Peculiarities of a Decision-Making Support System Development in Conditions of Uncertainty

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Abstract

The article analyzes existing methods and approaches that are used in the process of supporting decision-making in conditions of uncertainty, which made it possible to identify the peculiarities of their application and outlined the range of problems that arise. A conceptual diagram of the system consisting of the following subsystems was built: the core subsystem, the knowledge clarification subsystem, the communication subsystem, and the pairwise comparison subsystem. The main processes of the core subsystem are: preliminary collection of knowledge from the subject area, construction of a decision tree, finding the optimal decision-making strategy, saving/loading the results. The main process implemented in the knowledge clarification subsystem is detailing and verification of knowledge from the subject area. The communication subsystem implements the processes of explaining the obtained results and outputting auxiliary information. The pairwise comparison subsystem allows you to determine probabilities by comparing events pairwise and evaluate sequences of user statements. The sequence of the main stages of analysis in the decision-making process under conditions of uncertainty is defined and the justified feasibility of its solution using the decision tree method is established, as well as the corresponding algorithm is developed. The mathematical description of the specified process is performed using the algebra of algorithms. The design of the software system was carried out using a structural approach and displaying the created diagrams in accordance with the IDEF0 standard. The study presents a functional model and its decomposition, which created a basis for understanding the features of the functioning of the decision-making support system under conditions of uncertainty. An applied software system has been developed using the C++ language, which implements the decision-making support process under conditions of uncertainty. With the help of the developed system, it is possible to build a decision tree using a friendly user interface without prior special training. At the current moment, the software solution works in the form of a prototype.

Keywords

decision-making support, system, decision tree, design, functional model

1. Introduction

Decisions, which in most cases a person makes in his or her professional or personal life, mostly do not require significant mental costs. In some cases, the best option is clear without special analysis, in others, the decision is not so important to pay special attention to it. However, from time to time you may find yourself in a situation where it is necessary to spend time and energy to carefully and systematically consider various decision options [1, 2].

Nowadays, most commercial and government organizations do not make important decisions without the use of computer support. Hardware and software capabilities are constantly improving, corporations are developing distributed systems that allow access to information that is spatially distant.

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At the same time, the requirements for the personal qualities of the manager - his intelligence, subjective assessment capabilities, erudition, and ability to find solutions - are not decreasing, but increasing. Making decisions is a daily activity of a person, a part of his or her daily life. For the most part, it consists of possible decision options generation, their evaluation, and the selection of the best of them [3, 4]. At the same time, in the process of choosing alternatives, it is necessary to take into account a significant number of conflicting requirements and, therefore, to evaluate decision options according to many criteria. Conflicting requirements, ambiguous assessment of situations, and errors in choosing priorities significantly complicate the decision-making process. But the most difficult thing is that the range of tasks solved by a person in various spheres of his activity have changed, and new complex and unusual problems have arisen [5].

For centuries, people have been able to make decisions based on one or two major factors, to the exclusion of many others. They lived in a world where the pace of environmental change was slow, and new phenomena appeared one after the other, not all at once. As for the present, uncertainty is an integral part of decision-making processes, which is associated with both incomplete knowledge about the decision-making problem and a vague understanding of the goal by the person making it. As a solution to the specified situation, it is possible to use both the subjective assessments of experts (obtained on the basis of one's own experience or intuition) and the implementation of a system of backup options [6]. However, their application requires a detailed analysis of the subject area, which is not always possible within the framework of limited time characteristics. Therefore, the creation of a decision-making support system in conditions of uncertainty will allow to improve the quality of the decisions made, which will ultimately reduce the consumption of various types of resources in the process of their implementation.

1.1 Analysis of recent researches and publications

After analyzing the literary sources, it can be concluded that uncertainty creates many risks in the decision-making process and the specified industry is one of the leading in our time. If we analyze the information about developed countries, the financing of scientific research in the field of risk analysis and assessment is constantly increasing in them. In particular, in the US chemical industry, 25–30% of funds for scientific development are allocated to solving risk problems, and in pharmacology - more than 50% [7]. The theory of risk is intensively developing, but many foundations of this science remain debatable. Howard Raiffa was one of the first to study the topic of decision-making under uncertainty, who defined the problem of decision-making in situations where the decision-maker does not have complete information about potential consequences. He considered the issue of using statistical data, the strategy of conducting additional experiments to clarify information, the problem of building probabilistic models to describe the degree of subjective confidence in certain consequences of a decision, the rules for distributing risk between several people, and group choice algorithms [8].

In management theory, considerable attention is paid to the study of general decision-making technology, that is, the division of the entire process into several interconnected stages. The simplest decision-making technology is intuitive, in which the decision is determined by the accumulated experience of the management subject in the decision-making process in similar situations [9]. At the same time, the main criterion is the smallest losses to achieve the goal. If similar decisions have not been made before, the probability of making a wrong decision increases. The advantage of intuitive technology is the speed of decision-making, and the disadvantage is the high probability of error [10]. In contrast to intuitive technology, rational technology includes the following stages: decision preparation, decision making, and decision implementation. In the simplest case, after identifying the problem and establishing the factors that led to its emergence within the framework of existing resource or institutional limitations, solutions are developed, from which the best is chosen - the one that meets the stipulated criteria for solving the problem. The number of options offered to solve the problem depends on many factors, in particular, available resources, time, availability of information necessary to substantiate the decision, etc. [11].

An important issue in the decision-making process is determining the expediency of applying group or individual decisions. A model that allows you to solve this question was developed by Rick Roskin [12]. The created model has the form of a decision tree, which contains four components: the time factor, the level of trust between the manager and subordinates, the importance of making the right decision, and the importance of obtaining consent to implement the decision. The model requires the manager to weigh each of these variables and determine how he should make decisions: individually or with the help of a group. If time is a critical factor, the decision should be made on an individual order style basis. When time is not a critical factor, the factor of trust between the manager and subordinates must be taken into account. When it is high enough, the manager should use the 'consultation' style. If trust is low, then the next factor should be taken into account - the quality of the decision made.

During the research, it was possible to determine that in the process of decision-making in conditions of uncertainty, the methods of expert evaluations are most often used. This class of methods represents methods of organizing work with expert specialists and processing experts' opinions expressed in quantitative and/or qualitative form with the aim of forming a body of knowledge for making managerial decisions [13]. There are different methods of obtaining expert evaluations. In some, they work with each expert separately, he does not even know who else is an expert, and therefore expresses his opinion independently of authorities (Delphi method) [14, 15]. In others, experts are gathered together to prepare materials, while experts discuss the problem, learn from each other's experience, and reject erroneous opinions ('brainstorming' method [16]). Another method that identifies alternative decisions and the corresponding return probabilities for each combination of alternatives is 'decision trees'. Analyzing a problem using a 'decision tree' includes the following main steps [17, 18]: defining the problem, structuring and displaying the 'decision tree', determining the probabilities of individual states, evaluating the returns for each possible combination of alternatives, and choosing the optimal solution. The given list of methods that are used in the decision-making process under conditions of uncertainty is not exhaustive. But the analysis shows that there is no ideal method, and the choice of one or another depends on the input conditions and the expected result. Given that, it can be concluded that in the implementation of this task, existing methods can be applied by adapting them depending on the input conditions, which is planned to be implemented in the designed system.

1.2 The main tasks of the research and their significance

The purpose of the study is to develop a decision-making support system under conditions of uncertainty. The conducted research will provide means of obtaining the subjective probabilities values based on pairwise comparisons and will allow to increase the reliability of the received information and assess the level of contradiction of statements. To achieve the goal, the following tasks must be solved: analyze the existing approaches and methods used in the decision-making process under conditions of uncertainty; determine the main tasks that arise at the same time; develop a structure and determine the main components of the decision tree; formulate a decision-making algorithm using the method of the same name; carry out a mathematical description of the specified process using the algebra of algorithms; design a software system using a structural approach; construct an applied software system that implements the decision-making support process in conditions of uncertainty.

The results of the research solve the actual scientific and practical problem of obtaining the subjective probabilities values, which are based on pairwise comparisons and allow to increase the reliability of the received information and assess the level of contradiction of statements, which in turn, will provide mechanisms to support decision-making in conditions of uncertainty.

2. Major research results

The technological process of decision-making under conditions of uncertainty in decision-making support systems can be represented by a sequence of stages: obtaining information, structuring and presenting information in the form of a tree-like structure, finding the numerical characteristics of decision tree nodes, and determining the optimal strategy. The sources of input information are experts in a certain subject area, while the user collects the specified information and transmits it into the system through the user interface [Decision Making]. In order to present the main aspects of the studied subject area, its conceptual scheme was built, which is shown in Fig. 1.

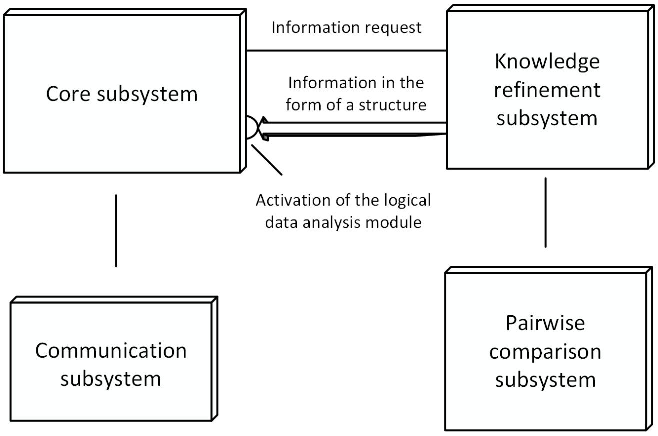


Figure 1: Conceptual diagram of the designed system

As can be seen from the figure, the key subsystems are: the core subsystem, the knowledge refinement subsystem, the communication subsystem, and the pairwise comparison subsystem. The main processes of the core subsystem are: preliminary collection of knowledge from the subject area, construction of a decision tree, finding the optimal decision-making strategy, and saving/loading the results. The main process implemented in the knowledge clarification subsystem is detailing and verification of knowledge from the subject area. The communication subsystem implements the processes of explaining the obtained results and outputting auxiliary information. The pairwise comparison subsystem allows you to determine probabilities by comparing events pairwise and evaluate sequences of user statements.

In order to determine the interaction features in the designed system, the functional modeling methodology and its IDEF0 standard, which is intended for the formalization and description of business processes, were used. A context diagram reflecting the decision-making support process in conditions of uncertainty is presented in Fig. 2 [19, 20].

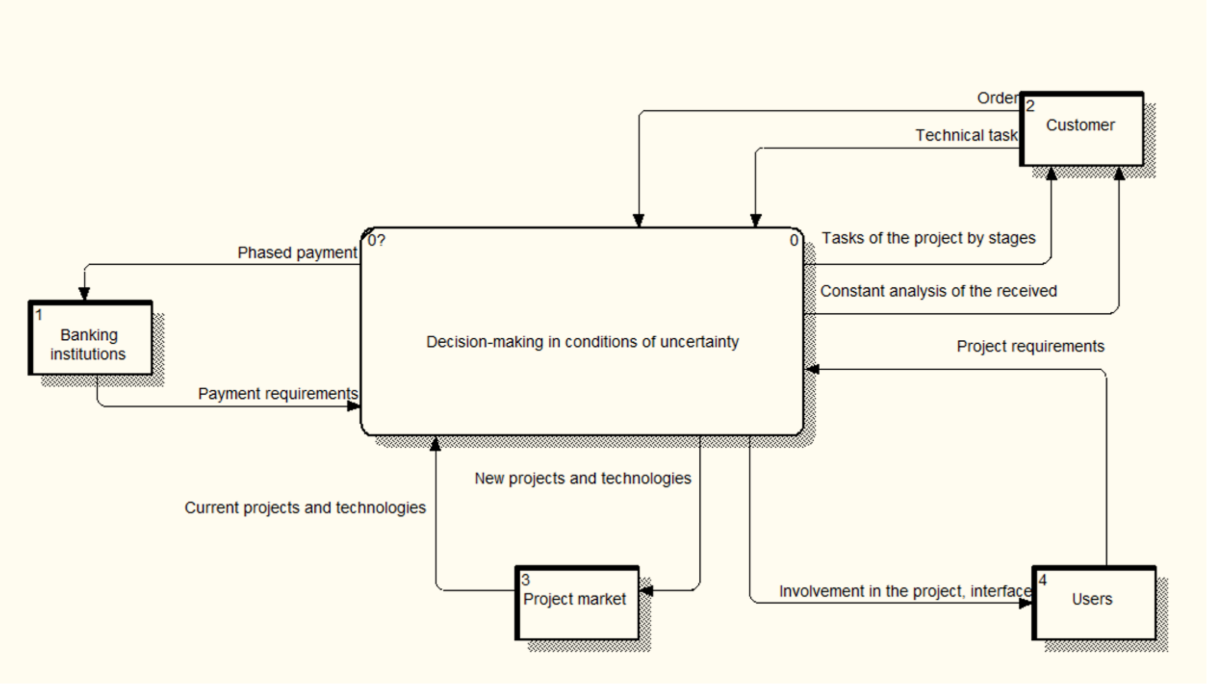


Figure 2: Context diagram of the designed system

Among the set of external entities of the designed system, the following were highlighted: customers who form the tasks and goals of the project, in which important decisions must be made; users, interaction with which allows the system to determine the needs of the project and its possible risks in more detail; project market, which provides information about existing projects and their impact. In order to detail the described functionality, we will perform the process of the created model decomposition. Taking into account the specifics of the task, the decomposition diagram shows four main processes: the process of identifying uncertainties, the process of analyzing and evaluating the results of decision-making, the process of project planning and operational management, and the process of monitoring [21].

The information that will be used by the decision-making system under conditions of uncertainty is located in certain data stores. Data flows, which are received by the system from the context diagram, are entered into data stores. In particular, the Customer's Terms of Reference are recorded in the project execution plan repository. Standardized requirements received from organizations involved in standardization and certification influence the project execution plan and project characteristics. Order data is entered into the order portfolio repository, which contains information about accepted and estimated orders. Project requirements formulated at the top level of the system hierarchy are recorded in the project specification repository and are the input stream for the uncertainty identification process. On the basis of the data contained in the storage of project implementation status, constant step-by-step analysis of the received data is carried out, which is the output stream for this level of system decomposition (Fig. 3).

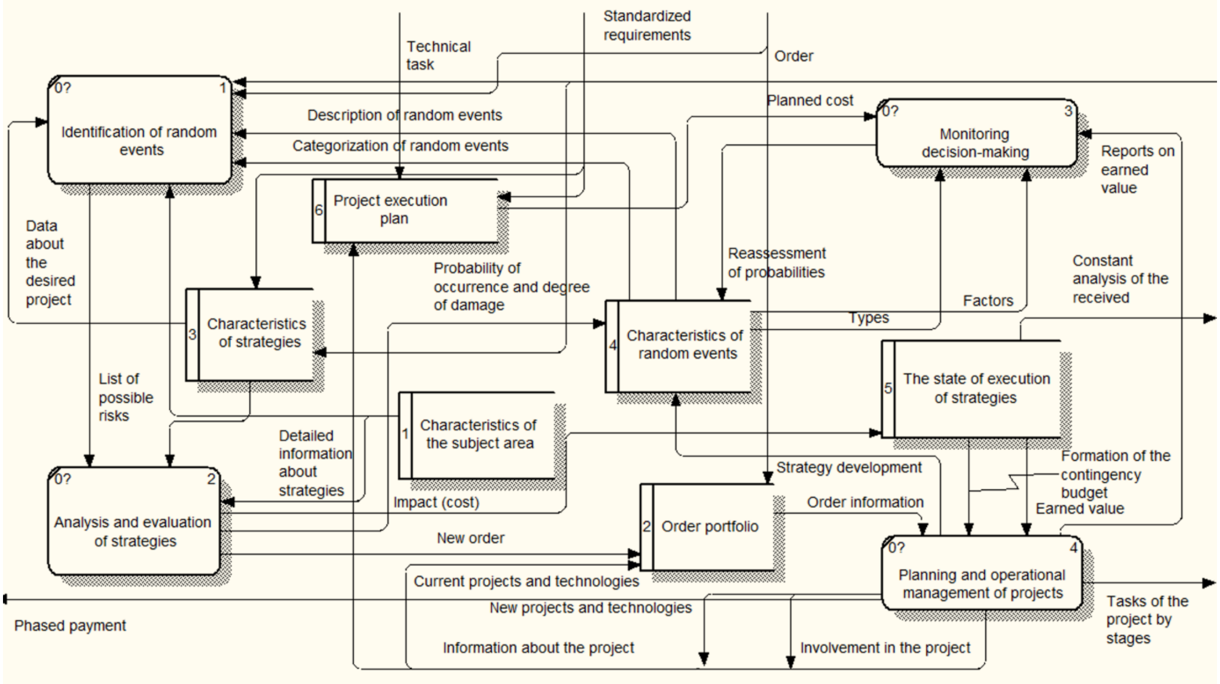


Figure 3: Decomposition diagram of the first level

There is a constant asynchronous exchange of data between the defined processes of the direction and data stores, and the processes themselves. Let's consider the main input and output streams for each process:

- The result of the Uncertainty Identification process is a detailed list of random events that can actually occur during the implementation of the decision-making strategy.
- The inputs to the Make and Explain Decisions process are order information from the Order Portfolio, as well as data from the Project Status repository in the form of earned value and contingency budget data. The result of this process for the system is the development of decision-making strategies.
- For the Decision Implementation Monitoring process, the input data is the planned project cost, which comes from the Project Implementation Plan repository. The initial data for Monitoring is a regular recalculation of the probabilities of random events.

To implement the system based on the presented functional model, it is proposed to use a set of production rules as the basis of software tools for supporting decision-making in conditions of uncertainty [22]. In particular, the system will ask the user a set of questions (such as - what decisions can you make to solve this problem?; if you make X decision, what events may occur as a result?; if Y event occurs, what are your actions?; what are the expected profits (losses) from the implementation of a certain strategy?), as a result of the answers, a decision tree will be built and the quantitative characteristics necessary for further calculations and display of recommendations for decision support will be determined. Questions will be asked in a logical sequence and will depend on previous answers. In the deterministic setting, the decision-making task can be described as follows [23, 24].There is a certain set of decisions (actions) D and a set of results R, which are achieved when performing actions with D, more precisely, the mapping:: $f: D \to R$ is given such that the decision $d \in D$ leads to the result $r = f(d) \in R$. If the set R is ordered by an arbitrary relation such that for $r_1, r_2 \in R$ he relation $r_1 \leq r_2$ means «r_1 is not worse than r_2», then the problem of choosing the best solution is presented in the form of an ordinary optimization problem: $f(d) \to \max_{d \in D}$.In practice, the choice of a fixed solution, as a rule, does not guarantee the achievement of a fully defined result $r \in R$, which can be represented in a mathematical model as an influence on the result of an uncertain state of the environment. Let all possible states of the environment be described by the set S, then obtaining the result can be presented in the form of a mapping $f: S \times D \to R$, so that the decision $d \in D$ under the condition that the environment is in the state $s \in S$ leads to the result $r = f(s, d) \in R$. Since the state of the environment s is unknown at the moment of decision-making, the representation of the decision-making problem in the form of$f(d) \to \max_{d \in D}$becomes impossible. Within the framework of risk theory [25, 26], it is natural to assume that the uncertainty of environmental states is probabilistic in nature. Such uncertainty can be modeled by introducing the structure of the probability space (S, A, P),on the set S, the structure of the measurable space (R,B) on the set of results and considering the mapping f to be measurable (for each fixed$d \in D$). At the same time, each solution $d \in D$ can be matched with the mapping $f_d: S \to R$ according to the rule$f_d(s) = f(s, d), s \in S$. The distribution on the set of states of the medium P and the mapping f_d generate on (R,B) the probability distribution P_d: $P_d(B) = P(f_d^{-1}(B)), B \in B$. Thus, each solution $d \in D$ leads, in the presence of uncertainty, to some distribution Pd. Choosing the best solution means choosing the "best" distribution from the set of distributions $F = \{P_d, d \in D\}$.

The decision-making process using a decision tree generally involves the following steps [18].

- Problem formulation. First of all, it is necessary to discard factors that are not relevant to the problem, but among the remaining set, distinguish essential and non-essential. This will make it possible to bring the description of the decision-making task into an analyzable form.
- Construction of a decision tree according to the standardized algorithm [18].
- Assessment of probabilities of environmental states, i.e. comparison of the probability of occurrence of each specific event. It should be noted that the indicated probabilities are determined either on the basis of available statistics or by expert means.
- Establishing gains (or losses) for each possible combination of alternatives (actions) and environmental states.
- Solving the problem.

At the same time, the indicator of the usefulness of the consequences is calculated starting from the terminals of the tree and directed to its trunk, that is, it goes from right to left. At the same time, the following rules must be observed: for each case node, the mathematical expectation of the indicator must be calculated, and when approaching the solution node, the value of the indicator assigned to the corresponding branch must be maximized (choose the maximum of them). In view of the given information, in the course of its operation, the designed system should perform the following functions [27]:

- build a decision tree based on communication with the user;
- analyze input and information obtained as a result of calculations;
- provide advice on choosing the optimal solution (decision-making strategies)
- provide help and save the obtained results.
- Input is information received from the user about the characteristics of the subject area in which important decisions need to be made. This information includes:
- a list of all possible solutions to the problem;
- a list of all possible random events;
- probabilities of random events;
- evaluations of strategy implementations (profits/losses, or other evaluations)

- The initial data are:
- a decision tree designed by the system, which is displayed to the user with all the numerical characteristics of its nodes;
- the recommended decision-making strategy (the decision tree displays those vertices of decisions that are recommended to be adopted within the framework of this strategy);
- the expected monetary values of each vertex of the tree.

The mathematical description of the specified process is performed using the algebra of algorithms [28]. The first stage of the implementation of the algebra of algorithms is the description of uniterms and the synthesis of sequences, which is given below.

Formed uniterms: *C(R)* – uniterm for creating the root of the Root tree; *CNode=Root* – determines the location of the node; *C(adv)* is the uniterm for creating a child vertex of *Adv*; *P(Adv)* is the uniterm of writing *Adv* into the queue; *Rw(Gq)* is the global queue rewrite uniterm; *Cl(Lq)* is the uniterm of cleaning the local queue; *Req(CNode)* is a uniterm for requesting information on *CNode;* u_1 – check for the presence of a solution; u_2 – checking the final *CNode,* u_3 – checking if the global queue is empty. As a result of the use of the apparatus of the algebra of algorithms, the following sequences and eliminations were synthesized:

S_1 – is the sequence of system operation in the case of a solution, when the CNode is not final and when the global queue is not empty;

$$S_1 = \left(\begin{array}{l} \overparen{C(R)\ ,\ CNode=R} \\ , \\ \overparen{C(adv)\ ,\ P(adv)} \\ , \\ \overparen{\overparen{\overparen{\overparen{Rw(Gq)\ ,\ Cl(Lq)}\ ,\ CNode=S}\ ,\ Req(CNode)}\ ,\ CNode=S} \end{array} \right.$$

S_2 – sequence of system operation in case of no solution, when the CNode is not final and when the global queue is not empty;

$$S_2 = \overparen{\overparen{C(R)\ ,\ CNode=R}\ ,\ F}$$

S_3 – is the sequence of system operation in the case of a solution, when the CNode is finite and when the global queue is not empty;

$$S_3 = \overparen{\overparen{C(R)\ ,\ CNode=R}\ ,\ \overparen{\overparen{C(adv)\ ,\ P(adv)}\ ,\ F}}$$

S_4 – sequence of system operation in case of no solution, when the CNode is final and when the global queue is not empty;

$$S_4 = \overparen{\overparen{C(R)\ ,\ CNode=R}\ ,\ \overparen{\overparen{C(adv)\ ,\ P(adv)}\ ,\ CNode=S}}$$

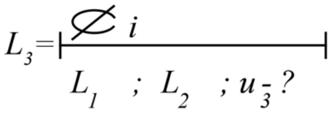
L_1 – check for the presence of a solution;

$$L_1 = \vdash\!\frac{\varnothing\ i}{S_1\ \ ;\ S_2\ \ ;\ u_{\bar{1}}\,?}\!\dashv$$

L_2 – verification of the final *CNode*;

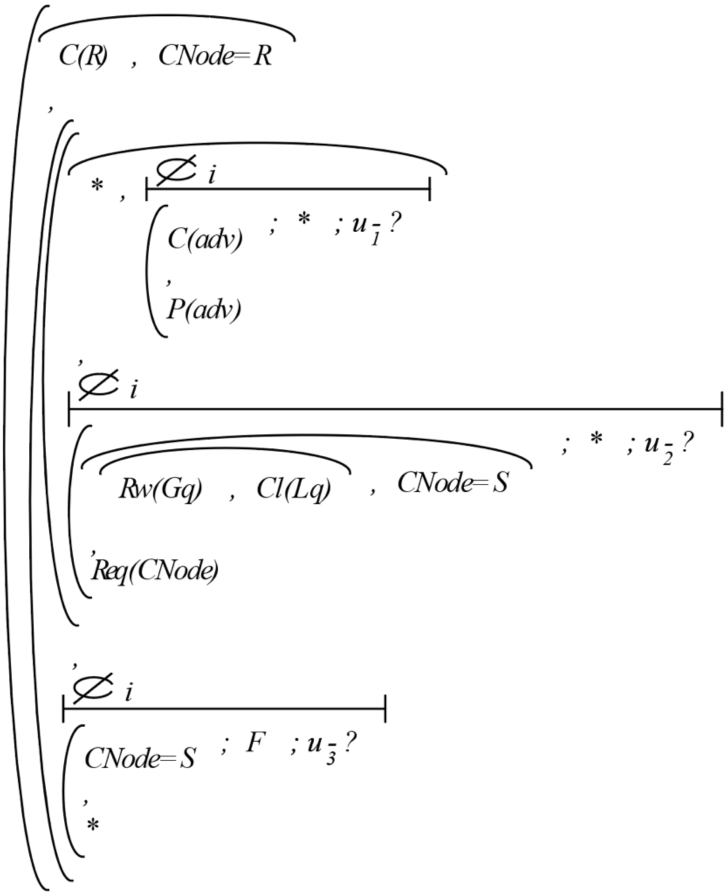
$$L_2 = \vdash\!\frac{\varnothing\ i}{S_3\ \ ;\ S_4\ \ ;\ u_{\bar{2}}\,?}\!\dashv$$

L_3 – checking whether the global queue is empty.



The next stage is the substitution of the corresponding sequences in the elimination.

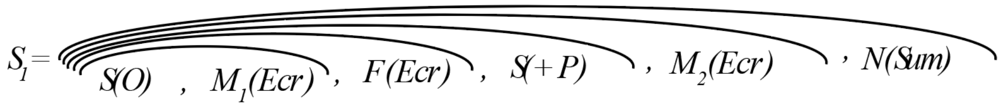
As a result of using the properties of the algebra of algorithms [28], we subtract the common uniterms by the sign of the elimination operation and obtain the following formula of the algebra of algorithms:



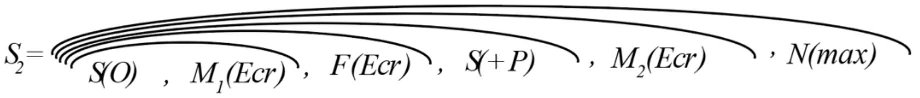
Formed uniterms: *S(O)* – initialization uniterm of the vertex counter; *M_1(Ecr)* – uniterm for assigning additional properties of the first level to the vertex *N*; *F(Ecr)* – uniterm for the search for the properties of the vertex *N*; *S(+P)* – uniterm of the vertex counter increment; *N(Sum)* – is the uniterm for assigning the result of the solution case at the vertex *N*; *N(max)* – is the uniterm for assigning the result of the case of the absence of a solution at the vertex *N*; u_1 – check for the presence of descendants of vertex *N*; u_2 – the conditional uniterm of the end of the search, u_3 – the uniterm of the final weight check; u_4 – is the uniterm for checking for the presence of a solution at the vertex of *N*.

As a result of the use of the apparatus of the algebra of algorithms, the following sequences and eliminations were synthesized:

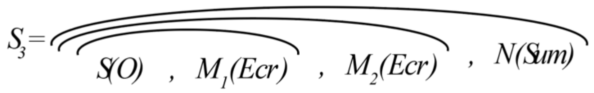
S_1 – sequence of system operation in the case of continuing the search procedure and assigning the result in the case of a solution at the vertex *N*;



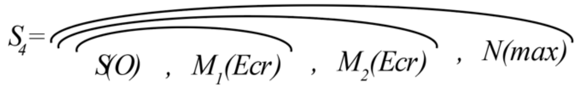
S_2 –sequence of system operation in the case of continuing the search procedure and assigning the result in the absence of a solution at the vertex *N*;



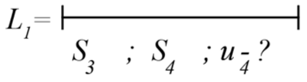
S₃ – sequence of system operation in the case of the end of the search procedure and assignment of the result in the case of a solution at the vertex *N*;



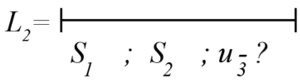
S₄ – sequence of system operation in the event of the end of the search procedure and assignment of the result in the absence of a solution at the vertex *N*;



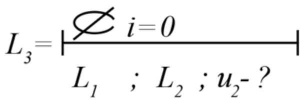
L₁ – check for the presence of a solution at the vertex *N*;



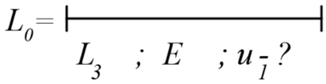
L₂ – check for the final vertex;



L₃ – check at the end of the search;

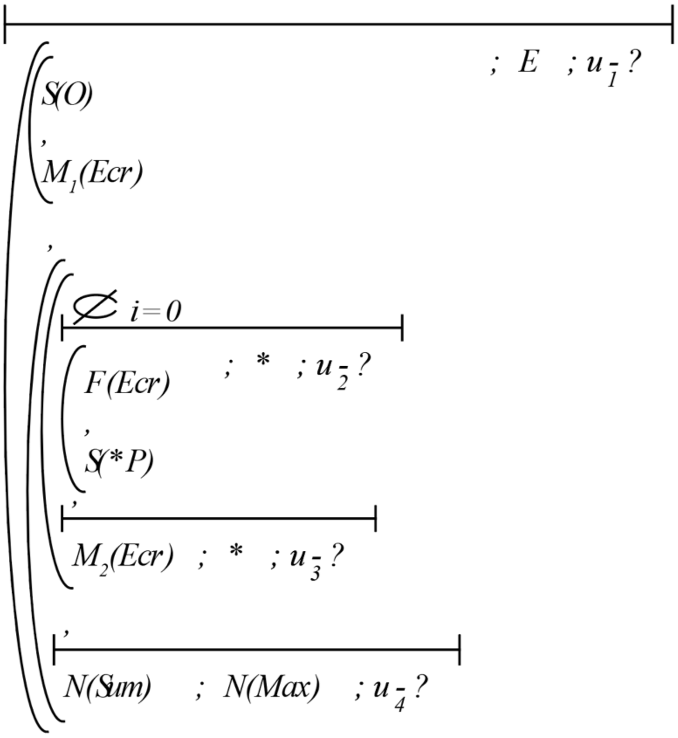


L₀ – check for the presence of descendants of vertex *N*;



The next stage is the substitution of the corresponding sequences in the elimination.

As a result of using the properties of the algebra of algorithms, we subtract the common uniterms by the sign of the elimination operation and obtain the following formula of the algebra of algorithms:



In view of the given material, the process of logical derivation is based on finding the expected monetary values for each vertex of the decision tree, their subsequent comparison, and choosing the best strategy. Expected monetary values are calculated on the basis of such characteristics of nodes of the decision tree as probabilities of random events and losses/profits from the implementation of the strategy, and they themselves become characteristics of the nodes. It should be noted that at the final vertices of the tree, the values of the expected monetary values are initially set by the values of the prices of strategy implementations. The function that implements the specified algorithm is recursive, as it uses recursive traversal of the tree. When calling this function, the root of the tree is passed as a parameter. Next, the mechanism of logical derivation continues with the comparison of expected monetary values and finding the optimal decision-making strategy based on this comparison (Fig. 4).

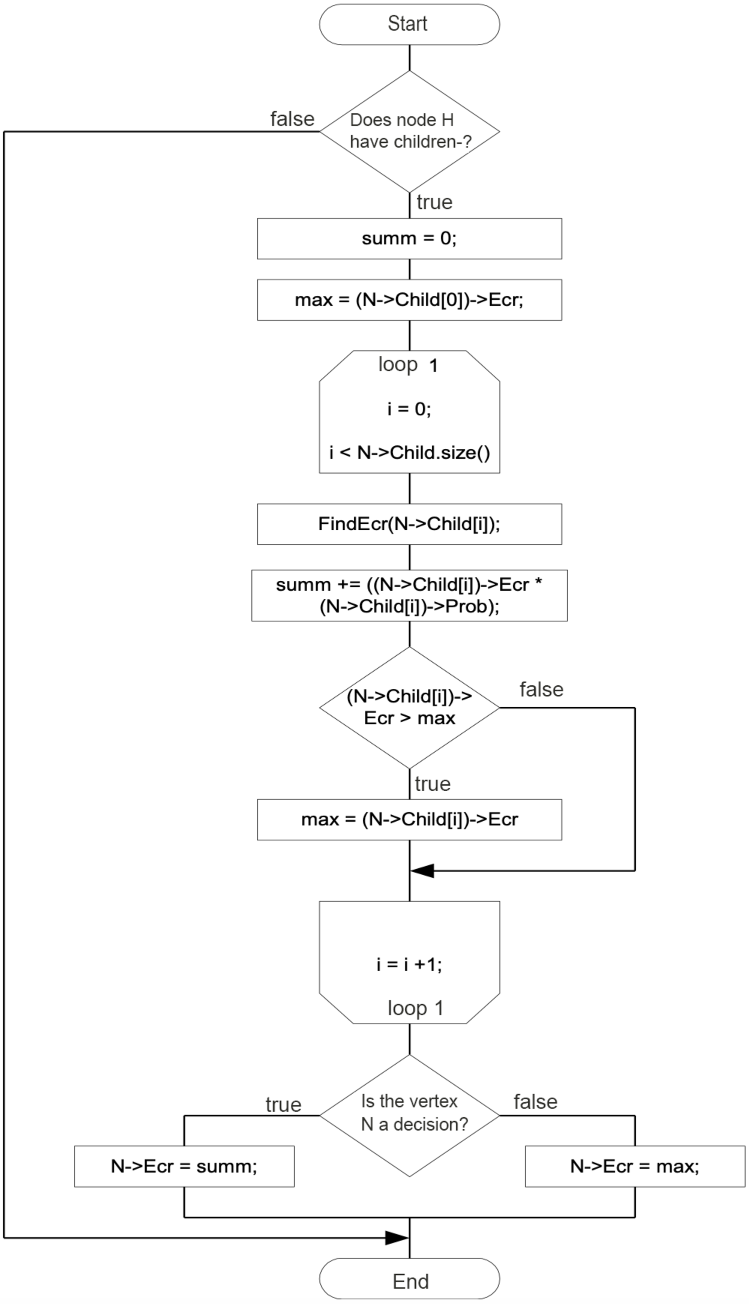


Figure 4: Algorithm of the recursive function of finding expected monetary values

The next stage was the development of the system, using modern software tools. The developed system is presented in the form of a desktop application. The application was created using the C++ [29] programming language in the environment of the Windows operating system. To create and manage the database of the decision support system, the MySQL database management system was used in combination with the MySQL Workbench [30, 31] tool.

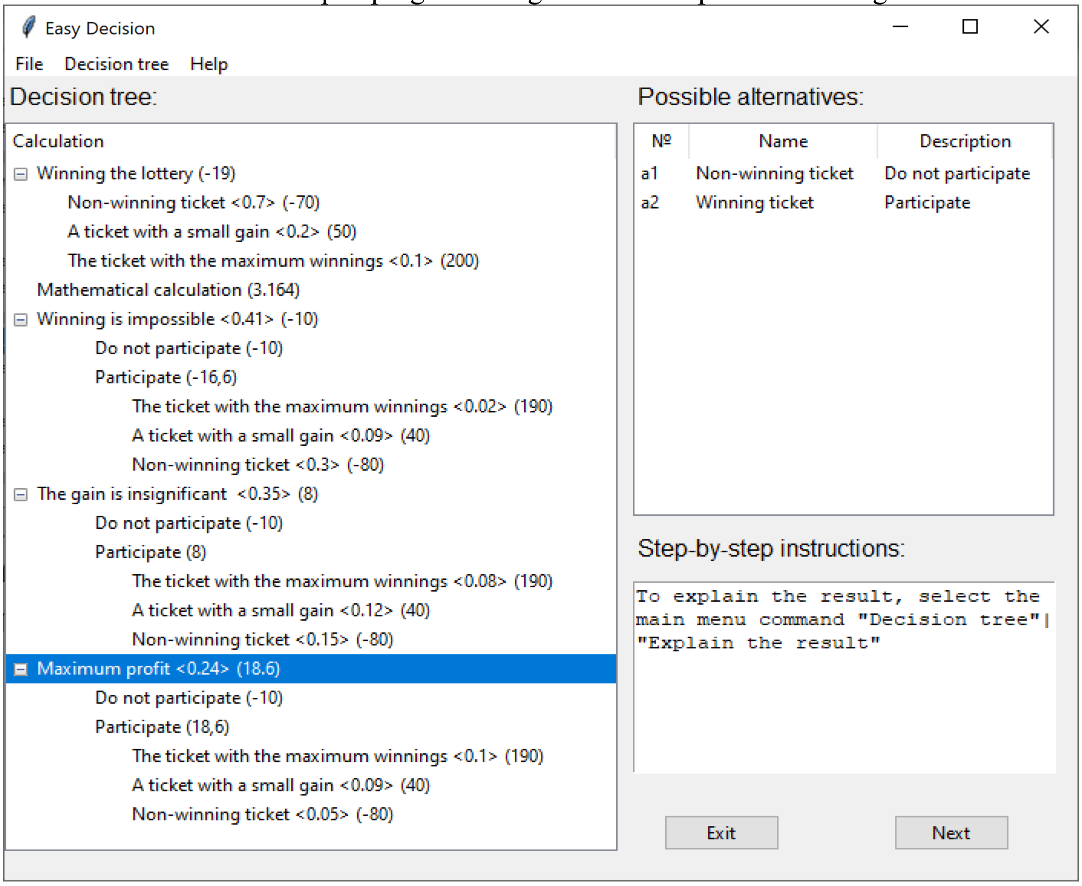
The structure of the program interface includes three key windows, according to the conceptual scheme: the main window (kernel subsystem), the knowledge refinement window, and the pairwise comparison window. In general, the construction of the tree is carried out by the initial description of the vertices of the tree and their gradual detailing in the order of the queue. The algorithm of this procedure can be described as follows. Specify all possible alternatives for solving the problem. This information is entered in the decision/event description table. Indicate what will happen as a result of a decision or random event. The following options are possible here: it is necessary to make new decisions; random events will occur; this decision/event is final. In the latter case, it is necessary to indicate the cash balance of the implementation of the strategy. If the current is a random event, then the probability of its occurrence should be specified for it (a real number in the range 0..1). In this way, the dynamic construction of the decision tree is carried out.

As a demonstration of the system's operation, consider the abstract problem of winning the lottery [32, 33]. The user must make a decision: either to buy or not to buy a lottery ticket. He is not sure whether the ticket will be 'no win' (probability 0.5), 'small win' (probability 0.3), or 'maximum win' (probability 0.2). In the first case, he loses funds in the amount of UAH 70,000, in the second case, the net profit will be UAH 50,000, in the third case, a profit of UAH 200,000. For a fee of 10,000 thousand UAH, the user can perform a mathematical calculation that will help determine the probability of winning. The calculation will show that either a win is impossible (V.N. - probability 0.41), an average win (V.S. - probability 0.35), or a maximum win (V.M. - probability 0.24). We present the probabilities of all random events in the form of Table 1.

Table 1
Information about the ‘Lottery Challenge’ [34]

Position	B.H.	B.C.	B.M.	Probability
Unwinnable combination	0,3	0,15	0,05	0.5
Minimum gain	0,09	0,12	0,09	0.3
Maximum gain	0,02	0,08	0,1	0.2
Mathematical calculation	0,41	0,35	0,24	1,0

Enter the data into the developed program and get the results presented in Fig. 5.



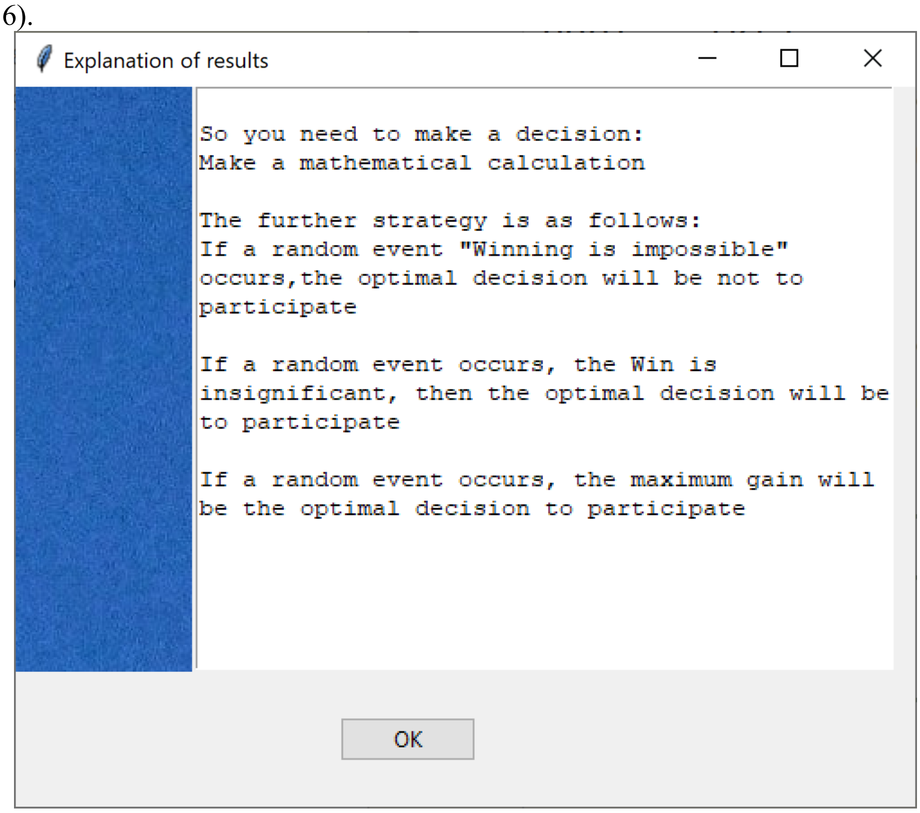
```
Calculation
⊟ Winning the lottery (-19)
      Non-winning ticket <0.7> (-70)
      A ticket with a small gain <0.2> (50)
      The ticket with the maximum winnings <0.1> (200)
  Mathematical calculation (3.164)
⊟ Winning is impossible <0.41> (-10)
          Do not participate (-10)
          Participate (-16,6)
              The ticket with the maximum winnings <0.02> (190)
              A ticket with a small gain <0.09> (40)
              Non-winning ticket <0.3> (-80)
⊟ The gain is insignificant  <0.35> (8)
          Do not participate (-10)
          Participate (8)
              The ticket with the maximum winnings <0.08> (190)
              A ticket with a small gain <0.12> (40)
              Non-winning ticket <0.15> (-80)
⊟ Maximum profit <0.24> (18.6)
          Do not participate (-10)
          Participate (18,6)
              The ticket with the maximum winnings <0.1> (190)
              A ticket with a small gain <0.09> (40)
              Non-winning ticket <0.05> (-80)
```

№	Name	Description
a1	Non-winning ticket	Do not participate
a2	Winning ticket	Participate

To explain the result, select the main menu command "Decision tree"| "Explain the result"

Figure 5: Results of the program

After pressing the Next button, a window with an explanation of the results will be displayed on the screen (Fig.6).



```
So you need to make a decision:
Make a mathematical calculation

The further strategy is as follows:
If a random event "Winning is impossible"
occurs,the optimal decision will be not to
participate

If a random event occurs, the Win is
insignificant, then the optimal decision will be
to participate

If a random event occurs, the maximum gain will
be the optimal decision to participate
```

Figure 6: Explanation of the obtained results

As a result of the analysis of the control example, we can draw the following conclusion that the process of building a decision tree is implemented in the form of a sequence of logical, interrelated questions, which helps the user to systematize his knowledge of the subject area and enter it into the system. The survey of the latter is carried out by means of binary comparisons of relative preference of probabilities. This method of obtaining probability estimates requires more comparisons than direct estimation but is significantly more reliable because it is usually easier for the user to compare two events than to rank all events by importance, much less to directly provide probability estimates for multiple events. In addition, it becomes possible to assess the contradiction of the user's statements by the degree of violation of transitivity.

3. Conclusion

As a result of the conducted research, the existing methods and approaches used in the process of supporting decision-making in conditions of uncertainty were analyzed, which made it possible to identify the peculiarities of their application and outlined the range of problems that arise. The general sequence of the main stages of the decision-making problem under conditions of uncertainty analysis is proposed and the justified feasibility of using the decision tree method for solving multi-step problems is proposed. The structure and main components of the decision tree are considered, and the decision-making algorithm is formulated using the method of the same name. The influence of external factors is analyzed, on the basis of which a method of obtaining the values of subjective probabilities is proposed, which is based on pairwise comparisons and allows to increase the reliability of the received information and assess the level of contradiction of statements. The mathematical description of the specified process is performed using the algebra of algorithms. The next stage was the design of the software system using a structural approach and displaying the created diagrams in accordance with the IDEF0 standard. The study presents a functional model and its decomposition, which created a basis for understanding the features of the functioning of the decision-making support system under conditions of uncertainty. An applied software system has been developed that implements the process of supporting decision-making in conditions of uncertainty. With the help of the developed system, it is possible to build a decision tree using a friendly user interface without prior special training. The decomposition of the software solution is based on visual windows that combine certain logical functionality. Thanks to the selected data formats and the use of recursion, the program code of the main modules of the system is simply adapted to further increase the functionality. At the current moment, the software solution works in the form of a prototype.

Further research will be directed to testing and improving the system, eliminating conflicts, and expanding functionality in accordance with the specified requirements.

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