Economic evaluation of mathematical methods application in the management systems of electronic component base development for forest machines

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Abstract. Machines and equipment used in contemporary forestry are based on electronic components. Development, design and production of high-tech products such as chip, IP-cores and other is a complex and expensive process. The cost of an error at one stage of the product life cycle can reach from several tens of thousands of dollars to hundreds of thousands or more if a faulty chip gets into the finished product.– an airplane, a rocket, a spacecraft, a nuclear power plant, etc.). Therefore, the process of management of high-tech industries needs informed management decisions. Management should be based on modern technical means, specialized software, management information systems and integration of the latter. When developing complex systems, it is not enough to make decisions based on an intuitive understanding of the problem by the decision maker. The use of mathematical methods in management systems will provide impartiality, adequacy, and optimality of solutions, taking into account all qualitative and quantitative factors. The study provides an example of the use of mathematical apparatus in the management of high-tech industries, the economics assessment of errors in management. The study will be interesting for decision-makers, top managers of high-tech industries, scientists, students, masters, graduate students in the field of management and management decision-making.

1. Introduction

Electronic control systems are used to solve the problems of forestry related to the implementation of precise expensive operations (for example, positioning of an unmanned aerial vehicle for monitoring forest landscapes, optoelectronic sorting [1] of forest reproductive material with improved quality indicators, etc.). They are closely integrated with the mechanical components of forest machines. The durability and reliability of the electronic component base determines the quality of control systems. As an example of high-tech industries are considered specialized centers of design of electronic components, microelectronics industry. Microelectronics is a sector of economy with high profit, stable rapidly growing demand and high unit cost of production. The volume of the domestic market of civil microelectronics of the Russian Federation is estimated at $2 billion [1-3], the world market will grow to $ 482 billion by 2022 [4] and, according to experts, in the conditions of Informatization and computerization will grow. For example, according to the estimates of J'son & Partners Consulting [5], the projected market volume of biometric systems will be about $40 billion by 2022; the world market of global navigation satellite systems technologies will grow to €134.19 billion in

2021, the annual growth rate will be 8.4% [6]; from 2017 to 2022, the automotive and industrial sectors will grow annually by an average of 9.6% and 6.8%, respectively [4]. Chip, IP-cores and other electronic components are the basis of development of technologies and technical means providing development of the listed directions. The use of microelectronic components is relevant for all spheres of human life and activity.

Development and design of electronic components takes place at specialized enterprises – design centers of microelectronics in the conditions of intensive changes in economic constraints, economic confrontation between corporations and countries, a sharp change in trends in the development of the economy individual sectors. These processes lead to the need to adjust the goals and objectives of knowledge-intensive industries: rapid reorientation to another consumer or sector of the economy; development and production of new models in the shortest possible time; reorientation to the production of goods other types. The dynamics of these processes and the improvement of technical systems and technologies create the need to develop new theoretical and methodological approaches to assessing the economic efficiency of the microelectronics design center. It is necessary to develop new approaches to solving problems of microelectronics design centers management.

2. Methodology
Previously, the authors obtained an optimization model for managing the development of a series of projects. The algorithm for solving the optimization model determined the structure of the network model. The network model included events, works, and work fronts. The data for the network model were collected because of scientific work of the Department of information systems and computer technologies of the Voronezh State University of Forestry and Technologies named after G. F. Morozov. Based on the Department organized scientific and educational center together with the leading enterprises of the industry. The specific stages and parameters of each element of the model (time of work, possible variants of work sequences, the number of working groups, laboratories) were taken from the technical specifications of successfully completed development work.

3. Results and discussion
In the conditions of informatization, the use of information management systems is a common business practice. However, standard automated information systems are aimed at the collection, processing of information (grouping of data, statistical processing), the issuance of information in the form of reports or other documents. It should be noted that automated information systems usually contain and manipulate economic data, partly production, to a lesser extent technical indicators. This is due to the principles and algorithms of data collection and processing. Economic data are structured and have a clear numerical expression. Technical and production indicators (e.g. sufficiency and feasibility of requirements for electronic components [7]) often have qualitative characteristics, which complicates the process of processing and accounting of such data.

Automated information systems allow the decision-maker to master a large amount of information in a short time. On the basis of this information there is a development of the administrative decision. However, this decision will have the following disadvantages related to the psychological, emotional and other qualities of the person making the decision: bias, interest, subjectivity, inability to calculate all the options in connection with physical abilities and the like. Therefore, there is a need to develop specialized control systems or decision support systems, which will be based on mathematical methods and models. The operation of the systems is shown in figures 1 and 2.

The description of specialized information management systems, it is meant that the system is based on mathematical models and methods, but most importantly – takes into account the specifics of the industry in the models. In figures 1 and 2 there are blocks – multiple calculation options – this shows the presence of several methods of processing the original data in order to develop an optimal solution. The methods include two main groups: heuristic and numerical (figure 3).

Thus, figure 1 presents an algorithm that assumes that a specialized information management system automatically selects the options for processing and calculating the initial data, then based on

the results obtained and the tasks set, selects the most optimal option. When applying such a specialized management system, the subjectivity of decision-making is excluded. However, there is a problem-the system needs to take into account various mathematical models and algorithms aimed at solving specific problems.

Figure 2 shows the algorithm of the management decision support system; this system develops solutions and provides them to the decision maker. The system calculates all the solutions and offers the most optimal of them; the decision-maker can choose one of them or refuse the solution proposed by the system.
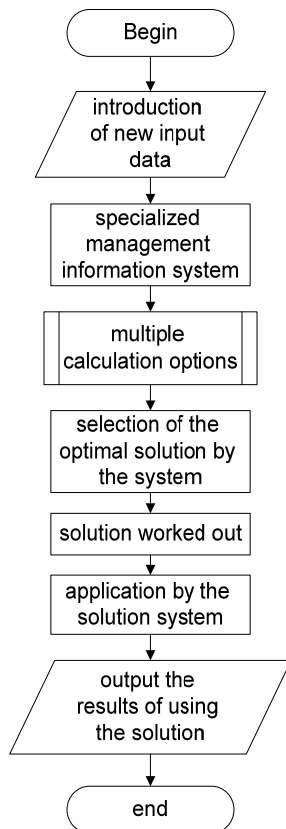

Figure 1. Algorithm of specialized information management system functioning.
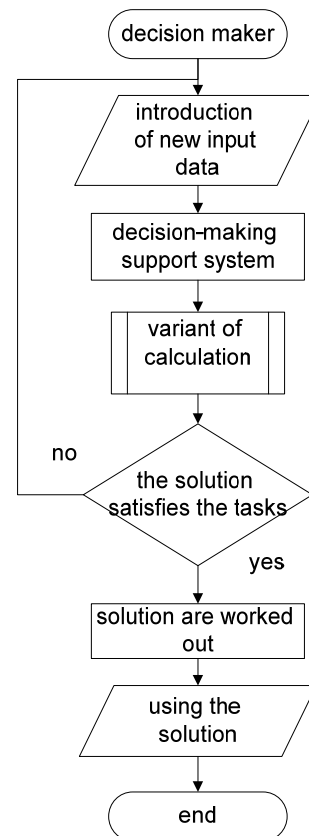
Figure 2. Algorithm of functioning of the system of managerial decision-making support.

Under the heuristic methods are understood informal methods, which are based on: logical, creative thinking of people, accumulated experience and analytical skills, intuition and other psycho-intellectual abilities. The advantage of the methods is efficiency; the disadvantages are the subjectivity of the decision-maker and the lack of a guarantee of optimal decision when choosing an alternative.

Heuristic methods were considered in detail in their works by Baker K. R. and Trietsch D. [8]; Lowndes V., Berry S., Parkes C., Bagdasar O. [9]; Musiał K, Górnicka D and Burduk A [10] and other [11-13].

Numerical (formalized) methods are understood as a group of methods based on a scientific approach, which involves finding the optimal solution by processing information (using modern tools, methods and technologies) and developing an optimization model [7].

Formalized methods are used to justify and select the optimal solutions including: economic and mathematical models and methods; system analysis; expert estimates and judgments, etc. In the aggregate, various mathematical methods, United by a common task of substantiating the best

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solutions, are called methods of operations research. Methods of operations research are divided into the following four main groups: analytical, statistical, mathematical programming, game-theoretic [14].

The classical means of studying mathematical models and research on the basis of their properties of real objects are analytical methods that allow you to obtain accurate solutions in the form of mathematical formulas. However, analytical methods assume the exact satisfaction of boundary conditions, and the class of problems for which they can be used is limited. Therefore, the solution is usually carried out by numerical methods. Numerical methods are methods of approximate solution of problems of applied mathematics, based on the implementation of algorithms corresponding to mathematical models [15].
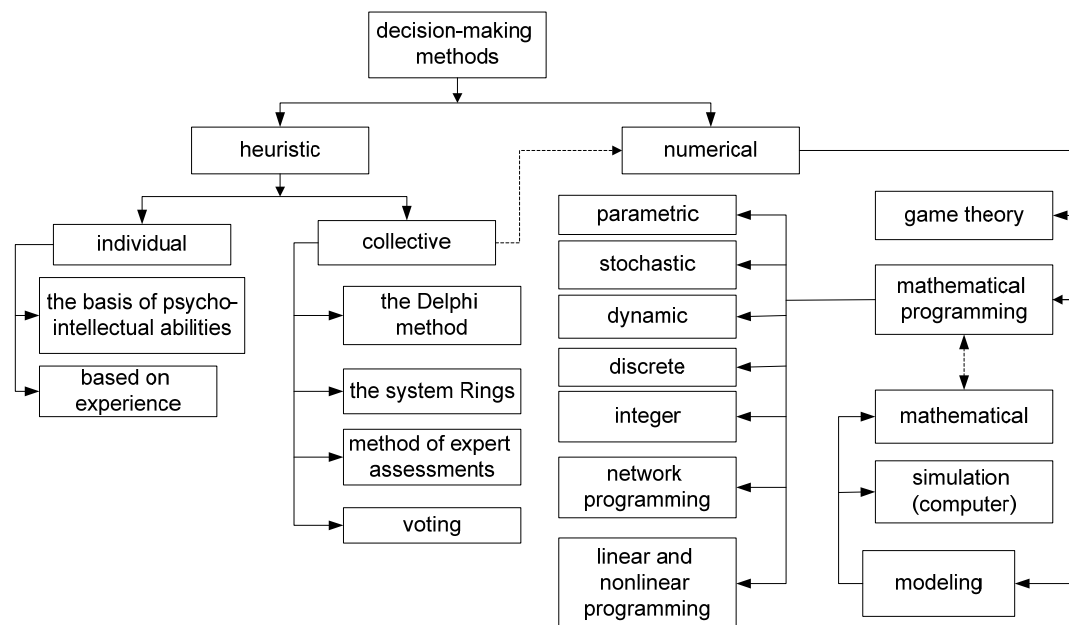

Figure 3. Classification scheme of decision-making methods.

Mechanisms based on the optimization models are divided into mechanisms that use the apparatus of probability theory (the theory of reliability, queueing theory, theory of statistical decisions), optimization theory – linear and nonlinear (and stochastic, integer, dynamic, method, network programming, differential equations, optimal control; discrete mathematics – mostly graph theory (transport task, the task of appointing the shortest path selection, scheduling and network planning and management, the problem of accommodation, the allocation of resources to networks, etc.). V. N. Burkov, S. V. Sokolov, K. R. Baker and others were engaged in these methods and models [16-23].

The application of these methods in practice, especially for complex science-intensive industries, is faced with the impossibility of using only one method (numerical or heuristic). There is a need to use either several methods simultaneously to obtain several options for management decisions, or the use of several methods sequentially. Consistent use of methods of different groups is associated with heterogeneity of qualitative and quantitative information in one production process.

For design centers of microelectronics the control process is very important, as it is necessary to solve:

1) The Customer often requires a whole series of electronic components with similar "core", but different composition of the additional blocks, the interface, the resistance to external influencing factors, etc., the Design centre of one of the products of the series has the groundwork, so to make the next device faster, better and with less expense.

2) Developed and tested blocks, for which it is possible to reuse, make up the library. In the future, such blocks are used at the functional and logical level of design without the need to "go down" to the circuit level. This saves time in development and testing. Therefore, the result of the design center project is not only a product, but also ready for reuse "library" blocks. In financial terms, the result will not only be revenue from the product, but also savings in the development of subsequent products.

3) Preparation of individual blocks for reuse is not always advisable, when possible, as in a particular product the use of such blocks may be limited.

4) The Development of a universal unit requires more complete design and testing, which means additional costs.

5) Other orders on products that can be useful one or the other library unit cannot be.

Therefore, a suitable reuse strategy cannot be formulated for each case. With the simultaneous parallel development of several projects, it is necessary to decide on which project which blocks will be developed, as universal. Based on the data obtained during the scientific work of the Department of computer technology and information systems, together with one of the design centers - the design center simultaneously works, as a rule, on 5 projects, in each project about 30 operations. The network schedule for one project is shown in figure 4.
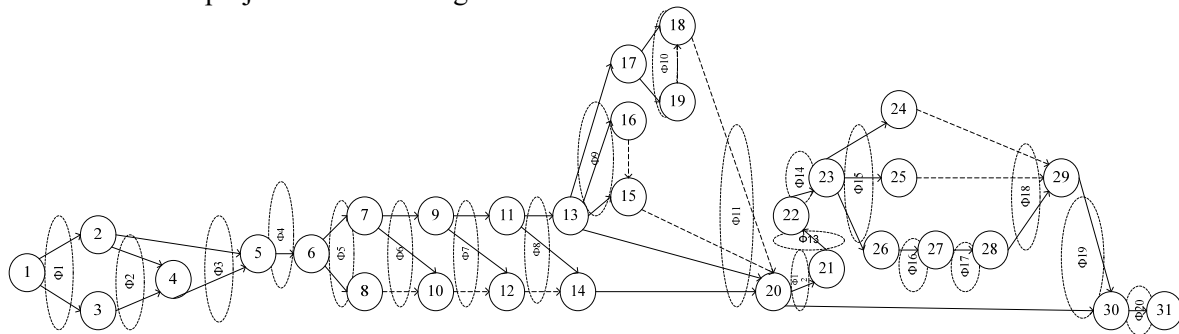

Figure 4. Network model of the project for the development of new electronic components.

At the same time-consistently at the enterprise at least 150 operations without development of the universal blocks having possibility of repeated use shall be carried out.

Thus, the choice of the method of management decision-making is directly related to: the volume, quality and quantity of information about a particular task; the time allotted to choose a solution; the level of the problem, etc. As an example of the choice of the method of solving the problem aimed at supporting management decisions in the implementation of a package of projects by the design center of microelectronics, we present the problem of work distribution: suppose you want to implement some project (for example, product development, production of pilot batch, test and run in series, etc.). For its implementation it is necessary to perform n works distributed among m performers, provided that each specific work can be performed only by one of several performers. And the time of work depends on the contractor, his skills and experience of previous projects; and limitations:

a) the sequence of work – the beginning of the work is possible only after the completion of the previous work;

b) for the duration of work;

c) on the implementation of Directive terms (decision-making period is some time later than which this work could not be completed). As a rule, policy deadlines are set for work that is final for a particular project (the completion of the work means the completion of the whole project).

Executors are not only departments (development, testing, software development), but also laboratories, separate groups within laboratories which can independently perform some works on the project. In [7] developed an optimization model including an objective function and system constraints.

The developed mathematical model is aimed at finding the distribution of work by performers, within a given time and minimizing the total cost of the performers by reducing the time of their work. The solution of the problem of distribution of works by classical methods (network planning, branches and boundaries, Gantt) is not possible, since the execution time of the work depends on the contractor, the appointment of the contractor for a specific job occurs only after the optimal distribution of previous works and depends on the time of previous works, there is also almost always the possibility of performing works by other performers.

The problem belongs to the class of NP-complete problems, for its solution there are no effective algorithms for determining the optimal solution other than exhaustive search. To solve this problem, we proposed an approximate algorithm called the "frontal" algorithm of limited search. Such an algorithm is based on the ideology of "greedy" algorithms, that is, algorithms in which the work included in the solution under construction cannot be excluded from it at the next steps of construction.

This network model formed the basis of the software developed by the authors, which allows obtaining numerical results for solving management problems aimed at choosing the implementation of a series of projects. Thus, with the simultaneous distribution of 96 works in 5 projects to 22 performers, the time of execution of works decreased by 1.2 times, that reduced the cost of production by 30-32 %.

4. Conclusion

In the structure of the price of a modern forest machine, electronic control systems are 60-70 %. Therefore, any analytical solution to the problem of improving the quality and reducing the design time of electronic components will provide a stable level of reliability and increase the life of forest machines. The choice of the method of management decision-making is directly related to: the volume, quality and quantity of information about a particular task; the time allotted to choose a solution; the level of the problem and more. It is necessary to understand that the design process of the design center of new electronic components carries a high price responsibility for each subsequent stage of the product life cycle. Design accounts for 70-80 % of the cost of creating electronic components, although the design costs themselves are only about 10 % of the total cost of electronic component development. Thus, an error in the design of electronic components is an expensive error, which aims to get a fully functioning system (chip, IP-cores) in the first iteration of the design, without returning to previous levels of design. This imposes increased requirements for management decisions for design centers of microelectronics – the maximum possible consideration of all factors and several options for calculating all possible situations.

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