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SELECTION OF ARTIFICIAL INTELLIGENCE TOOLS TO SUPPORT GIS SYSTEMS

Abstract: The aim of this paper is to characterise the selection process of artificial intelligence tools that, using artificial intelligence for different purposes and tasks, can best support the operation of GIS-class systems. The selection process proposes the use of selected formal methods of multi-criteria comparative analysis belonging to the repertoire of systems analysis methods. Artificial intelligence tools can help improve the quality and performance of GIS-class systems, for example by automating processes, facilitating visualisation, detecting anomalies, generating forecasts, optimising routes, etc. The intention is not to compare specific tools, but only to indicate the importance of the various stages of the selection process, and in particular the importance of the criteria for evaluating AI tools for GIS support.

Keywords: multi-criteria comparative analysis, artificial intelligence, GIS

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Introduction

The optimal use of available resources, including tools in a specific area and time is always the goal of decision-makers. Achieving this goal is always contingent on having certain information regarding these very resources, tools, and the area and time of their operation. This also applies to the issue of selecting GIS geographic information systems. Today's emerging GIS systems rely on so-called web-based geo-information services, such as spatial data distribution and retrieval. They allow users using a simple web browser and easy-to-use IT tools to access advanced GIS functions.

However, the use of GIS tools (both simple and the most advanced) is only one of many prerequisites for building a geographic information system. This requires up-to-date and reliable spatial and descriptive data, experienced staff, and above all, a rational conceptual model describing the structure of the database. After all, a spatial information system is created for the needs of a specific user, using IT tools and source data adequate to the purpose of the study. Therefore, nowadays, available artificial intelligence tools are increasingly used for these tasks.

With the development of information technology, as well as the improvement of methods of acquiring, storing, processing, analyzing and sharing information that has a spatial reference to the Earth's surface (i.e. geographic information), there is a growing need to support decision-making processes in solving the basic problems of planning their development, i.e. making rational choices of goals, ways and means of action. Important factors in these processes include(Sienkiewicz, 1994):

- the study of the objectives of an activity (action or course of action);
- study of possible ways to achieve the intended goals, taking into account new alternatives.

The importance of evaluation for the success of the system analysis of any complex object is due to the fact that the choice of system characteristics – parameters, features and criteria for evaluating the system (variants of its organization, operational equipment and development) determines the accuracy of subsequent choices, leading to the final decision.

Related to decision-making, i.e. making choices in action, is planning, understood as analyzing the internal and external conditions of an action (i.e. the internal and external elements of a situation) and developing means and modes of action suited to both goals and conditions. This applies as much as possible to planning the use of GIS systems supported by artificial intelligence tools.

It becomes necessary here to make:

- evaluation of the positive and negative, short-term and long-term consequences of each possible option, taking into account future uncertainty and risk;
- comparative analysis of the options according to various criteria and presentation of the results in a way that makes it possible to make a choice – to make a decision.

Methodology

Decision-making process for selection of GIS systems supported by AI tools.

In the decision-making process concerning any sphere of human activity, including the selection of the best, in the sense of the adopted purpose of action, variant of the GIS system supported by artificial intelligence tool systems, an important role is played by the proper definition of the problem (diagnosis of the situation), collection of the necessary information (relevant to the defined problem), review and analysis of the available variants, comparison and evaluation of the results, which ultimately leads to a decision (selection of a specific variant).

Decisions are made under the conditions of a decision-making situation (Figure 1). In a decision-making situation, the following elements must appear:

- the decision maker;
- causal circumstances, i.e. causing the decision situation;
- the set of possibilities under consideration;
- the criteria for their selection.

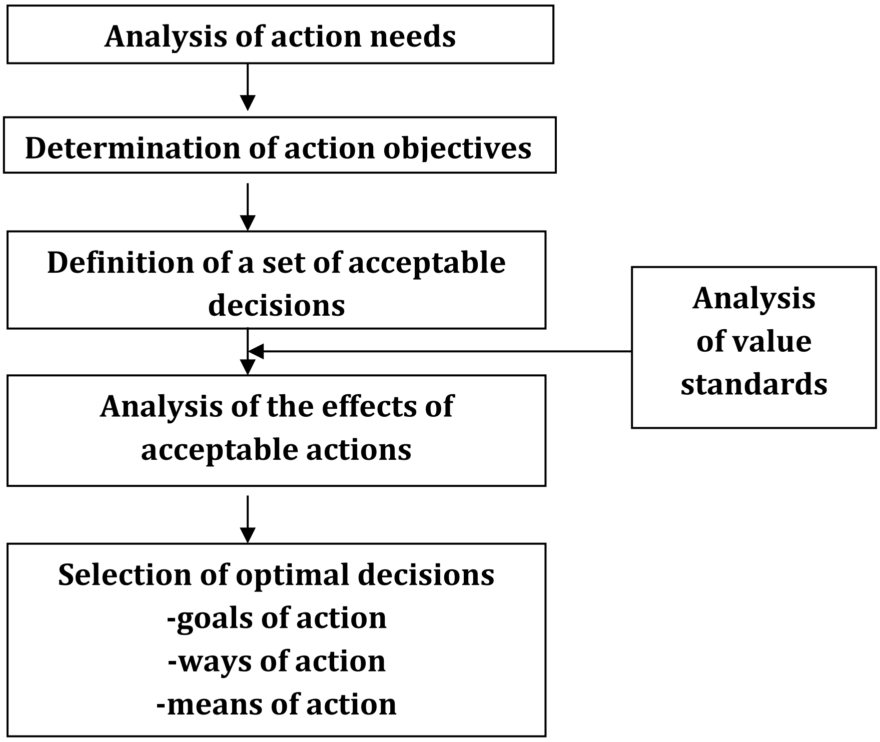

Figure 1. General diagram of the decision-making situation
Source: The author's own elaboration

The decision-making situation must include the following elements:

- decision maker;
- the causal circumstances, i.e., causing the decision situation;
- the set of possibilities under consideration;
- the criteria for their selection.

The decision-making process is a step-by-step process, beginning with the definition of the problem, through the evaluation of options, and ending with the selection of one of them.

It includes the generation of:

- a set of alternative options for designing a decision;
- a set of actual and probable states of affairs that characterize the conditions for action;
- a utility function that expresses the evaluation of alternatives from the point of view of the decision-maker (action objectives, preferences) or a group of decision-makers.

Therefore, there must be two basic phases in the implementation of the decision-making process (Górny, 2004):

- Identification (of the needs we want to satisfy and the requirements, conditions and opportunities);
- Evaluation (assessing and comparing the identified options for meeting the identified needs according to the decision-maker's value system and the adopted evaluation model).

Completion of these two phases will allow to make a final decision on further actions related to meeting the identified needs.

In general, we can say that the decision-making process consists of the following phases:

- gathering the necessary information;
- definition of the problem or diagnosis of the situation;
- review and analysis of available options and possibilities;
- evaluation of options and comparison of the results obtained;
- decision-making (selection of an option).

Understood in this way, it should lead to a decision, that is, the selection of the most advantageous option (in the sense of the adopted criteria and decision rules).
A single attempt to solve the problem is rarely sufficient. Successful analysis depends on a continuous cycle of problem formulation (Figure 2).

Multi-criteria comparative analysis in the selection process.

In solving decision-making problems, including the selection of artificial intelligence tools to support the operation of GIS systems, analytical-assessment models that form the basis of multi-criteria comparative analysis can be very useful. They provide an effective tool to assist decision-makers.
Methods of multi-criteria comparative analysis, which include a number of analytical and evaluative techniques, are designed to compare (evaluate) objects characterized by multiple features (parameters, decision variables) with identical or similar functional purpose. They can be a tool to assist the decision-maker in decision-making processes. They allow to order the compared objects from "worst" to "best" on the basis of the values of the characteristics that characterize them.

The basis of comparison here is always a certain value system – a criterion – which is a function of the relevant characteristics of the compared objects.

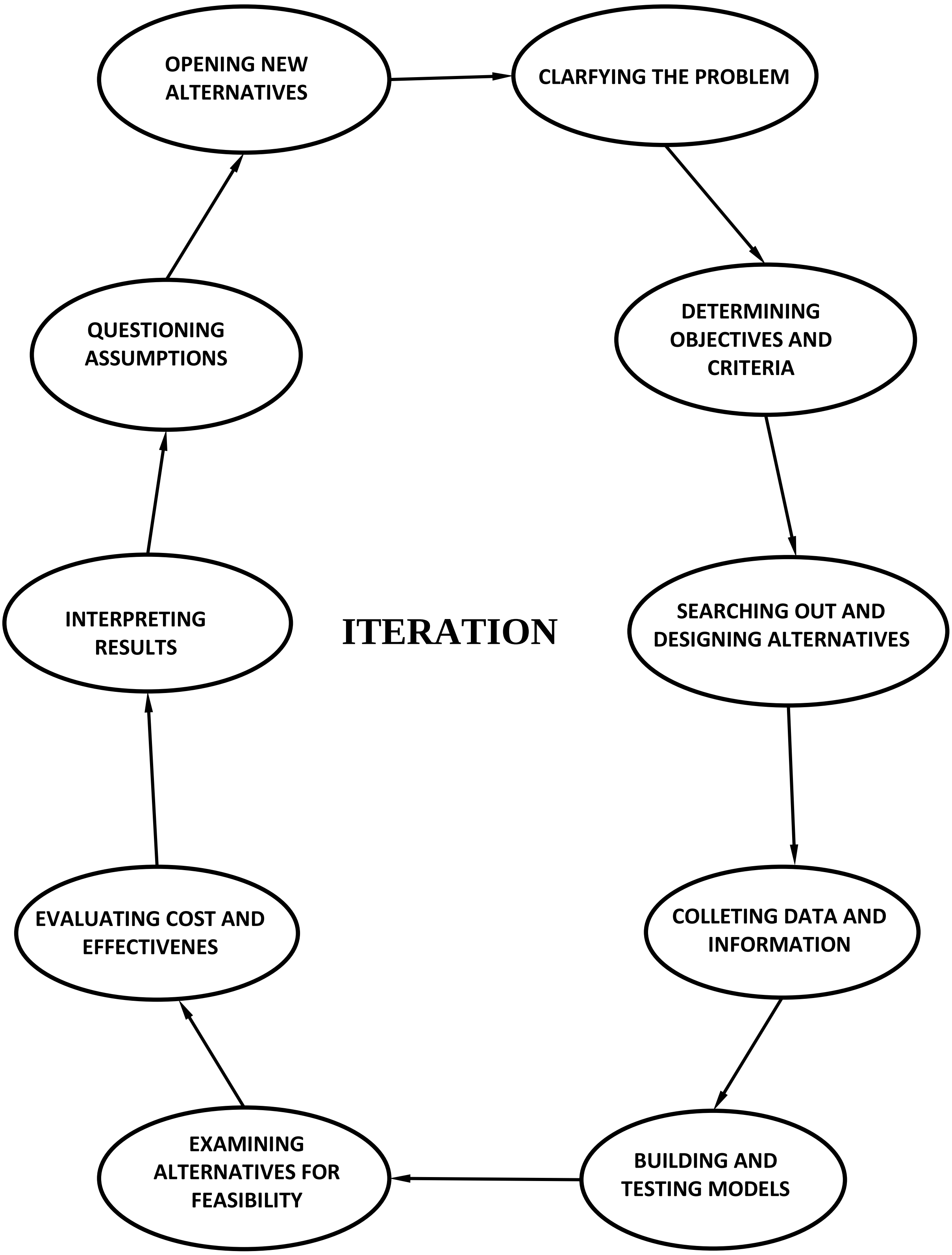

Figure 2. Decision-making process as an iterative process
Source: Quade, 1989

Methods of multi-criteria comparative analysis consist of the following steps (Panek & Zwierzchowski, 2013):

1. Identification of the compared objects and their parameters (qualitative characteristics).
2. Normalization of parameters.
3. Aggregation of the parameters of the compared objects into a comprehensive quality index using additional information about the preferences of the decision maker.

In multi-criteria comparative analysis, the initial step is to evaluate the objects considered as options in the decision-making process.

The responsible task of the system analyst for the correctness of evaluations under the conditions of multi-criteria decision support is to define a "consistent family" of criteria for evaluating the effectiveness (quality) of options. This is because it must meet several basic conditions, such as:

- exhaustibility, i.e. preventing such cases that, for example, for any two variants equivalent to each criterion in practice there is an advantage of one of them, inconsistent with the situation of equivalence;
- consistency between the role accruing locally to each criterion at the level of bounded preferences and the role accruing globally to the family of criteria at the level of global preferences;
- lack of redundancy, i.e. the removal of a criterion causes the family of criteria to cease to meet at least one of the previous two requirements.

Once the set of relevant parameters of the compared objects has been determined and their importance coefficients have been established, one can proceed to the next stages of comparison, i.e. determining aggregate ratings of the compared objects.

The nature of the decision issues involved in comparing alternatives, as well as the nature of the (partial) evaluations of alternatives, is quite diverse. Among other things, they differ in terms of precision and certainty.

The concept that allows objects to be compared with each other based on the chosen set of criteria, called similarity. Thus, it is reasonable to say that two objects are more similar, the closer the values of the variables describing them are. In the methods of multi-criteria comparative analysis, the similarity of objects is measured by the distance, i.e. by the following function:

$d: A \times A \rightarrow R$

i.e. a function that assigns to a pair of objects from the set of objects A a real number, called the distance between the objects, which satisfies the following conditions:

1. $d_{ij} > 0$
2. $d_{ii} = 0$
3. $d_{ij} = d_{ji}$
4. $d_{ij} + d_{jk} \geq d_{ik}$

The distance function is most often treated by the decision-maker in evaluation models as the distance from the target called the ideal element, which corresponds to the value system (preference model) adopted by him. The search for a solution consists in finding the object closest to the goal so defined (Ameljańczyk, 2021).

The calculation of the overall evaluation of the decision option is based on the aggregation of the values of partial evaluations (criterion features). Aggregation is an operation that allows to obtain a comprehensive evaluation index for ordering the objects to be compared.

Currently, there is a wide repertoire of methods of multi-criteria comparative analysis. Among such methods are (Trzaskalik, 2008; Górny, 2004; Goodwin & Wright, 2014):

- SMART (simple multi-attribute assessment technique),
- ELECTRE (Elimination and Choice Translating Reality),
- PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluations),
- AHP (Analytic Hierarchy Process),
- Numerical taxonomy methods,
- and more.

Among the wide repertoire of multi-criteria benchmarking methods, the AHP method, which is based on modeling a hierarchy of objectives to represent a problem in the form of a hierarchical tree, has recently been very popular, enabling a simple description of the structure of a decision-making problem in which the fulfillment of the main objective by each alternative follows from the fulfillment of intermediate objectives expressed by their corresponding criteria.

In contrast, the Bellinger method, in which the values of the criterion features are normalized as a percentage of the path from the least to the most desirable state, appears to be relatively computationally simple.

The Bellinger method allows objects to be ordered according to the value of the total score obtained from a set of sub-criteria. This method of multi-criteria analysis was first used by Bernhard Bellinger to order a list of customers applying for credit at a bank in order from most reliable to least reliable. Each evaluated customer was assigned a certain cumulative score. Loans were awarded to those with the highest scores(Malara, 1995).

The method consists in bringing the results of the evaluation by means of various sub-criteria to a state of additivity and determining the cumulative score – as an aggregate of these sub-scores. Bringing to a state of additivity, necessary because of the variety of criteria and their measures and meanings (weights), consists in determining for each subcriterion two states: the least desirable and the most desirable, and then expressing each number resulting from the measurement of a given subcriterion as a percentage of the "path" from the least desirable state to the most desirable state. The total score is obtained by adding up the percentages of paths traveled by all sub-criteria. Before that, however, the importance (weight) of each sub-criterion must be taken into account, so that the percentage of "paths" traveled is multiplied by the weight of the criterion. The weights must, of course, meet the condition of adding up to a value of 1.

The procedure applicable to the method under discussion can be summarized in the following eight stages:

Stage I. Refinement of the criteria to determine the best, from the point of view of the value of the aggregate site assessment.

Stage II. Determination of the units of measurement and the desired direction of change within a given criterion.

Stage III. Determining the lower and upper limits of change for each criterion.

Stage IV. Determining the meaning hierarchy for each criterion, i.e., the weight that the decision-maker assigns to the adopted evaluation criteria, so that the sum of all weights equals unity.

Stage V. Creating a table containing the actual values of the criteria corresponding to each evaluation object.

Stage VI. Present each number in the table from Stage V as a percentage of the "path" from the least desirable state to the most desirable state.

Stage VII. Multiplying the numbers obtained in Stage VI by the weights adopted in Stage IV.

Stage VIII. Determination of the best option after summing the scores given to each location from the point of view of all criteria.

Discussion. AI tools for GIS as options and proposals for evaluation criteria

The subject of multi-criteria analysis and evaluation here are GIS geographic information systems using the support of AI tools.

There are many GIS systems supported by artificial intelligence tools available on the market. Each of them has its own advantages and disadvantages, and the choice of the best tool depends on the purpose, task, data, budget and user preferences.
In this collection we can include, among others (ArcGIS: Esri's comprehensive geospatial platform; GIS Sofware):

- ArcGIS,
- ArcGIS Online,
- BatchGeo,
- Google Earth Engine,
- Carto.

ArcGIS as one of the most popular and advanced GIS tools, which offers many features and solutions based on artificial intelligence, such as ArcGIS Image Analyst, ArcGIS GeoAnalytics Server, ArcGIS Insights, ArcGIS Pro and many others. ArcGIS enables you to create and manage geospatial data, create interactive maps and applications, perform spatial and statistical analysis, leverage machine learning and deep learning models, integrate with other cloud platforms and services, and much more (Jażdżewska & Lechowski, 2018).

ArcGIS Online is a cloud platform that enables access to advanced GIS features such as 2D and 3D mapping, spatial analysis, sharing and collaboration. ArcGIS Online offers a free plan for individual users with capacity and credit limits.

BatchGeo – a tool that allows you to create interactive maps from any data containing locations. You can easily import data from Excel, CSV or Google Sheets files and choose different options for map styling and filtering. BatchGeo offers a free plan with limits on the number of maps and records (BatchGeo).

Google Earth Engine – a powerful, cloud-based geospatial data analysis and visualization platform that provides a huge collection of satellite and aerial data, as well as data processing and modeling tools. Google Earth Engine enables custom algorithms and applications based on artificial intelligence, such as detecting land cover changes, classifying land use types, generating elevation maps, forecasting climatic phenomena, and much more (Google Earth Engine Tutorials).

Carto is a platform that enables everyone from business analysts to data analysts to transform location data into business results. This cloud-based, open-source software provides insight into where something is happening, why it is happening and predicts what will happen in the future. The software accelerates innovation, finds solutions to increase productivity, powers new applications and revolutionizes business models by leveraging Location Intelligence. Carto combines spatial and temporal data to drive business results. It uses artificial intelligence to automatically generate maps and reports from geospatial data. Data can be loaded from a variety of sources, such as CSV files, GeoJSON, Shapefile or APIs, and receive ready-to-use maps and reports with insights and recommendations. Carto offers a free plan with limits on the number of projects and data Perplexity – an AI-based interactive assistant that acts as an enhanced version of ChatGPT. Perplexity uses up-to-date information and web browsing to provide concise answers to questions related to GIS and other topics. It cites sources for further reading and allows you to find images for specific queries (What is CARTO?).

When choosing criteria for selecting artificial intelligence tools, one should not forget the accompanying challenges. And these can include:

- Confidentiality and data security issues, especially when working with sensitive project information.
- The possibility of errors in field data analysis or modeling, which can lead to erroneous design decisions.
- The risk of relying on AI system performance and the possibility of losing control of the design process if overconfidence is placed in AI system decisions.
- The need to ensure compliance with legal and ethical regulations regarding the use of artificial intelligence in linear infrastructure design.
- The requirement for continuous improvement of the artificial intelligence system to ensure its effectiveness and relevance to changing design needs.

For multi-criteria analysis and comparative evaluation of artificial intelligence tools, appropriate criteria should be selected depending on the purpose of the comparison. An example set of criteria may include the following:

1) Functionality.
   a. What tasks and functions can be performed by the tool?
   b. How well does it handle them?
   c. What are its limitations and capabilities?

2) Ease of use.
   a. How easy is it to learn and use the tool?
   b. What are its requirements and dependencies?
   c. What are its interfaces and documentation?
3) Scalability.
   a. How well does the tool handle large and complex data and models?
   b. How easy is it to expand and customize?
4) Resource utilization.
   a. How many resources such as memory, processor, disk, network, etc. does the tool consume?
   b. How efficiently and optimally does it use resources?
5) Cost.
   a. How much does it cost to use the tool?
   b. Is it free, paid, or does it have different plans and options?
   c. What are the licensing and legal terms?
6) Support.
   a. What is the technical and community support for the tool?
   b. How often is it updated and developed?
   c. What are its feedback and reviews?

It is worth noting that each of the above-mentioned criteria in itself can be a target for comparison, and each nothing consists of two or three (of course, the number can be greater) sub-criteria, whose values/ratings are answers to the questions posed in quantitative form. These ratings, when added together, constitute a rating in terms of a given criterion for the tool under study. After making such ratings for all adopted criteria for each tool being compared, we aggregate these ratings into a comprehensive rating. In this way, we obtain a rating for each compared tool that takes into account all adopted criteria and all factors affecting the value of the rating according to each criterion separately.

Determination on the basis of certain evaluation parameters of the aggregated evaluation of the object (comprehensive quality index) obviously raises the problem of determining the relative importance of individual parameters (the degree of severity of the influence of the state of the parameter on the value of this evaluation). The determination of a relatively objective and constant for a certain group of systems vector of importance coefficients is of vital importance in the process of object evaluation. In comparative analysis, an extremely important role is played by the decision-maker himself with his value system. For this reason, in the comparative process it will be important to take into account the importance of the individual criteria considered here as the value weights assigned by the decision-maker. It is required to take into account the preferences of all or part of the participants in the decision-making process. The viewpoints of different participants on the options being compared may be compatible or incompatible (unequal value systems or information systems) (Górny, 2004). When selecting experts, several requirements should be observed:

1) the group of experts should be universal, consisting of versatile people interested in the future and include representatives of specialized fields of science and practice;
2) the group should be large to represent a variety of views;
3) the selected individuals should think independently and have an independent vision of evaluation.

If $_{ie}$ is the importance coefficient of the parameter number $_i$ given by the expert number $_e$ and $\overline{\alpha}_{ie}$ ∈ [1,N], then the parameter preference vector $A = \left[\alpha_i\right]_{1*L}$ has the following components:

$$\alpha_i = \frac{\sum_{e=1}^{E} \alpha_{ie} - \left(\min_e\left\{\overline{\alpha}_{ie}\right\} + \max_e\left\{\overline{\alpha}_{ie}\right\}\right)}{E-2}$$

where :

E – number of experts

Therefore, it is necessary to build a preference model that is acceptable to the various participants in the decision-making process. The expert preference method can take into account the preferences of a single expert or a group of experts. The expert's preferences, as a system of subjective valuation criteria, have inherently limited cognitive value. A greater degree of objectivity in the weighting procedure characterizes the preferences of a group of experts.

Conclusions

Today, with the passage of time, there is a growing awareness of the need to use analytical and evaluative methods in supporting decision-making processes related to the selection of tool options used in almost every field of life. The use of mathematical models, computer techniques and various analytical methods is becoming increasingly common. The decision-making technique can be quite simple: it is only necessary to follow a specific step-by-step procedure, starting with the formulation of the problem, through the selection and evaluation of alternatives according to specific criteria, and finally selecting the best solution among those available. It is systems analysis with its wide repertoire of methods to support the decision-maker's actions that can protect against making investment mistakes, making mistakes in licensing purchases and selecting systems to support the tasks of analyzing and using geographic data and information. In any case, it should at least reduce the likelihood of making such mistakes.

In selecting the features used as criteria in the decision-making process, it is necessary to perceive, take into account, reproduce and overcome the richness of features, multiplicity of things and multiplicity of conditions, in particular:

- take into account both quantitative and qualitative features of the object;
- distinguish relevant from irrelevant features; ignore the latter and aggregate the former to form features for evaluating the state of the system;

- consider the most likely of a set of possible states; seek to identify typical and characteristic conditions;
- consider an object from different points of view and at different levels of reference, taking into account its partial indeterminacy.

Multi-criteria analysis can be helpful in evaluating and comparing approaches, objectives, conditions and other factors related to the use of artificial intelligence tools in GIS for different applications. However, it should be remembered that in the decision-making process, the evaluation criteria are formulated by the decision-maker. The purpose of systems analysis, especially on issues with broader implications, is not to say what the decision should be; the systems analyst can only determine, given an ordering criterion and to the best of the decision-maker's knowledge of value scales, how the options under consideration should be ranked. Once the analyst has made recommendations based on his or her own valuation, he or she ceases to be an analyst and begins to be an adviser (Findeisen, 1986).

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