v GIS zapisih. Kljub temu, da danes to ni več problem, pa lahko problem predstavljata organiziranost in opis podatkov. Posebej to velja, če vemo, da je za določene GIS analize potrebna predhodna organiziranost podatkov. Pokazali bomo, da podatki, ki so nam ta čas na voljo, že zadostujejo za izvedbo osnovnih analiz s poceni GIS orodji z uporabo osnovnih GIS tehnik. Prav tako bomo pokazali kako pomembno je, da projektanti že v fazi projektiranja pripravijo dokumentacijo na tak način, da je ta pripravljena za uporabo znotraj GIS orodij; če temu ni tako, direktna uporaba GIS-a ni možna in zahteva dodatno obdelavo opisa podatkov zlasti pa topologije prikazov. Za primer uporabe je bila izbrana tretja razvojna os. Ta bodoča avtocestna povezava bo povezovala Avstrijo preko Koroške in Savinjsko dolino z avtocestno povezavo A1 Koper-Šentilj.

Key words: GIS, data models, third development axis, environmental report, limiting factors, GIS analysis

Ključne besede: GIS, podatkovni modeli, tretja razvojna os, okoljsko poročilo, omejitveni faktorji, GIS analiza

Introduction

The aim of this paper is to show the possibilities GIS offers when making an environmental report. The first part of the paper comprises some general information about GIS, followed by a general overview of data that can be used in GIS environment. We also presented data models, which can be used to process data. The second part of the paper demonstrated the use of a GIS tool in form of an aid in making an environmental report. We also listed the methodology used and analysed the limiting factors that we took into consideration when calculating the optimal result of an environment assessment.

Geoinformation system (GIS)

GIS is an information system, designed to work with data referenced by geographic coordinates. In other words, GIS is a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working [analysis] with the data. We could also refer to it as a system for capturing, storing, checking, integrating, manipulating, analyzing and displaying spatially referenced data. It is a system of hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modelling and display of spatially-referenced data for solving complex planning and manage-

ment problems. Data is a representation of a fact in a formalised manner suitable for communication, interpretation, or processing. Data are joined in data tables; the system that defines the connection between data and determines the manner of processing is called a database. It is a collection of data on a certain subject, organised in a way that a user can add, change and review data. Databases are used to store data. They are easy to review and data is therefore easy to manage. The advantages lie in a large quantity of data, quick and precise transfer of data through computer programmes and quick data processing. GIS depends on real world data and the decisions, based on which a human intervenes into the real world, depend on data from GIS. GIS database contains spacial (graphic) and descriptive (attributive) data. Spacial data, which determine the location, form and relations between space elements, are stored in the spacial database and descriptive data in the relational database. Spacial database differ from other types of data by being georeferentiated (placed on the Earth's surface). The reference may be implicit or explicit. An implicit reference refers to object with a known geographic location, while explicit reference refers to geographic co-ordinates. Both types of spacial reference determine the position of data and events on the Earth's surface and enable the study any analysis of the occurrences, described by data (Ribičič, 2002).

Geoinformation data types

Geoinformation data types depend on the structure of reality data and reflect the for-mal equivalent of the conceptual model, built to understand geographically dependent events. It is used to formalize the discretisation of space into parts, suitable for an analysis, to re-establish the correlation between individual parts and establish a clear identification of events within them. The data can be acquired in different ways; it is important to know the method of acquisition and the resolution upon entry. Before deciding on a certain type of data we need to know how data functions in space. The data on surface geology, geology of rivers, winning areas, wells and almost all data on anthropogenic factors (residences, roads, agricultural land etc.) can be presented in space as points (wells, wining areas, run-offs etc.), lines (rivers – the boundaries of feeding or draining of water from aquifer, traffic routes etc.) or concluded polygons (agricultural land, forests, different areas for calculation of evapotranspiration etc.). Other data are continuous and smooth – they do not have large leaps and therefore it is not possible or reasonable to limit them to one of the before mentioned forms. Such data are data on the distribution of substances in the terrain, height above sea-level, temperature etc. It is much more appropriate to present these types of data in a continuous form by giving the values in points, where the measures have been taken, and do an interpolation with a mathematic function in the rest of the space. According to the occurrence of data in the real environment and the possibilities of presenting them in the virtual environment the data is divided into two groups (Burrough and McDonnell, 1998):
• vector data and
• raster data

Vector data

Geographic data structure, which uses points, lines or polygons to describe geolocated events in space, is known as vector data structure. To present the data with vector units they have to have a well-known geographic location, they have to be independent and clearly defined. The deviation between data within the vector units may be zero or very small, considered from the viewpoint of the problem that is being analyzed. The position in space is defined by geographic location and suitable quality and/or qualitative descriptions. A well can be presented as a point with (x,y) coordinates with additional corresponding descriptions (name, angle, depth etc.). A river segment is presented as a line with all other required description (the quantity of feeding or draining of water from aquifer per unit of length). Geological layer on the surface is presented by a polygon and descriptions of name, age, lithology etc.The simple elements of vector data base enable more demanding ones. For example, subsidiary streams of rivers form a river grid across defined points, called hubs. The hubs also define the relations between contiguous vector elements.

Raster data

If the data is presented in a regular square grid, the type of data is a raster data type. The main difference between raster and vector data is that the units of raster are grid cells. Cells differ from each other according to different indicators, contrary to different vector data, which differ according to data base indicators. As the data available rarely matches the number of cells in a raster grid, the values of the unknown cells need to be determined by an interpolation.

The choice between vector and raster data

The choice of the type of spacial data depends on the following factors:

- quantity of data (raster data take up more space in the computer);
- topology and spacial analysis (the search for data in the raster data base is easier and more efficient, spacial and topological analysis are simpler);
- characteristics of the problem – generalisation of data differs according to the user (clarity, accuracy, detail). Vector data are easier to generalize as raster data;
- analytic possibilities and needs;
- accuracy of the data source.

Vector format is usually based on maps. Reliability depends on their origin and accuracy. Raster data are usually gained by converting vector data or from images, captured by satellite and aircraft. These images are captured in different seasons and provide additional information on the chronological sequence of an event. The results of overlay in raster data are questionable, as the interpolations between point data bring a certain level of an error (RIBIČIČ, 2002).

Database

Data are the description of the real world and present a fact in an agreed way, which is suitable for communication, interpretation and further processing. Data are joined in data tables. The system that defines the correlation between them and determines the way the data are worked with is called a database (WORBOYS, 1995; HERRING, 1992; ARCTUR and WOODSFORD, 1996).

Table 1. Advantages and disadvantages of vector data
Tabela 1. Prednosti in slabosti vektorskih podatkov

Advantages (+)	Disadvantages (-)
• good data presentation, • compact data structure, • explicit presentation of topology, • the transformation of coordinates is simple and inexpensive, • the sharpness of the graphic presentation is not dependent from the scale of the presentation, • simple generalization.	• complexity of data model, • the combination of multiple polygon grids and lines is time consuming and demanding, • the outline of the graphic is time consuming, • special analysis within the polygons is very demanding, • modelling according to the vector data is more demanding than according to the raster data.

Table 2. Advantages and disadvantages of raster data
Tabela 2. Prednosti in slabosti rasterskih podatkov

Advantages (+)	Disadvantages (-)
• simple structure, • simple processing, • simple mathematic modelling, • simple filtration, • inexpensive technology.	• large quantity of data, • large cells mean worse resolution, • the sharpness of the graphic presentation is dependent from the scale of the presentation, • the transformation of coordinates is slow and information may be lost in the process.

There are more definitions of database:

- it is a model of the environment, which is presenting the basis for decision-making and performing actions;
- it is number of interrelated data, saved in a computer system; the access is centralised and enabled with the database management system (DBMS);
- mechanised, for more users, formally defined and centrally monitored collection of data.

Database management

Data are the foundation of a whole organisation; therefore their management, as with other organisation means needs to be sensible:
- provision of data availability;
- supervision of data use.

Table 3. Differences between raster and vector data structure
Tabela 3. Razlika med rastersko in vektorsko podatkovno strukturo

Raster data structure	Vector data structure
Simple data structure	More complex data structure
Efficient overlay of individual layers	Overlay of individual layers is more difficult
Space is presented with matrix, every cell represents a value for a square of analysed area and has only one attribute value	Locations, lengths, distances and areas of object are clearly shown with consideration of geometric laws
Simpler and more effective spacial analysis, search for data is easier	Spacial data and search for data are not as simple as with raster structures
Accuracy of the description is defined by the size of the cell and demands a lot of memory	The accuracy depends on the measure or source of the map, where the vector data is gained from
Graphic presentation is not as good; we get »toothed« lines, which can be avoided with a large number of cells, but the file is larger	More suitable for a graphic presentation (map outlines)

The data part of a data base consists of:
• physical database (PDB), it comprises the value of data elements;
• meta database (MDB), it comprises the description of physical data, storage, meaning, their accessibility.

Meta database has a three-level composition:
1. Outer scheme: users point of view, the model of an individual user's surroundings;
2. Conceptual scheme: global model of the environment;
3. Inner scheme: the collection of logical records.

Data model types
Large quantity of data which can be used when analysing the position in space need to be stored in databases. The most fundamental element in a database is the record of the most fundamental information about the position of an individual entity. Entity is something that exists in the real world, whether an object, subject or a notion.

Their interaction, purpose and practicability dictate the type of the data model. The basic demand of every database system is that it enables a quick access to data and interoperability. The computer program intended for data management is called DBMS (**D**atabase **M**anagement **S**ystem).

Data model: consecutive sequence files
The most basic data system is a consecutive record of data, which are not arranged by any rules. The advantage of this system is the adding of data, which is very simple. Everyone who has ever worked with data saved in this way knows that searching through such a structure can be very demanding. Also, in such a structure data is not gathered according to the content of information.

Data model: organising sequence files
When describing consecutive sequence files, we can compare them to a phone book. The data is organised in a logical way and the system needs more time to record the data. Its advantage is the algorithm, based on the manner of searching – it starts in the middle of all data in the database, verifies, whether the data searched for according to its bit value is in front or behind its position and moves to a new centre of a newly chosen data group. Such manner of searching is approximately four hundred times faster than searching in the previous data model.

Data model: indexed files
Data models explained above do not solve the problem of recording data, which has additional information, as for example data on a well. The name of the well is the basic data, with additional data on depth, x,y,z

angles etc. Searching in such a data model is the quickest if we set up an index. We could say that index is as a page in a book, which comprises certain information. If indexation and searching is based on the main data, the file is a directly indexed file, and if indexation is based on a field, added for this purpose, we speak of an inversely indexed file.

Data model: hierarchic data base
When speaking of a relation model type one against many, the data system is of hierarchic type. These are used mainly in environmental sciences, as they can be used to classify the soil, vegetal and animal taxonometry etc. Such models can be used, if the data fills two criteria:
- a good correlation between the main and other attributes;
- it is possible to set a number of discriminatory criteria, which define the hierarchic structure.

The main advantage is a simple access to the data through the structure defining criteria. The structure is simple and easy to comprehend (the data can be easily filled in), and the data can be added easily. Even though the advantage is access to data, which is simple, the problem arises when searching for bound data, where the structure is set up in advance. Such data structure can be used only if the filters are set in advance. The main weakness of this system is that it is not flexible and does not enable the search for bound data, if that was not already foreseen in the structure.

Data model: Net database (vertical and horizontal interoperability)
It is a version of the hierarchic model

above. The data structure is more open and enables connections within same and/or different levels. The search for bound data is simpler, however the structure, set up beforehand, demands that filters are set up in advance. The main advantage is the option of setting filters between same and different levels, while the weakness is the form of the filters, which is determined in advance and according to the data model. The relation between data is based on indicators, which are a special part in the database (after every correction of the base the indicators need to be "refreshed", as the quantity of indicators presents the majority of the quantity of data) and can take up a lot of memory in very extensive databases.

Data model: relational database

Relational database is the simplest data structure, where there is no hierarchy between data groups. The data is saved as a record, representing a number of fields. They join together in two-dimensional tables called relations. Indicators from the net data models and keys from the hierarchic data models are replaced by redundancy data in form of single key identificators. Relational data bases have a great advantage in comparison with other data models - they are very flexible and enable us to use any filters, based on Boole's logic and mathematical operators. As the relational databases function on the basis of redundancy, it is very important to allow only the most necessary redundancies, needed for proper functioning of the database. Too many redundancies reflect in slow performance and accumulation of unnecessary data within the base, which results in a greater use of memory.

Data model: object-orientated database

This is the latest development in the field of data structures. It was made on the basis of a wish to join all the advantages and reduce the weaknesses of above mentioned data models. The phrase "object-orientated" derives from the Simul (DAHL and NYGAARD, 1966) and Smalltalk[1] (GOLDBERG and ROBSON, 1983) programme language, which were the first to work with objects in the programming field. The advantage is that everyone, who can programme, can make an object with specific characteristics. An object can be made of already pre-programmed objects and the new object "inherits" the characteristics of object(s), from which it is made of. In the relational data structure every entity is determined by the recorded data and relations, determining the relation between individual data. In the object-orientated bases the data with certain common characteristics are joined in an object and objects are joined in classes. The relations between different objects and classes are set with explicit connections. The characteristics of objects are determined by the state of the objects and functions, determining their form. This way the data are joined in an object, which has a determined form within the database. It does not change, even if the values that determine the characteristics of the object change - as an object, whose structure and usage changes with time, but its label remains the same. In the relational data model the data tables are connected through certain data in the tables. In object-orientated data structures the tables become objects with relations

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1 Smalltalk is a programme language, the predecessor of C++ language, which is the foundation for most of today's software.

as "is as follows". Once the data are integrated into objects, the performance of preprogrammed functions is the only way to change the data or choose it according to a certain condition. A choice according to a condition depends on operations, used for definition of an object. The response of an object to a "demand" depends on the state of the object, which means, the responses to a same "demand" will be different. That is called polymorphism. The data in object-orientated data structures have to be clearly structured. It is possible to use them especially where the data is gathered according to different hierarchy principles. Setting up an object is a demanding operation, which takes up a lot of time, but, in the end, offers optimal options of search according to an object. Despite this the relational data structures have the advantage when searching according to value attributes.

As already mentioned, we can choose between four different data models:
• hierarchic data model;
• net data model;
• relational data model;
• object-orientated data model.

Hierarchic data model enables a simple division of large quantities of data into tables, which are easy to manage, but do not enable associational relations between different levels due to the vertical hierarchy. That influences the quantity of multiplied data, as it can not be taken from other tables. The net model reduces the quantity of multiplied data and has quick access times due to pre-programmed searches. Object-orientated data models enable a great flexibility and optional relation dependency, which can change according to the demands of the user, but demand a great programming knowledge and a lot of programming in order to set them up. Relational models are also very flexible and can adapt to different data reviews, but are often too occupied by repeating data, the basis of relation, which reflects in longer search times in the data base (VIŽINTIN, 1999).

Database management system (DBMS)
DBMS stands for a computer programme, intended for organisation and management of data. The basic aims of DMBS are: a quick and easy access to data, stored in the base, preservation of the integrity of the base, protection of data from deletion and abuse, and a simple way of adding and removing data. It can be build on the basis of data models, introduced above, or as a combination of the models. For the DBMS to be successful, Frank (FRANK, 1988) introduced the following demands:

1. It enables saving and entering of data and the choice of data according to one or more attributives or relations.
2. It enables a standardised access to data, which separates the data, used in different computer programmes.
3. It enables an interface between the user programmes and the data base on logical data descriptions, without any necessary knowledge of saving data in a physical way.
4. It enables user programmes to be independent from saving data in a physical way.
5. It enables access to data to more users.
6. It disables unauthorised access to the base.
7. It disables illogical entering of data into the database and has a control and warning system built in for such purposes.

The majority of DBMS programmes enable access to data by a high-level programme language, as for example SQL (**S**tructured **Q**uery **L**anguage), which is mostly used in the relational databases with a large quantity of data. A good DBMS programme enables saving of data to a physical medium in such way that they take up the least possible amount of space and have very short access times (Vižintin, 1999).

For analysis of practicability of GIS tools we anticipated a GIS system which enables working with relational data bases. At present there are numerous GIS programs on the market which enable the analysis needed for making of environmental reports. A particularly useful tool seems to be Manifold, which operates on the basis of operational system Windows XP and is highly compatible with Microsoft products. When choosing a program, it does not really matter who software belongs to, the most important factor is its ability to perform the tasks needed. We found that Manifold combines the GIS environment with relational bases into a robust integrity and enables performance of basic topological operations needed for evaluation of an individual area for a relatively low price. We used Manifold to test the methodology on the proposed alignments of the future transport infrastructure. Because the whole area would be too extensive, we concentrated on the part of the alignment that is going to link Koroška to the central Slovenia.

CASE STUDY

For case study we selected to make the environmental report for the third development axis and made an environmental impact assessment according to the future motorway alignment with the help of limiting factors. The third development motorway axis is an important project of the future and therefore it is of outmost importance to do the research needed and find the most optimal alignment of the axis without doing too much harm to the environment. That is one of the reasons we chose this project and analysed, with the help of GIS tools, how different the impact of the limiting factors is on the environment, which gave us the most optimal motorway alignment. The purpose of this project is to explain construction, modernization and renovation of the state road network on the prioritised third development axis. The project of the third development axis is to insure public good in form of road infrastructure, one of the necessary conditions for achieving the objectives of an integrated and sustainable society development. The project contributes to achieving competitiveness, a more coherent regional development and a more balanced space policy. That will enhance the regional potential for development, which will enable the development of the economy and a quality living environment for people in the regions. Modernisation of road links and partially construction of new ones already figure in a number of national implementation

programmes. It is necessary to improve the capacity in the alignment by elimination of bottlenecks on the state road network. In the development of the project the emphasis is on the large contents of environmental report development and adoption of the infrastructure to the needs and the benefits. In order to achieve set goals, according to Slovenian legislation, an environmental report is required; it introduces an expert impact assessment of the third development axis on the environment. Due to the before mentioned requirement the goal of this project was primarily to determine the factors that have a restricting effect on the construction of the third development axis.

- For the chosen motorway alignment an environmental report is made; on the basis of required information the report determines, along with the monitoring during the construction and operation, all necessary parameters, which are considered in the outline scheme. The environmental report is a constituent part of the detailed motorway plan.
- Specific researches, aimed at the construction of motorways, are carried out at the earliest possible stages of planning, during the construction and once the motorway is opened to traffic.

The third development axis stretches from the northern border of the Republic of Austria via Koroška and Savinjska region to the motorway A1 Koper - Šentilj, continues to Novo mesto and through Dolenjska and Bela Krajina regions to the border of the Republic of Croatia. The northern part of the axis, which this project analyses more precisely, stretches through the Koroška and Savinjska regions, mostly on the existing transport corridors. The middle part between motorways A1 and A2 is the most demanding as it stretches over the ridges of the hills, lying in the transverse direction.

For the purpose of our research we chose only one part (Part F) of the alignment – the constituent part of the Koroška - central Slovenia connection (Figure 6). This decision is based on the inconsistency of the project documentation topology and data descriptions.

METHODOLOGY

For testing the GIS approach, we chose the method of elimination factors. Every used parameter has a different effect on space and it is the latter that gives us an assessment on environment. To get an optimal assessment we have evaluated the individual factors and given the equation for calculation of a more or less optimal impact assessment. In the foreseen project three variants of alignments of the future motorway alignment were proposed. The most optimal solution takes account of the environmental impact assessment. The environmental report was carried out with the help of the GIS system. To achieve the most optimal results the use of informational layers needs to be well thought-out. With our work the following limiting factors have been used:
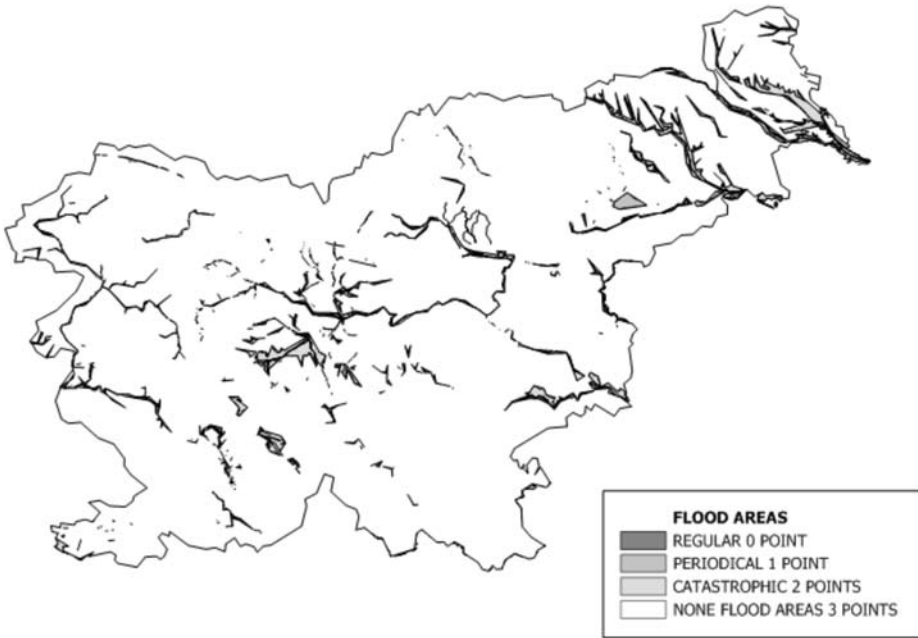
Figure 1. Map of Flood Areas in Republic of Slovenia
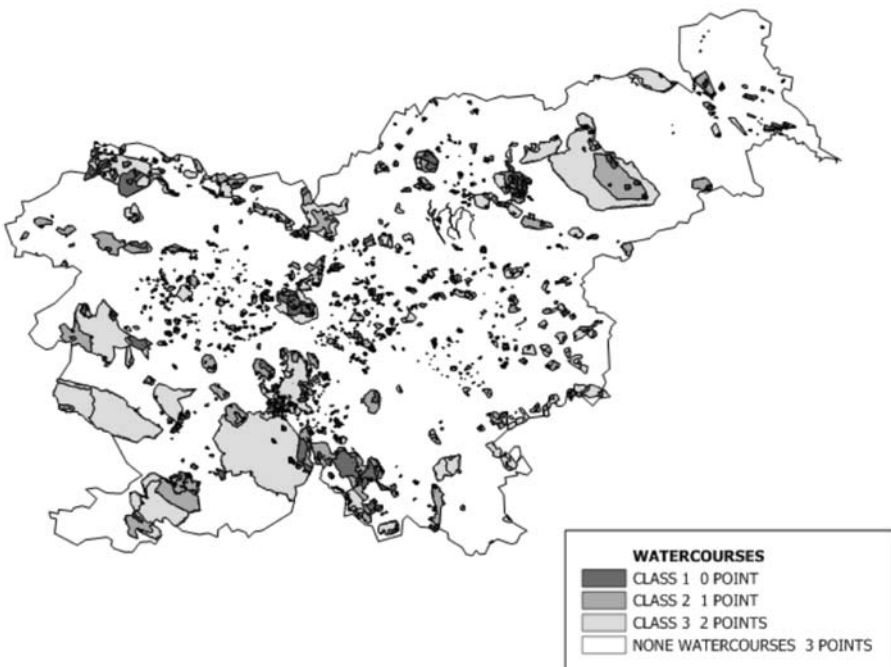**Slika 1.** Karta poplav v Republiki Sloveniji

Figure 2. Map of Water protection zones in Republic of Slovenia
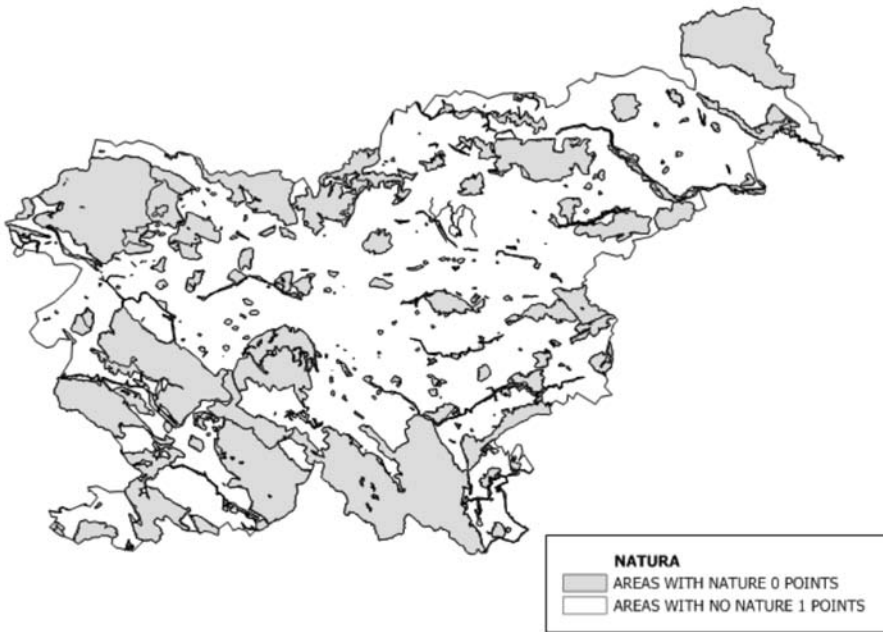**Slika 2.** Karta vodovarstvenih območij v Republiki Sloveniji

Figure 3. Map of "Natura 2000" in Republic of Slovenia
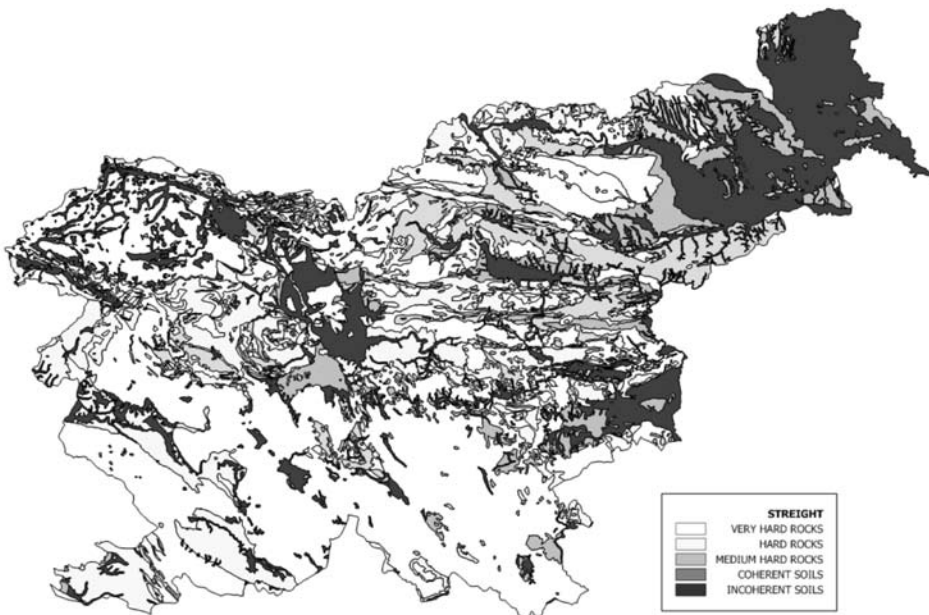**Slika 3.** Karta "Nature 2000" v Republiki Sloveniji

Figure 4. Map of rock straight in Republic of Slovenia
Slika 4. Karta trdnosti kamnin v Republiki Sloveniji

1. Flooding areas;
2. Map of water protection zones;
3. Map of "Natura 2000" protection zones;
4. Variants of (motorway) alignments;
5. Strength of terrain (derived from geology information);
6. Stability of terrain (derived from geology information).

The limiting factors we considered when making this report will be presented in a greater detail at the end of the report.

Flood map

The flood map was made by Institute for Water of the Republic of Slovenia; the scale is 1:25.000 (Figure 1).

Flood areas are divided into three classes:
1. Regular flood areas
2. Frequent flood areas
3. Catastrophic flood areas

Map of water protection zones

The map of water protection zones was made by the Geological Survey of Slovenia. The water protection zones are divided into three different areas according to valid criteria set by an institution (Figure 2).

Map of "Natura 2000" protection zones

The map "Natura 2000" presents areas, protected in accordance with the EU directives. Any activities on such areas are forbidden and construction may be done only with the consensus of EU (Figure 3).

Map of rock strength

Map of rock strength is a map, based on a geological map. It presents the structure of the area according to rock stability. It divides rocks into five classes (Figure 4).

Map of rock stability

Map of rock stability is a map, based on geological map. It presents the areas of stability (Figure 5).

Review of six variants of motorway alignment

Table 4 below presents the evaluation of individual limiting factors. According to the set calculation we received the numeric value of a more or less optimal result, depending from the evaluation of an individual information layer. It can be seen that only flood areas, "Natura 2000" and water protection zones are also the elimination factors, but the parameters deriving from geology are not. This can be seen as an erroneous conclusion but in our cases this was made because the scale on geological map used for GIS analyses were too small for showing the geological risk hazard in a proper way.

Despite this it has to be noted that the authors are aware that the geological structure of an area is the cause for a disaster on many occasions. For such analyses a really exact geological mapping is needed, and it has to be presented with large ratio maps. When this analysis was taking place we did not have access to such information and that is why we did not eliminate the condition valued 0 to the adequacy parameters. When doing the evaluation, we used only a part of the segments of anticipated variations and performed their evaluation according to the methodology, presented below (Figure 6).

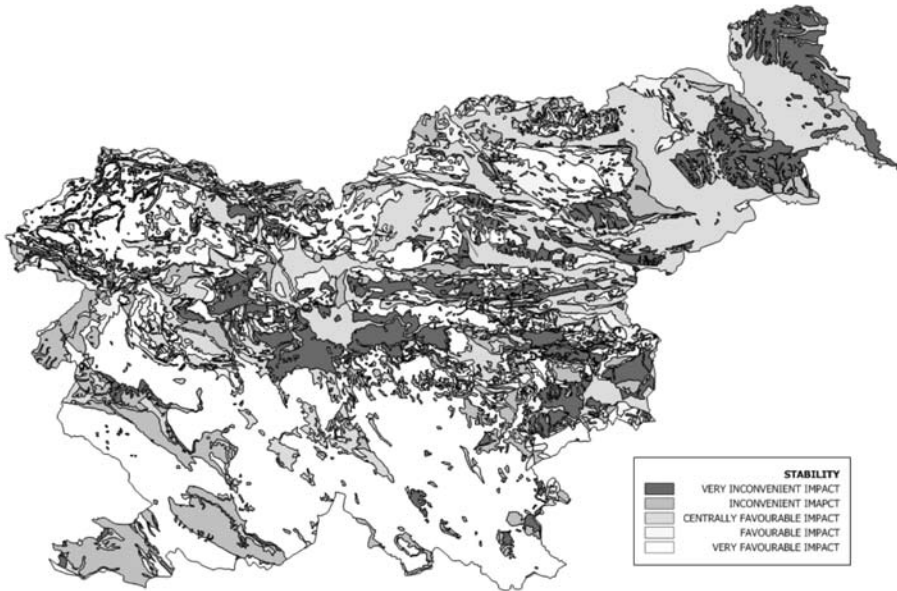The equation for a common estimate of an individual alignment is:

Figure 5. Map of rock stability in Republic of Slovenia
Slika 5. Karta stabilnosti kamnin v Republiki Sloveniji

$$P = P(f) \cdot P(n) \cdot P(wp) \cdot P(str) \cdot P(s) \quad (1)$$

Individual parts of the equation are calculated according to the following equations (when one part of the amounts is 0, the collective values of sum have to be 0):

$$P(f) = \sum y_f \cdot x_{fi} / \sum x_{fi} \quad (2)$$

$$P(n) = \sum y_n \cdot x_{ni} / \sum x_{ni} \quad (3)$$

$$P(wp) = \sum y_{wp} \cdot x_{wpi} / \sum x_{wpi} \quad (4)$$

$$P(str) = \sum y_{str} \cdot x_{stri} / \sum x_{stri} \quad (5)$$

$$P(s) = y_s \cdot x_{si} / x_{si} \quad (6)$$

The parameters are: $P(f)$ mean value of flood area, $P(n)$ mean value of natura, $P(wp)$ it is value of water protection zone,

$P(str)$ mean value of strength and $P(s)$ mean value of stability.

Y is the evaluation of an individual factor; x_i is the length of value of a certain factor of the alignment. Equations above are pondered values of estimations for an individual factor in subordination to the length of the alignment.

TOPOLOGICAL OPERATIONS AND ANALYSES

As we said before a GIS package is different than an "atlas" package products that can display only one, built-in, read-only map. A GIS can work with many different maps and can be used to create new maps, to edit maps and to combine maps with database information. It is also a "database

Table 4. Marks used for individual parameters of the analysis
Tabela 4. V analizi uporabljene ocene za posamezne parametre

FLOOD AREAS	P
REGULAR	0
PERIODICAL	1
CATASTROPHIC	2
NONE	3
"NATURA 2000"	
YES	0
NO	1
WATER PROTECTION ZONES	
NONE	3
WATER PROTECTION ZONE 3	2
WATER PROTECTION ZONE 2	1
WATER PROTECTION ZONE 1	0
STRENGTH	
INCOHERENT SOILS	1
COHERENT SOILS	2
SOFT ROCK	3
MEDIUM ROCK	4
SOLID ROCKS	5
STABILITY	
VERY INCONVENIENT IMPACT	1
INCONVENIENT IMPACT	2
CENTRALLY INCONVENIENT IMPACT	3
FAVOURABLE IMPACT	4
VERY FAVOURABLE IMPACT	5

system for maps" that will allow us to embed database information into a map so that the map can be used as a visual interface into the data. One of the most important features of every GIS is topology overlay. It is used for making the GIS analysis and transferring data between vector data types which pass the topological analysis. The below descriptions is based on the Manifold User Manual.

Topology Overlay

The Topology Overlay dialog modifies drawings using Identity, Intersect, Union and Update overlay functions. These functions may also be performed by a sequence of transform toolbar operators. The Topology Overlay tool provides one-step functionality to make it easy to perform these common functions. Overlays simultaneously modify objects and also manipulate
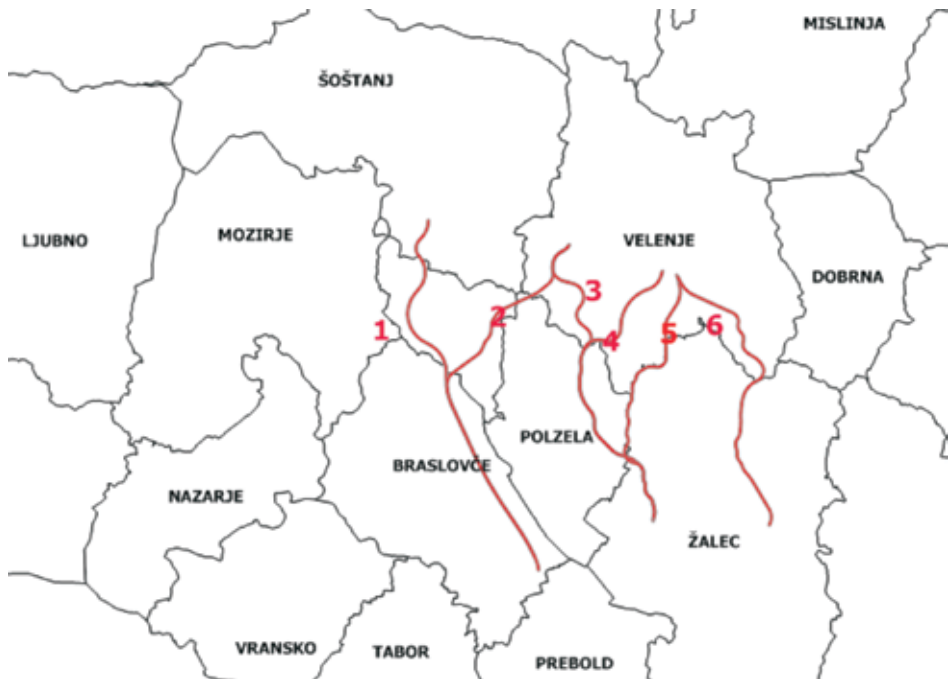
Figure 6. The estimated segments of variants
Slika 6. Ocenjevani odseki variant

data columns as necessary. Overlay functions are also referred to simply as overlays. All overlays in Manifold require two drawings: a target drawing that may contain areas, lines and points and a source drawing that must contain areas. The areas in the source drawing guide the overlay function used. The result is either to modify the target drawing or to create a new result drawing (the default). When creating a new result drawing, the result drawing will inherit all columns from both the source drawing and the target drawing. When modifying the target drawing, the source drawing will retain its own columns and will also acquire all columns from the target drawing. There is no mapping between the columns in the source drawing and the target drawing. Each resulting object inherits all data from the source and target objects it has been produced from, according to the transfer rules specified for those columns. Update intersects all areas, lines and points in the target drawing with areas in the source drawing and first places each part of the original target object that does not lie in any source area into the result drawing, then second placing each source area into the result drawing. The above overlays are similar to those in various legacy GIS systems. However, because legacy GIS systems typically cannot handle drawings with overlapping areas and Manifold can, the overlays are defined in a slightly different manner than their equivalents in other GIS products. If neither the target nor the source drawing contains overlapping areas, the outcome of the overlays is

identical to that produced by similar tools in other GIS products. If either the source or target drawing contains overlapping areas, the outcome of the Intersect and Union overlays will be asymmetric. That is, the result will depend upon which drawing is chosen as the source and which as the target drawing. Because of the potential of the outcome to be asymmetric if either drawing contains overlapping areas, launching Intersect or Union overlays with drawings that do not contain overlapping areas within themselves yet contain vastly different numbers of objects has the potential of being much be faster if the drawing that contains the higher number of objects is used as the source drawing. Using the topology overlay a transfer rules are of essential importance.

Transfer rules

Transfer rules come into play when the transform commands transfer fields between objects. A transfer rule may be set for each column (field) in the table that specifies how that field will be transferred to any new objects created by various transform operators. By default, all fields in a table are copied to the new record created for the new object. The transfer rules specified for each field will be used whenever a transform operator creates a new object. There are two types of transform operators that create new objects: One to Many (1 to N) Operators - For each original object these operators create one or more new objects. The task for transfer rules for such operators is to specify how one value from the original object should be apportioned to the possibly many new objects created. Many to One (N to 1) Operators - These operators create a single new object from many original objects.

Buffers

Before we started with the analysis we needed first to transform the axis of motorways in closed regions which are presenting the influence perimeter of different variants of motorways. For doing this the buffer command was used. We use an option to make a buffer for all variants of motorway alignment. Exactly the same procedure as is here describes but with a different choice of transform operator is used to create inner buffers or other buffer zones. For our analysis we created a border buffer zone extending 50 m outward from the boundary. To check what units of measure are in use, we use the tracker tool to measure a distance near the areas. The result was a newly created area in the shape of the border buffer that appears in the drawing. The newly created areas presenting the variants of motorways were the basics GIS table used in the analysis process.

In the process of analysis we used buffered motorways axes and put them trough separated topology overlays operations. As a transfer rule for one to many relations we always selected a copy and for many to one an average transfer rule. Using this procedure we get divided axes according to the areas they were cutting. The results are presented in the Table 5.

Table 5. Individual marks of suggested variants of motorways
Tabela 5. Ocene posameznih predlaganih variant

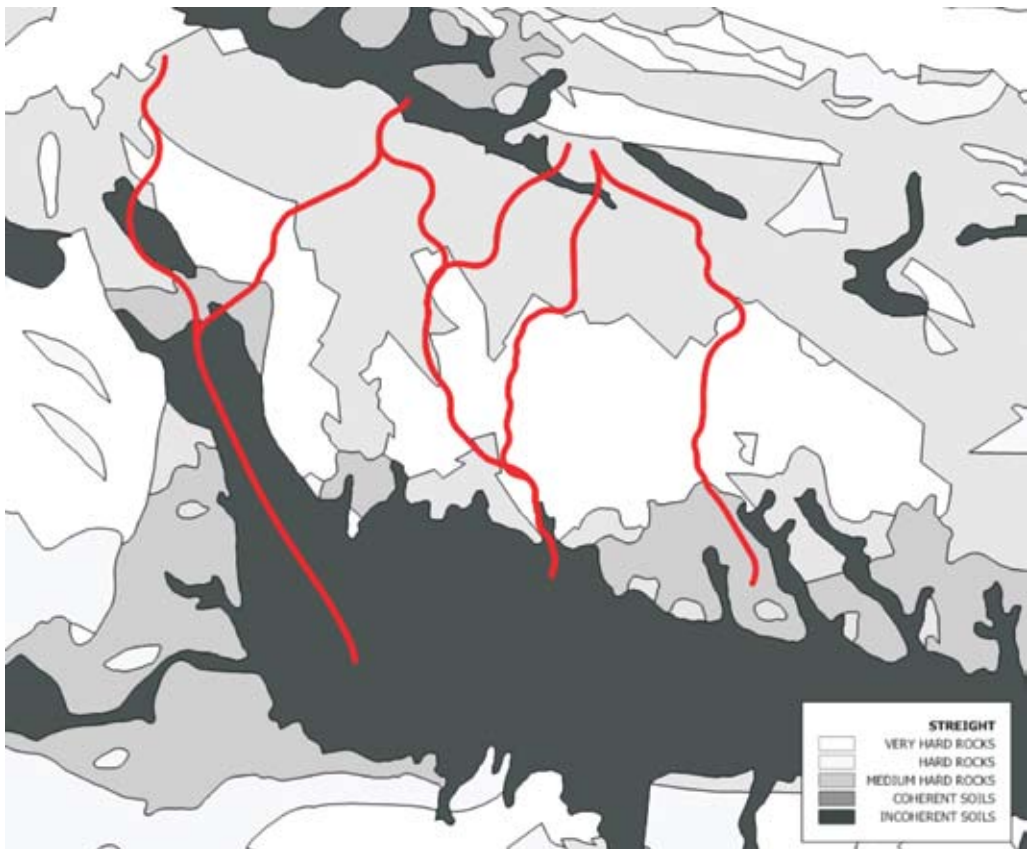| Variant	Strength	Stability	Flood	WPZ	"Natura 2000"	Altogether mark
1	1.94347987	2.9184488	2.9881478	3	0	0
2	2.02245731	2.7401818	2.9888004	3	0	0
3	3.37622426	2.9193593	3	3	1	88.70770524
4	3.36373513	3.0746551	3	3	1	93.42652497
5	3.64852875	3.4898871	3	3	1	114.5965803
6	3.53021057	2.9769197	3	3	1	94.58237946

Figure 7. Alignment crossing areas with different rock stabilities
Slika 7. Primer prečkanja tras različnih območij trdnosti kamnin

RESULTS OF ANALYSIS

The results were extracted to Excel, where we were able to finish the evaluation based on equations 1 to 6. As it can be seen from Table 5 there are two alignments, variant 1 and 2, with evaluation 0 – meaning, they run through areas that do not allow any construction, or it is highly undesirable. The individual evaluations were not evaluated according to the meaning of an individual factor. We believe that that would demand a special economic-social analysis, which can be done within GIS programme environment, but it is highly demanding, as it bases on knowledge of expenses evaluation according to parameters of areas.

All values which are not whole numbers are due to the fact that individual alignments cross two or more differently evaluated areas of an individual factor (Figure 7). Alignments 1 and 2 have evaluation 0 at "Natura 2000" factor due to the fact that they cross (partly or in whole) the "Natura 2000" area (Figure 8).

From the Table 5, a variant number 5 has the highest number, so according to our methodology it should be select. But we have to take into account also that we did the evaluation purely on the natural depended factors and that we didn't take into account the socio-economic factors, which in some cases can completely different the choice.

CONCLUSIONS

The evaluation was made on the basis of already existing data, describing certain natural factors as geological-geomechani-cal factors, protected areas "Natura 2000", flooding areas and water protection zones of underground water. As shown, we have selected the alignment in a transparent and repeatable manner using GIS tools. A part of a subjective evaluation lies in the composition of map of strength and stability of rocks, made on the basis of geological map, as well as on the protected zones and flood lines maps. The advantage of GIS is that it enables verification on every step of the analysis. As shown in Table 5 variant 5 was chosen as the best one. Its evaluation is based solely on the parameters from this article. Realistic evaluation should comprise a larger spectrum of parameters. Two of the proposed alignments run through protected areas and are as such automatically eliminated (Figure 8). When doing the evaluation the biggest problem presented GIS documentation, which was made on the basis of the project. The most problematic are the errors in topology; so we had to use only the axes and expand them for 50 m to gain a "buffer" zone. That is how we were able to determine the influence of future motorways on the environment. We did not analyse the quality of data in the article. Despite this we believe that such an analysis is useful for a quick overview, but acknowledge that for a more detailed evaluation verification on the spot is a necessary factor. We also did not do an evaluation of the influence of an individual factor on the field, as it requires an economical and sociological analysis of an individual intervention.

Based on the analysis done we can see that the use of GIS tools for transparent and repeatable analysis of evaluations of different environmental impact is possible. On the other hand the biggest problem presents the data, which is often not processed enough

Figure 8. Variants 1 and 2 cross "Natura 2000" and are excluded according to our methodology
Slika 8. Varianti 1 in 2 prečkata območje "Nature 2000" in sta zato v skladu z našo metodologijo ocenjevanja izključeni

and do not contain the information, needed to make the estimations of the impact the infrastructure would have on the environment. Whatever the case – we have to know that the quality of gained values depends on the quality of input data.

Povzetek

Uporaba GIS-a za določitev naravnih kriterijev možnosti okoljskega razvoja

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Izdelava okoljskih poročil je določena z okoljsko zakonodajo. Glavni namen okoljskih poročil je, da se v času odločanja za posamezno varianto posega v prostor izbere tista, ki je s stališča naravovarstvenih kriterijev najugodnejša. V času izdelave okoljskega poročila se zato, za potrebe presoje in njegove izdelave, zbirajo različni prostorsko vpeti podatki. Njihova ocena je zmeraj podvržena subjektivnemu ocenjevanju presojevalcev, ki so sicer specialisti za področje, ki ga presojajo.

Največji problem pri presojanju pa pred-
stavljajo številni kriteriji in prostorski po-
goji, ki se med seboj prepletajo in veliko-
krat izključujejo. Veliko primerov ocen je
postavljenih pod vprašaj tudi zaradi nepre-
glednosti uporabljene metodologije. Prav
uporaba orodij, ki temeljijo na GIS tehno-
logiji je tisti pristop, ki naredi metodologijo
ocenjevanja bolj transparentno. Hkrati pa
poskrbi, da so vse prostorske danosti, ome-
jitve in specifičnosti istočasno ocenjevane
in pregledane. Poleg tega pa GIS omogoča
tudi oceno socioekonomskih parametrov,
ki včasih zaradi razumevanja razvoja pre-
magajo parametre naravnega izvora.

Kot primer ocenjevanja smo izbrali tre-
tjo razvojno os, ki bo povezala Koroško
z osrednjo Slovenijo in Dolenjsko. Zaradi
problemov v tehnični dokumentaciji smo
obdelali le odsek F, ki je bil razdeljen na
šest variant. Ocenjevali smo le naravne
danosti, kot so vodovarstvena območja,
pojavljanje poplav, geološko-geomehanski
pogoji gradnje itd. Na začetku ocenjevanja
smo izdelali metodologijo in izbrali račun-
ski model. Na osnovi izdelane metodologi-
je smo naredili oceno posamezne trase, kot
je razvidno iz ocen v tabeli 5 je najbolj op-
timalna varianta 5. Pri ocenjevanju je treba
vedeti, da smo ocenjevali le odsek F brez
ostalih in tudi socioekonomskih faktorjev.
Zato je oceno variante treba jemati z re-
zervo. Hkrati pa je v članku lepo pokazan
primer in zmožnosti, ki jih GIS tehnologija
omogoča pri izdelavi okoljskih poročil in
študij vplivov na okolje.

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