TECHNOLOGY, CREATIVITY, IMPLEMENTATION

DECISION-MAKING PECULIARITIES ON THE BASIS OF GEOGRAPHIC INFORMATION SYSTEMS

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Summary

The work considers advantages of the geographic information systems use within maintenance of the decision-making and proposes a step-by-step decision-making (SDM) method on the GIS basis. The method allows to search a solution under uncertainty of: a situation, data, models, criteria etc. Conditional division of problems into a series of sub-problems solutions allows simplifying greatly the decision searching by a comparative analysis of probable variants of solutions. It allows choosing the best solution at every stage on the basis of a qualitative evaluation of a compliance with the main purpose of SDM and an aim of a particular stage. In case of difficulties with the choice, it is possible to use expert assessments. The decision of the previous stage is the basis for the next stage SDM. Last stage decision will be the main one for the whole research. The method requires high competence of researchers and all the maximum available information in the relevant direction. As experience has shown the method gives acceptable results where other methods of finding solutions are failed.

Keywords: geographic information systems, decision searching, decision-making maintenance, uncertainty.

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1. Introduction

GIS-based decision-making maintenance has its own characteristics. One of the main ones is the presence of a spatial component, which makes a significant contribution to important aspects of decision-making maintenance. Let's consider the main ones.

Physical description is a major component of a situation in which the spatial component plays an important role. Situation – is a state in which a system finds itself including a history, dynamic, social or environmental processes that have led to such state. An analysis of both the critical situation and all possible situations is extremely important for the decision-making maintenance. While analyzing the situation, physical and informational uncertainties emerge which stem from the difficulty of determining the internal and external processes that ensure the functioning of the system. Identifying the external influences on the system and system's influences on the environment as well as the mutual influence of system elements, occupies a special place. However certain regularities of the system functioning, regularities of external and internal processes, characteristics of influences have already been studied. Thus, this allows them to be indirectly taken into account.

Spatial information expands the analysis possibilities and provides a certain increase in information content for both the system and its elements due to the fact that it allows you to obtain the necessary additional attribute data. At the same time attribute data deepen and clarify spatial data. In fact they form a spatial data field which, in turn, allows discovering new patterns.

The analysis of the situation, determining of the main effect-forming processes and influences on them allows to increase to some extent the information content of the system and thus to reduce uncertainty not only for the situation but also for information description, and also allows to reasonably determine the possible situations and possible information about their state which provides an opportunity to reduce uncertainty within SDM. Besides, it allows dividing reasonably the search for solution to the stepwise system optimization which greatly simplifies the solution of the problem as a whole. This is especially useful for assessing the effectiveness of options the number of which decreases by an order of magnitude and more at each stage. Moreover the evaluation criteria at each stage are intuitive and do not require special methods. As for the formation of the problem in conditions of uncertainty, it is desirable to consider this issue in more detail in terms of the importance and significant impact of this process on the effectiveness of the decision-making maintenance.

The problem – is the statement of unsatisfactory condition or abnormal functioning of the system (object) which requires its solution. In order to solve the problem it should be analyzed. The analysis begins with a description. The description of the problem can be made from a physical or informational point of view. Physical description characterizes the processes or actions that led to the critical state. These can be wear, aging, failures, the influence of operational and human factors, changes in operating conditions, changes in requirements etc. Information description – is a qualitative and quantitative description of critical and other possible states of the system.

It might be an abnormal functioning because of internal processes in the system. For instance, declined reliability, reduced efficiency (economic, dynamic, physical), a decrease in the safety of operation, threats to the environment or human life. Changes in the system status might be also associated with changes in external influences or operating conditions. In other words, the problem – is a compelled necessity for changes in order to bring the system to the desired state: the development of a new one, restoration or improvement of the existing one. And the solution to the problem is to determine the optimal set of changes for bringing it to the optimal state under the given conditions. In this regard, it is necessary to find a solution but rather a set of solutions that would allow restoring or creating a new system for the desired state (required capabilities) for the given requirements and existing conditions. Due to the specifics there might be two strategies for solving the problem: a radical or compromise ones. The radical one is the creation of a new progressive system even with a certain stock of updated features and capabilities using modern technology. Of course, such a solution will have the highest efficiency of further use of the system. But due to real possibilities it is not always possible or rational to do so.

A compromise strategy is the most commonly used but at the same time it should be clearly understood that the restoration or modernization of an existing system that has fallen into a critical state is not always possible to achieve the level of efficiency of the newly created system. Both in the first and in the second cases it is necessary to search the optimum decision and technology of its achievement. However they are strategically different. In the first one we search a structure of equal subsystems capabilities that provide the maximum state of the desired efficiency. In the second one – we search the optimal efficiency increase of one or more subsystems in order to ensure a close to normal level of system efficiency or its minimum allowable level. And it is the most important that the system sets the requirements and conditions for the decision to upgrade these subsystems and while it is necessarily should be taken into account the impact of subsystems that have remained unchanged. Based on this, it is necessary to find a solution that would increase the subsystems efficiency at least to the minimum allowable level of efficiency of the system in general.

2. Statement of the article aim

Despite the vast experience gained by mankind over the next 150-200 years in solving the problem of finding a solution, the problem still remains. The global problems have been developed in more detail and they are being solved. Classical theories of operations research and decision-making work in economies, military affairs, public and regional government etc. But there are a large number of small, but no less important, problems that need to be solved every day and at every step. Unfortunately, in this case the powerful SDM system slows down significantly due to its own specifics: staff qualifications, the lack of data, the lack of theoretical developments as a result of the wide field of solutions and multifactorial impact on it etc. And, the most interesting thing in this situation, is that the solution to any problem is very individual, which, in fact, makes it impossible to use models, data, criteria (target functions) or computer programs designed for other problems. Formally, no one forbids it but it is necessary to study wether the use of the finished product is suitable for solving a new problem (what is wrong with such use).

Therefore, the task was to find an opportunity to find a solution in such difficult circumstances.

3. Method description

Let's suppose there is a system that is in a critical situation and its further use, for various reasons, has become impossible or impractical. To resolve the situation, it must be analyzed in terms of causes, effects, changes in conditions that brought the system to a critical state in order to be able to return to normal operation. Based on the analysis it is necessary to determine:

- a strategy to bring the system out of critical condition;
- to analyze the external and internal influences that led the system to this state;
- to determine the significance of the influence of certain factors on the functioning of the system and to change its state;
- to identify uncertainties and identify the ways to increase information content in the necessary directions in order to reduce their impact;
- to analyze the possibility of changing the system and, accordingly, critical subsystems in order to reduce the impact of negative factors;
- to determine the technology of improving the efficiency of the system in the direction of changing the functioning or structure of the system;
- specification of the tasks of finding optimal solutions as for bringing the system out of critical condition;

- determination of stages and performance of search of optimum decisions at each stage according to the corresponding criteria;

- to develop or use the necessary technologies in order to achieve the optimal state of the system in accordance with the solutions found;

- assessment of the possible system functioning, restored or improved by the decisions made and relevant technologies;

It should be borne in mind that:

• the problem system should be considered as a subsystem of the higher level system in which it is included;

• its level of efficiency is determined by the higher level system;

• the input data for finding a solution for the studied system are the internal influences of the higher level system;

• uncertainty (lack of information) is overcome by studying the higher level system and increasing information in relevant areas;

• problem solving is an algorithm or technology for finding and achieving optimal or rational solutions at each stage, based on the conditions and possibilities of their implementation;

• optimality or rationality of decision-making should be sought at each stage based on the principle of equal entropy.

Uncertainty is the lack or incompleteness of information, which is also probable, the lack of models to describe the effect-forming processes in the new external and internal environment, the difficulty of taking into account the factors of influence, incompleteness or inaccuracy of data, etc.

Uncertainty leads to errors in forecasting the new state of the created system, in fact it leads to possible losses (effect, gains, profits, opportunities), which, in turn, are difficult to assess. To some extent, they can be assessed by the risk of loss. Assessing losses or risks does not fully characterize the effectiveness of the solution. On the one hand, the minimum loss or the minimum risk gives a certain guarantee of efficiency: "if we lose little, we gain a lot." But this is not always the case. To get more you need to risk something. It would be logical to look for the optimal balance between gains and losses. But their assessment depends on the level and type of uncertainty. So uncertainty must be overcome. It sounds judiciously, but the uncertainty comes from trying to solve a new situation for new conditions. This means that it is necessary to determine the situation for new conditions, which is impossible, or to lead to a situation in the previous conditions, which is not necessary. Thus, uncertainty cannot be overcome, it can only be changed, as far as possible, for these conditions, while estimating the amount of losses. In other words, it can be changed by searching the opportunities to increase the informative content of the decision support system, assessment of losses and gains.

Consider the main possible components of uncertainty. First of all it is uncertainty of:

• situations;
• problems;
• problem-solving strategies;
• models of basic processes description;
• time;
• goals;
• criteria;
• information;
• factors of influence;
• losses and gains;
• risks.

Uncertainty of the situation arises in cases of difficulty in determining the causes of its occurrence and the strategy of bringing the system out of it. It leads to vague wording of the problem and strategy for solving it.

Uncertainty of the problem arises from the difficulty or inability to understand or describe the nature of the processes that create the situation.

The uncertainty of the strategy for solving the problem arises from the difficulty of forecasting the state of the system or the lack of scientific research into the processes that led to the situation or abnormal functioning.

Uncertainty of models arises from the complexity of describing effect-forming processes of the situation or the use of known models that partially or completely do not meet the new conditions, as well as in the absence of scientific developments of the model.

Uncertainty of the time to make a decision leads to hasty underdeveloped decisions instead of using some time to do more intimate research and increase the informative content of the system.

Uncertainty of the goal arises from a shallow understanding of the causes of the problem and the main effect-forming processes, which leads to incorrect or unclear formulation of the goal.

Uncertainty of the criterion or criteria arises from the impossibility or misunderstanding of the means of unambiguous assessment of the effect-forming processes results when the situation changes.

Uncertainty of the information needed to make a decision arises in cases in which it does not exist at all or it is not in the right form, or there is no time to obtain it, or its insufficiency (incompleteness), or it is incorrect, inaccurate, or consists large errors.

Uncertainty of influencing factors arises in cases of absence or incompleteness of the necessary information for the correct analysis of influences of external and internal factors on efficiency of the system's functioning.

Uncertainty of losses (risks) and gains does not allow assessing the effectiveness or even the correctness of the prepared decision.

Having a pretty complete thematic geographic information system, which includes the object of study, it may be conducted a detailed analysis of the situation in which he found himself, external and internal factors and their effects on its functioning, which will correctly formulate the problem, detail the structure of uncertainties, explore each trying to reduce their negative impact by increasing the informative content of the decision support system, modeling the main effects-generating processes, the use of adjusted information products analogues, using expert assessments with mandatory assessment of the balance of gains and losses in the right dimension.

Spatial analysis based on GIS allows to consider the situation in conjunction with the environment and identify the problem more fully and efficiently, and, consequently, to make a more reliable decision. Moreover, analyzing changes in the system itself and the systems which include it, you can assess or ensure that the solution is positive in the desired direction and does not lead to negative changes in the environment.

It should be noticed that the concept of space is not limited to physical objects in the complex. This can be an information space, a field of data, various kinds of influences, effect-forming processes, a subjective field of "vision" or influences, a field of technology, etc. The most interesting thing is that GIS technologies allow, depending on the state of science and technology, to describe these spaces and, to some extent, even combine them, which greatly expands the capabilities of GIS in decision support technologies. The harmonious combination of spatial and attributive components provides opportunities based on sufficient primary data and already acquired information from previous studies allows to obtain the necessary secondary information to support decision-making and, most interestingly, increasing information in the right direction to reduce uncertainty, which in turn affects SDM qualitatively.

As for GIS-based SDM, the SDM field almost completely covers all areas of solution. If the use of the first GIS was aimed at collecting, plotting, monitoring mostly spatial data, it became clear soon that the harmonious combination of spatial and attributive data in one information system greatly increases the ability to find a better solution for its technologies. Moreover, GIS has given a rise to new SDM technologies and significantly expanded the horizons of their use.

In fact, it is quite difficult to find the optimal solution, taking into account all the factors of influence. And if we take into account their mutual influence and the fact that each of them brings its own uncertainties, then solving the problem becomes very difficult or even impossible. This situation can be overcome by making assumptions about the insignificant influence of most factors and their uncertainties, except for one or more of the strongest or most definite one, which allows us to focus on these areas. But at the same time there are some doubts about the correctness of the decision. As for the criteria of effectiveness, it is difficult to determine them by the same logic. The economic criterion helps in many cases, but certain difficulties arise as for its calculations because of the conditions of unaccounted for uncertainty.

There is a possibility of solving a complex problem with a help of its conditional division, after the analysis, on the logical functional stages (sub-problems), at which the each next step is the optimal solution for solving the previous one. It provides significant advantages, and, most importantly, more correct solution to the problem in general. The solution of the last stage will be the solution of the main problem. A step-by-step solution to the problem provides:

- simplified solution of sub problems;
- reduction of uncertainties at stages;
- simplification of finding a solution in stages and in general;
- simplification of determining the criterion of efficiency up to high-quality intuitive choice of the best option;
- ability to take into account the influence of only one factor at the stage;
- ability to take into account indirect data to reduce uncertainty and to determine the criteria at each stage;
- significantly reduce the number of possible options, which is important for quality or intuitive selection criteria;
- ability to qualitatively and, to some extent, quantify the mutual influence of factors on decision-making.

The number of possible multiple solutions decreases because we have a reverse tree – the best option of the previous solution is considered at each subsequent stage, from which the possible options for this stage will be selected an optimum variant, for which the search for solution will be performed at the next stage etc.

If there is a need for clarification, you can go back a few steps and go through a new branch to the end.

We propose to increase the efficiency of the researcher's brain or expert's by assisting him with a powerful device of computer-aided design systems (CAD, and GIS is also CAD), which is able to receive and keep in mind many solutions and provide comparative analysis of possible options and take a well-considered decision at each stage.

The using of modern GIS allows developing options for possible solutions that can not be done manually relatively quickly and effortlessly. Decision options can be developed simultaneously by separate small offices to eliminate intellectual plagiarism and increase the individuality of each project. Each office divides the project into stages according to the principle of completed functionality. For example, the stages of development of the technical task, the choice of technical proposal, the choice of the effect-forming process, the choice of the planning basis, the construction of possible solutions at the stage from general to phased detail, etc. The amount and depth of detail is not limited in principle, the more detailed the functionality and technology, and depending on how it will work, the more likely to get the perfect solution. At each stage, possible options are developed, analyzed, compared and a decision is made on the further development of the selected option at the next stage, where options are developed, decisions are made, the next stage, etc. The decision is made by qualitative analysis, expert evaluations or comparative analysis between project options. There are two aspects – the development of solutions and their evaluation. As a practice shows, the same function can be provided by different technological solutions. Many of them have already been implemented somewhere and by someone, to one degree or another, for different conditions. There are also completely new implementations, some of which are declared inventions, and others are either out of time or practically ineffective. Of course, all the developed options have their own characteristics, qualities and properties. It is very difficult to evaluate them from all points of view, and especially from the point of view of efficiency, but to a certain extent it is possible if to carry out the comparative qualitative analysis purposefully and by a certain technique.

An analysis of options and decision-making has certain difficulties and features:

- as a rule, there are a large number of influencing factors and evaluation criteria;
- determination of quantitative indicators of criteria is almost impossible at this stage;
- if it is necessary, the severity of the influence of factors can be determined depending on the direction of assessment, conditions and requirements;
- it is desirable to take into account the experience of functioning of analogues;
- as a rule, the expert assessments of external experts are not used in terms of confidentiality;
- researchers can use the expert assessments with advanced methods in complex cases of comparative analysis;
- all qualitative indicators are used in the analysis and comparison taking into account weight, but the indicators of reliability and safety are decisive at equal weights.

Even for an experienced researcher who intuitively feels novelty, quality and functionality it is a quite a difficult task to conduct a comparative analysis of a new solution, and, moreover, to choose the best of several new solutions. Again, if we divide the global analysis into a number of areas, we will allow a differentiated approach to solve the problem, taking into account the novelty, efficiency, manufacturability, cost and other "pros" or "cons" from different points of view. And it is, most importantly, to take into account the main focus of the decision. These areas of analysis can be formulated in such a way:

- how advantageously the new solution differs from the already known ones;
- what the benefits are and how many of them the object will receive while implementing the decision;
- how interesting this option is in terms of the future using of the system at this stage and in the future;
- how much efficiency will increase (decrease);
- how much the cost will increase (decrease);

- how difficult it is to ensure the implementation of the solution;
- how much the cost will increase using the chosen solution compared to improving the efficiency or quality of the system.

For convenience of comparison, it is possible to use, if it is necessary, the assessment of aspects of the decision in points, taking into account the weights. In disputes, a commission

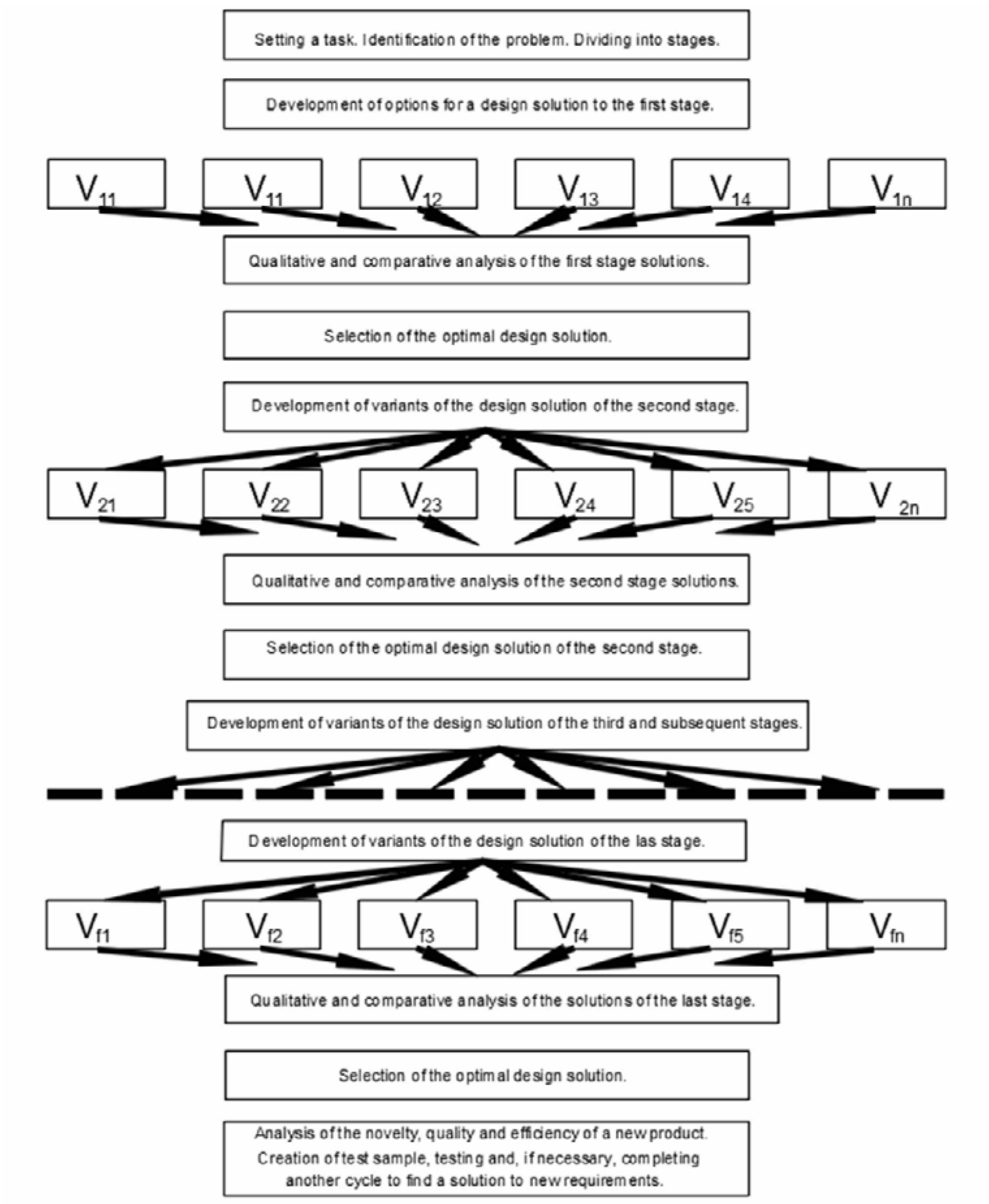

Fig. 1. The scheme of a step-by-step search for the optimal solution

of higher rank is convened or independent experts are invited. The selected option at each stage becomes the basis for the options of the next stage, etc. Thus, the solution is gradually and consistently refined, detailed and improved. Consider the scheme of a step-by-step search for a solution to explain (fig. 1).

The obtained "inverse" tree of the step-by-step search of design solutions allows obtaining a perfect (optimal) solution without using complex mechanisms for finding a solution by one criterion, which is almost impossible to determine. Moreover, according to such a scheme, a qualitative comparative analysis of options is quite sufficient, in which the researcher himself acts as an expert. This analysis, however, allows diving even deeper into the process of finding the optimal solution. The method does not preclude the use of weight points or the invitation of outside experts in controversial situations.

The step-by-step search for a solution can be illustrated by an example of solving the problem of creating a beauty salon (a simple and clear option is chosen for illustrating this). The following steps can be suggested:

- determining the type of salon;
- choice of the room type;
- determination of the financing method;
- choice of the location (according to the suitability of microdistricts for the location of the salon);
- determining the flow of possible orders (customers living around and according to the ability to get there);
- determining the structure of the salon (analysis of possible plans);
- optimization of the number and types of workplaces;
- optimization of staff;
- calculation of profit for the formed salon options;
- decision making and justification.

4. Conclusions:

- the use of GIS significantly expands the possibilities of search and decision-making;
- creation of the thematic GIS with constant replenishment of primary data and formation the necessary secondary data on their basis allows to increase informative content in the necessary direction and to reduce uncertainties by that;
- the use of the method of the step-by-step decision-making on the basis of GIS allows to make decisions in case of impossibility to find analytical dependences for the target function and complex criterion;
- since GIS belong to the category of CAD, the method of the step-by-step decision-making can be used for an optimal design of complex spatial objects or spatially distributed processes (transportation, logistics, etc.).

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