AVIATION
ISSN 1648-7788 print / ISSN 1822-4180 online
2011 Volume 15(3): 63–68
doi:10.3846/16487788.2011.624263

MULTI-CRITERIA MODELS OF DECISION-MAKING SUPPORT IN AIR NAVIGATION SYSTEMS

Volodymyr Kharchenko[1], **Olexiy Pysarchuk**[2]

[1]National Aviation University, 1 Kosmonavta Komarova Ave, Kiev, Ukraine
[2]S. P. Korolev Military Institute in Zhytomyr, Zhytomyr, Ukraine
E-mail: [1]kharch@nau.edu.ua; [2]dized@narod.ru (corresponding author)

Received 16 June 2011; accepted 07 September 2011

Volodymyr KHARCHENKO, *Prof. Dr Sci (Eng)*
Education: Kiev Institute of Civil Aviation Engineers.
Honours, awards: honoured scientist of Ukraine, state prizewinner in the field of science and technology.
Present position: vice-rector for scientific-research work at the National Aviation University.
Publications: over 300 research papers, monographs, textbooks, manuals, articles, and patents.
Research interests: effective management of complicated socio-technical systems, development and improvement of air navigation systems based on the application of satellite systems.

Olexiy PYSARCHUK, *Ph.D.*
Education: Zhytomyr Higher Military School of Air Defence Radio Electronics, 1995.
Present position: head of research centre of S. P. Korolev Military Institute in Zhytomyr, National Aviation University.
Publications: over 100 scientific papers.
Research interests: problems of analysis and synthesis of difficult ergative sensor-based systems in navigation and traffic control.

Abstract. Multi-criteria models of decision-making for the rational allocation of limited resources and evaluation of the efficiency of a result are proposed in the article. A cost efficient system of particular criteria and the resultant of a nonlinear chart of compromises are used for optimum allocation of resources. Analogue description of particular criteria of optimal distribution is applied, which allows the necessity of surplus in all possible decision variants to be avoided and the amount of calculations to be decreased.

Keywords: multi-criteria models, air navigation, transportation task.

1. Introduction

The effectiveness of solving problems in modern management systems is to a great extent determined by the quality of the specialised mathematical software of the decision-making process support systems (Vasin *et al.* 2003; Gerasimov *et al.* 2004) Making timely and reliable decisions in CNS/ATM systems, that ensure high levels of flight safety are especially urgent (Air… 2006; Babak *et al.* 2007). One of the major components of decision-making process support programs (systems) is a block of calculations, the main task of which is to make decisions, based on incoming data, about the current state and references to the system. The final decision-making is performed in accordance with rules and by mathematical procedure blocks of calculations input in algorithms. The quality of the mathematical software of the algorithms, the adequacy of the accepted models in the real environment, and the complete consideration of the specific tasks in the field where the decision-making process support programs are used to determine the quality of data and efficiency of the management system as a whole. Optimal allocation of limited resources, as a kind of transportation task, is a common objective for management systems of various types.

In consideration of the intensity of IT development, the dynamic increase of all internal and external processes should be considered. The urgent task is therefore to develop effective approaches for decision-making in management systems and allocate limited resources optimally.

2. Analysis of recent research and publications

Solving the task of optimal allocation of limited resources in conditions of changing requirements for efficiency and adequacy should be considered together with evaluating the efficiency of decision-making. Traditionally, the optimal allocation of limited resources is carried out using known theory operation methods (Konin, Kharchenko 2010). This initial problem is formalised as a chain of linear constraints, often delimitation, usually as a single function that is offered in a single-chip model. The resource allocation problem is however more complex and is adequately characterised by a significant number of often conflicting partial criteria that require multi-criteria approaches.

In the case of decision making in management systems, the solution of the problem of efficiency evaluation can traditionally be made by evaluating the efficiency of a solution by goal-oriented estimation or without the use of decision-making support systems or by comparing the efficiency of system analogies (Grigorak, Shkvar 2011; Nechiporenko 1977; Chumakov, Serebrianyi 1980). The dominant criterion or vectors are used as indicators and criteria for the evaluation of efficiency. Often the final decision is also made by a single-chip model, which reduces its adequacy and requires the development of multi-criteria approaches for efficiency evaluation.

The target of this article is to develop mathematical software for optimally allocating limited resources and evaluating the efficiency of decision-making.

3. Theoretical aspect

The management of radio observation processes for monitoring the compliance of electromagnetic compatibility with clutter conditions and the allocation of aims to monitor the movement of aircraft (particularly in the subsystem of observation) are good examples of problems for rational limited resource allocation in SK8/ATM systems. In consideration of the large number of types of optimal resource allocation problems, it is necessary to emphasise some limitations and assumptions that are considered during decision-making:

1) different resources should be distributed;
2) heterogeneous consumer needs of inventories are characterised during resource allocation;
3) the main rational resource allocation requirement is the efficiency of the solution of the target problem by customers after the resource allocation itself at minimum expence;
4) the distribution criteria of all available resources is not suggested;
5) the situation when the target problem is solved and meets at least one requirement is possible.

4. Experimental research

In light of what is mentioned above, it is necessary to state the problem of optimally allocating limited resources in the following way. A certain amount of customers with known needs and limited resources is suggested. It is possible to set priorities in the services for customers and to meet their needs. The amount of suppliers for certain types of resources is given. The number of suppliers and resources is less than the number of customers and the list of their needs. Thus, we have a set of customers, $SP = \{SP_i\}$, $i = 1...I$ – number of customers, each of which has a limited set of needs, $SP_i \subset \{Pot_{ij}\}$, $j = 1...J$ – the amount of customer needs by type. Suppliers are characterised by the expression $PS = \{PS_k\}$, $k = 1...K$ – the amount of suppliers, and the list of limited inventories $PS_k \subset \{Zap_{km}\}$, $m = 1...M$ – the amount of inventories of a certain type. It is necessary to make a distribution of limited resources, Zap_{km}, of suppliers PS_k by customers SP_i so that meeting their needs provides the best performance for target tasks.

Distribution of resources should be implemented according to the priorities of consumer service. For the formal solution of the task, customers are rated according to priority groups in their service. The initial information for this, depending on the practical direction of distribution tasks, can include directive requirements, experience in solving this type of task, or external factors.

The rating may be in accordance with either a numerical algorithm or by expert assessment. So, groups (subsets) $l = 1...L$ are formed from a set of customers, $SP = \{SP_i\}$, and for each of them the conditions of meeting the needs, W_l, and problems of the performance of target tasks by the consumer, P_l, are laid out. Thereafter, in each selected group, a rating is made according to the priority needs of each i customer; the efficiency of solving target tasks when satisfying their j need and Pot_{ij} expended resources by k provider – Zap_{km} – is determined.

The customer rating made with the observance of the rules mentioned provides specified distribution of limited resources and makes it possible to avoid the need to consider all possible distribution variants peculiar to operation theory, which is especially important under the conditions of task complexity.

In order to determine the criteria requirements for optimal allocation of limited resources, it is necessary to define the variable parameter (parameter that is optimised). The amount of suppliers that are allocated to service the needs of customer n_i with limits of the total number of suppliers N is:

$$n_i, \ \sum_{i=1}^{I} n_i \le N, \tag{1}$$

So, for the first customer, $\ddot{\imath}_1$, the amount of suppliers is given, etc., and for example $n_i = 2$ means that for i-customer the amount of given suppliers meets their first needs Pot_1 (with first priority) and Pot_2 (with secondary priority).

Optimal allocation of limited resources is based on criteria of the effective-cost model. The quality of customer performance target tasks in meeting their needs is considered the efficiency criterion:

$$P(n) \to \max. \tag{2}$$

Mean costs of supplier resource for customer needs and high performance of target tasks are selected as the value criterion:

$$S(n) \to \min. \tag{3}$$

Then, for some customers within the same rating group, we have a system of partial criteria:

$$\begin{cases} P_1(n_1) \to \max, \ S_1(n_1) \to \min, \\ P_2(n_2) \to \max, \ S_2(n_2) \to \min, \dots, \\ P_i(n_i) \to \max, \ S_i(n_i) \to \min, \dots, \\ P_I(n_I) \to \max, \ S_I(n_I) \to \min. \end{cases} \tag{4}$$

The system of partial criteria (4) is contradictory; that is why it is reasonable to express the task of allocating resources in a multi-criteria form. Its solution requires changes in the descriptions of partial criteria (2)–(4). This will be calculated by obtaining discrete values, the approximation of which gives a similar representation of partial criteria in the form of polynomials:

$$\begin{aligned} P_i(n_s) &= P_0 + P_1 n_i + P_2 n_i^2 + \dots, \\ S_i(n_s) &= S_0 + S_1 n_i + S_2 n_i^2 + \dots, \end{aligned} \tag{5}$$

where the parameters of the models $P_0, P_1, P_2, \dots$ and $S_0, S_1, S_2, \dots$ are consistent with models of discrete data by the norm of the least square method.

Further solution of the optimisation task is carried out by mixing together partial criteria for the generalised functional in accordance with convolution for non-linear scheme of compromises (Voronin 1992):

$$\chi^* = \underset{\chi \in G}{\arg\min} \sum_{f=1}^{b} \gamma_{f0} (1 - \varphi_{0f}(\chi))^{-1} = F(\chi), \tag{6}$$

where χ – the parameter that is optimised (variable parameter), G – the definition area of partial optimality criteria; γ_{f0} – the importance of f partial criterion advantage, $\varphi_{0f}(\chi)$ – standardised function of f partial optimality criterion, χ^* – the optimal value of variable parameter.

Normalisation of partial criteria models (5) in a limited range of interval parameter n_i changes are made separately for minimised and maximised parameter criteria in order to bring them to a dimensionless form by minimising the expressions:

$$\varphi_{0i}(n_i) = \frac{\min P_i(n_i)}{P_i(n_i)}, \ \varphi_{0S}(n_i) \frac{S_i(n_i)}{\max S_i(n_i)}. \tag{7}$$

At the stage of partial criteria standardisation of the optimisation problem, restrictions for parameter n_i allow taking into account the needs of i customers during standardising criteria $P_i(n_s)$ and limited resources of k supplier during standardising criteria $S_i(n_s)$. According to convolution (6), taking into account the introduced signs (7) during standardising we will have the optimisation model of optimal limited resource allocation of suppliers for one group of importance of customers:

$$\begin{aligned} &\delta(n_1, n_2, \dots, n_i, \dots, n_I) = \\ &\gamma_{01}(1-\phi_{01}(n_1))^{-1} + \gamma_{0S1}(1-\phi_{0S1}(n_1))^{-1} + \\ &\gamma_{02}(1-\phi_{02}(n_2))^{-1} + \gamma_{0S2}(1-\phi_{0S2}(n_2))^{-1} + \dots + \\ &\gamma_{0i}(1-\phi_{0i}(n_i))^{-1} + \gamma_{0Si}(1-\phi_{0Si}(n_i))^{-1} + \dots + \\ &\gamma_{0I}(1-\phi_{0I}(n_I))^{-1} + \gamma_{0SI}(1-\phi_{0SI}(n_I))^{-1}, \end{aligned} \tag{8}$$

where $\gamma_{01}, \gamma_{0S1}, \gamma_{02}, \gamma_{0S2}, \dots, \gamma_{0i}, \gamma_{0Si}, \dots, \gamma_{0I}, \gamma_{0SI}$ are standardised and relative to the sum of introduced values that characterise the importance of appropriate criteria in obtaining the solution of the final task of optimally allocating limited resources.

After considerations it is possible to form a criteria system for optimally allocating limited resources in terms of customers referred to as the $l = 1 \dots L$ groups of importance:

$$\begin{cases} \delta_1(n_{11}, n_{12}, \dots, n_{1i}, \dots, n_{1I_1}) \to \min, \\ \delta_2(n_{21}, n_{22}, \dots, n_{2i}, \dots, n_{2I_2}) \to \min, \dots, \\ \delta_l(n_{l1}, n_{l2}, \dots, n_{li}, \dots, n_{lI_l}) \to \min, \dots, \\ \delta_L(n_{L1}, n_{L2}, \dots, n_{Li}, \dots, n_{LI_L}) \to \min, \\ S(n_{11}, n_{12}, \dots, n_{1i}, \dots, n_{1I_1}, n_{21}, n_{22}, \dots, n_{2i}, \dots, \\ n_{2I_2}, \dots, n_{l1}, n_{l2}, \dots, n_{li}, \dots, n_{lI_l}, \dots, n_{L1}, \\ \qquad n_{L2}, \dots, n_{Li}, \dots, n_{LI_L}) \to \min. \end{cases} \tag{9}$$

Generalised criteria are obtained by convolution (6) according to the expressions below:

$$\delta_l(n_{l1}, n_{l2}, \ldots, n_{li}, \ldots, n_{lI_l}) =$$
$$\gamma_{0l1}(1-\phi_{0l1}(n_{l1}))^{-1} + \gamma_{0l2}(1-\phi_{0l2}(n_{l2}))^{-1} + \ldots +$$
$$\gamma_{0li}(1-\phi_{0li}(n_{li}))^{-1} + \ldots + \gamma_{0lI_l}(1-\phi_{0lI_l}(n_{I_l}))^{-1},$$

$$S(n_{11}, n_{12}, \ldots, n_{1i}, \ldots, n_{2I_1}, n_{21}, n_{22}, \ldots, n_{2i}, \ldots, n_{2I_2}, \ldots,$$
$$n_{l1}, n_{l2}, \ldots, n_{li}, \ldots, n_{lI_l}, \ldots, n_{L1}, n_{L2}, \ldots, n_{Li}, \ldots, n_{LI_L}) =$$
$$\gamma_{0S11}(1-S_{011}(n_{11}))^{-1} + \gamma_{0S12}(1-S_{012}(n_{12}))^{-1} + \ldots +$$
$$\gamma_{0S1i}(1-S_{01i}(n_{1i}))^{-1} + \ldots + \gamma_{0S1I_1}(1-S_{01I_1}(n_{1I_1}))^{-1} +$$
$$\gamma_{0S21}(1-S_{021}(n_{21}))^{-1} + \gamma_{0S22}(1-S_{022}(n_{22}))^{-1} + \ldots +$$
$$\gamma_{0S2i}(1-S_{02i}(n_{2i}))^{-1} + \ldots + \gamma_{0S2I_2}(1-S_{02I_2}(n_{2I_2}))^{-1} +$$
$$\ldots + \gamma_{0Sl1}(1-S_{0l1}(n_{l1}))^{-1} + \gamma_{0Sl2}(1-S_{0l2}(n_{l2}))^{-1} + \ldots +$$
$$\gamma_{0Sli}(1-S_{0li}(n_{li}))^{-1} + \ldots + \gamma_{0SlI_l}(1-S_{0lI_l}(n_{lI_l}))^{-1} + \ldots +$$
$$\gamma_{0SL1}(1-S_{0L1}(n_{L1}))^{-1} + \gamma_{0SL2}(1-S_{0L2}(n_{L2}))^{-1} + \ldots +$$
$$\gamma_{0SLi}(1-S_{0Li}(n_{Li}))^{-1} + \ldots + \gamma_{0SLI_L}(1-S_{0LI_L}(n_{LI_L}))^{-1},$$

where $\gamma_{0ij}, \gamma_{0Sij}$ are general importance criteria that characterise the preference (importance) of appropriate criteria when optimally allocating resources. Double indexation of parameters n_{li} by index l characterises the number of customer groups according to priority service, and index i is the number of consumers in the group.

To continue with the application of embedded convolution technology, the integrated criteria for optimal allocation of limited resources of suppliers are formed (10). Criteria standardisation (9) is made relative to the value that is recognised in the worst case of resource allocation. General importance criteria referred to in (10) G_{01}, $G_{02}, \ldots, G_{0l}, \ldots, G_{0L}$, F_0 are consistent with the requirements of target task performance by groups of importance groups of different customers after supplier resource allocation.

$$\Omega(n_{11}, n_{12}, \ldots, n_{1i}, \ldots, n_{1I_1}, n_{21}, n_{22}, \ldots, n_{2i}, \ldots,$$
$$n_{2I_2}, \ldots, n_{l1}, n_{l2}, \ldots, n_{li}, \ldots, n_{lI_l}, \ldots, n_{L1},$$
$$n_{L2}, \ldots, n_{Li}, \ldots, n_{LI_L}) =$$
$$G_{01}(1-\delta_{01}(n_{11}, n_{12}, \ldots, n_{1i}, \ldots, n_{1I_1}))^{-1} +$$
$$G_{02}(1-\delta_{02}(n_{21}, n_{22}, \ldots, n_{2i}, \ldots, n_{2I_2}))^{-1} +$$
$$\ldots + G_{0l}(1-\delta_{0l}(n_{l1}, n_{l2}, \ldots, n_{li}, \ldots, n_{lI_l}))^{-1} + \quad (10)$$
$$\ldots + G_{0L}(1-\delta_{0L}(n_{L1}, n_{L2}, \ldots, n_{Li}, \ldots, n_{LI_L}))^{-1} +$$
$$F_0(1-S(n_{11}, n_{12}, \ldots, n_{1i}, \ldots, n_{1I_1}, n_{21}, n_{22}, \ldots, n_{2i},$$
$$\ldots, n_{2I_2}, \ldots, n_{l1}, n_{l2}, \ldots, n_{li}, \ldots, n_{lI_l}, \ldots, n_{L1},$$
$$n_{L2}, \ldots, n_{Li}, \ldots, n_{LI_L}))^{-1}.$$

Functional (10) is an optimization optimisation model of rational allocation of supplier-limited resources of suppliers among customers, where conflicting effective -cost partial criteria are taken into account (4) and are established for several groups of importance of customer service (9). The formed model is made using sub- convolutions with a nonlinear compromise scheme that provides consideration of limited resource allocation of conflicting criteria requirements, different consumer needs, stocks of supplies,' stocks and limited resources.

Determination of optimal values of varying parameters in model (10) is done by solving a number of nonlinear equations:

$$\frac{\partial^{(I_1+I_2+\ldots+I_l+\ldots+I_L)}\Omega(n_{11}, n_{12}, \ldots, n_{1i}, \ldots, n_{1I_1}, n_{21}, n_{22}, \ldots, n_{2i}, \ldots, n_{2I_2}, \ldots, n_{l1}, n_{l2}, \ldots, n_{li}, \ldots, n_{lI_l}, \ldots, n_{L1}, n_{L2}, \ldots, n_{Li}, \ldots, n_{LI_L})}{\partial^{(I_1+I_2+\ldots+I_l+\ldots+I_L)} n_{lI_{(1,2,\ldots,l,\ldots,L)}}} = 0. \quad (11)$$

The result (11) is the value of variable parameters n_{li}^* that if necessary, are rounded to the integer n_{li}^{opt} managing the condition (1). The results are further interpreted in the following way. For the first customer from the first priority group of rating $\ddot{\imath}_{11}^{opt}$, suppliers are given, and so on. For example, $n_{li}^{opt} = 2$ means that for i -customer from l -group the suppliers are given to meet their first Pot_1 and second Pot_2 needs.

Thus, a multi-criteria optimisation model for allocation of limited resources is formed. The feature of the proposed approach is in the allocation of analogue models to describe changes in the distribution of partial rational criteria. Despite the nature of the discrete resource allocation task, the application of analogue models is justifiable because the combination with rating of customers can help to avoid the need to consider all variants of resource allocation, which is necessary for discrete approaches. The model mentioned above allows reducing the computational complexity of optimal allocation procedures.

It is suggested to evaluate the effectiveness of the solution obtained in the following way. For example, the distribution of a limited amount of supplier resources between consumer groups of different importance was received:

$$\begin{aligned}
&n_{11}^{opt} = N_{11}, n_{12}^{opt} = N_{12}, \ldots, n_{1i}^{opt} = N_{1i}, \ldots,\\
&n_{1I_1}^{opt} = N_{1I_1}, n_{21}^{opt} = N_{21}, n_{22}^{opt} = N_{22}, \ldots,\\
&n_{2i}^{opt} = N_{2i}, \ldots, n_{2I_2}^{opt} = N_{2I_2}, \ldots,\\
&n_{l1}^{opt} = N_{l1}, n_{l2}^{opt} = N_{l2}, \ldots, n_{li}^{opt} = N_{li}, \ldots,\\
&n_{lI_l}^{opt} = N_{lI_l}, \ldots, n_{L1}^{opt} = N_{L1},\\
&n_{L2}^{opt} = N_{L2}, \ldots, n_{Li}^{opt} = N_{Li}, \ldots, n_{LI_L}^{opt} = N_{LI_L}.
\end{aligned} \quad (12)$$

It is necessary to evaluate the effectiveness of the performance of target tasks by the system, for which resource allocation according to the plan is made (12).

It is suggested to make the evaluation of the suppliers resource allocation following two partial criteria: the maximum of the average amount (within the group of importance) of satisfied consumers needs, $\overline{E}_l$; the maximum of the effectiveness of consumer target task performance in meeting their needs according to resource allocation, $\overline{P}_l$, and taking into account the importance of different consumer groups. Thus, we obtain a set of partial criteria characterising the efficiency of limited resource allocation between consumers:

$$\overline{E}_l \to \max,\ \overline{P}_l \to \max,\ l=1...L. \quad (13)$$

In order to take into consideration the criteria (13) and different requirements for resource allocation, based on consumers' belonging to a corresponding group of importance, it is suggested to create an integrated multi-criteria assessment of the effectiveness of limited resource allocation by applying the convolution opportunities via a nonlinear scheme of compromises with discrete presentation of partial criteria changes:

$$Y(y_0) = \sum_{f=1}^{b} \gamma_{0f} \left(1 - y_{0f}\right)^{-1} \to \min, \quad (14)$$

where $f = 1...b$ is the amount of partial criteria included in the convolution; γ_{0f} is the unified weight coefficient; and y_{0f} is the standardised partial criterion that is being minimised.

Then the integrated assessment of the effectiveness of resource allocation is determined by this expression:

$$E_S = \sum_{l=1}^{L} \gamma_{0l} \left[(1-\overline{P}_{0l})^{-1} + (1-\overline{E}_{0l})^{-1} \right]. \quad (15)$$

Unification of the parameters included in (15) is made with relation to the sum of the discrete values, which describe their change by taking into account the direction of the extremisation of criteria (13) and the requirement to minimise those, included in convolution (14) according to these expressions:

$$\gamma_{0l} = \gamma_l / \sum_{l=1}^{L} \gamma_l,\ P_{0l} = \left[P_l \cdot \sum_{l=1}^{L} \frac{1}{P_l} \right]^{-1},$$
$$E_{0l} = \left[E_l \cdot \sum_{l=1}^{L} \frac{1}{E_l} \right]^{-1}. \quad (16)$$

Thus, expression (15) is a mathematical model for a multi-criteria effectiveness evaluation of limited resource allocation by partial criteria (13). In order to form the model, the technology of inserted convolutions is applied, which in the process of solving the task allows taking into account different requirements of service for various consumer groups according to priority by means of the introduction of the appropriate weight coefficients.

The absence of the availability of the absolute value of the integrated estimation E_S for forming the decision about the effectiveness of limited resource allocation requires a transition to its dimensionless value that would change from zero to one. This is possible to implement by E_S normalisation against the worst abstract version of allocation with E_n effectiveness:

$$E_{0S} = 1 - \frac{E_S}{E_n},\ E_n \neq 0. \quad (17)$$

The unified value of integrated evaluation comes up to one under high effectiveness of limited resource allocation, if not to zero.

5. An example of application of the suggested approaches

To evaluate the operability of the suggested approaches, the task of allocating radio-observation stations was considered. It is typical for the organisation of radio-monitoring process for radio-frequency source (RFS) (radar stations, repeaters, radios) to identify the type of observed objects (OO) containing RFS (command posts, air traffic management systems, etc.). It is necessary to distribute 19 observation stations for the identification of 22 observed objects (OO) with the total number of RFS being 105. Thus, three groups of observed objects (OO) of importance are defined: in the first group $N_1 = 9$, in the second $N_2 = 7$, and in the third $N_1 = 6$.

As a result of the application of the limited resource allocation model, the following results are obtained. To identify through RFS observation the first observed objects (OO), that refer to the first group of importance $n_{11} = 4$ stations are selected; similarly $n_{12} = 2$, $n_{13} = 1$, $n_{14} = 2$, $n_{15} = 1$, $n_{16} = 1$, $n_{17} = 1$, $n_{18} = 2$, $n_{19} = 0$, $n_{21} = 1$, $n_{22} = 1$, $n_{23} = 0$, $n_{24} = 2$, $n_{25} = 0$, $n_{26} = 0$, $n_{27} = 0$ are selected to identify the second group, and for the third group $n_{31} = 0$, $n_{32} = 1$, $n_{33} = 0$, $n_{34} = 0$, $n_{35} = 0$, $n_{36} = 0$ are chosen. The value $E_{0S} = 0{,}9$ is defined for the results in accordance with the effectiveness evaluation model formed. Thus, the suggested models provide a solution according to the purpose of use.

The use of the suggested approaches, besides the example given, is also possible for the distribution of rational resources of ground radio navigation facilities used in aeronautical systems for aircraft tracking, scheduling, transportation, etc.

6. Conclusions

Thus, the multi-criteria model of limited resource allocation, based on the statement of problem in a multi-criteria form by the effective cost model using a nonlinear scheme of compromises is suggested. The model differs from the analogue description of partial criteria of optimal discrete resource allocation in that it allows avoiding the need to consider all possible solutions and reduces the number of calculation procedures. The model created to effectively evaluate the allocation of limited resources is based on forming multi-criteria estimates for a nonlinear scheme of compromises and provides the solution in the form of numerical characteristics of effectiveness.

References

Air Navigation Plan. European Region. 2006. Basic ANP 1: 239.

Babak, V.; Kharchenko, V.; Vasylyev, V. 2007. Using generalized stochastic method to evaluate probability of conflict in controlled air traffic, *Aviation* 11(2): 31–36. doi:10.1080/16487788.2007.9635958.

Chumakov, N. M.; Serebrianyi, E. I. 1980. *Ocenka effektivnosti slozhnykh tekhnicheskikh ustroistv*. Moskva: Sov. radio. 192 p. (in Russian).

Gerasimov, B. M.; Diviziniuk, M. M.; Subach, I. J. 2004. *Sistemy podderzhki priniatiia reshenii: proektirovanie, primenenie, ocenka effektivnosti*. Sevastopol: Izdatelstvo СНИЯЭ и П. 320 p. (in Russian).

Grigorak, M.; Shkvar, O. 2011. A logistic approach for description of decision-making process, *Aviation* 15(1): 21–24. doi:10.3846/16487788.2011.566316.

Konin, V. V.; Kharchenko, V. P. 2010. *Sistemy sputnikovoi radionavigacii*. Kiev. 520 p. (in Russian).

Nechiporenko, V. I. 1977. *Strukturnyi analiz sistem (effektivnost i nadezhnost)*. Moskva: Sov. radio. 216 p. (in Russian).

Vasin, V. A.; Vlasov, I. B.; Egorov, J. M. 2003. *Informacionnye tekhnologii v radiotekhnicheskikh sistemakh.* Uchebnoe posobie. Moskva: Izdatelstvo MGTU im N. E. Baumana. 672 p. (in Russian).

Voronin, A. N. 1992. *Mnogokriterialnyi sintez dinamicheskikh sistem*. Kiev: Naukova dumka. 160 p. (in Russian).

SPRENDIMŲ PRIĖMIMO ORO NAVIGACIJOS SISTEMOSE PALAIKYMO DAUGIAKRITERINIAI MODELIAI

V. Charčenko, O. Pysarčuk

Santrauka. Straipsnyje pateikti daugiakriteriniai sprendimų formavimo modeliai, sprendžiant optimalaus ribotų išteklių paskirstymo ir gautų rezultatų efektyvumo įvertinimo užduotis. Optimaliems ištekliams pasiekti taikyta tokių kriterijų, kaip efektyvumas ir vertė, sistema, o sprendžiant optimizavimo užduotis – paketas pagal nelinijinių kompromisų schemą. Čia taikytas analoginis atskirų optimalaus paskirstymo kriterijų aprašymas, leidžiantis išvengti visų įmanomų sprendimų variantų perviršio būtinybės ir sumažinti būtinų operacijų skaičių.

Reikšminiai žodžiai: daugiakriteriniai modeliai, oro navigacija, transportavimo užduotis.