A. POTOȚCHI
M. I. OROVEANU
ȘT. MUSTĂȚEA
A. MARCU

The organization and coordination of a scientific research aiming to determine the required type of agricultural aircraft, using the graph's theory.

An essay is given of using the graph's theory to the planning of the research actions aimed to determine, in the shortest possible delay, an agricultural aircraft type. The study implies an ad-hoc methodology, based on the actions' analysis, and tries to establish the critical path of the process' development together with a fixation of the strength of specialized personnel.

The last decade has seen an important reshaping of the civil aviations' being and activity concepts, a reshaping which took different forms from a country to another.

The aviation's effort of modernization is by no means limited to transport activities; a large number of utility services, of public services, makes up today the list of the civil aviations' list of applications. Among the most important ones there are those destined to agriculture and forestry. When confronted with the terrestrial means, they afford a much faster intervention, especially as required by the weather and climatic variations, and on great areas, with a distinctly superior degree of efficiency.

In our country's agriculture, aircraft is used in :

— soil melioration (chemical fertilizers, amending substances, a.s.o.);
— crops' protection (insecticides, fungicides, herbicides);
— and sowing.

In forestry the aircraft is used for the protection of plants and for fire prevention and extinguishing.

Also, in both cases, air survey and aerofotogrammetry have an essential role, being the only ones to permit a correct and fast economic organization of the territory.

Our country has sufficiently large agricultural areas, to permit an efficient intervention by aeronautical means. A conclusive example may be the following one : for pest control, and using terrestrial devices, 36 hours-man are necessary for 16 hectares of land, namely 2.25 hours-man per hectare, while using aircraft 62 hours-man are needed for 250 hectares, viz. 0.248 hours-man/hectare. And it must be added that an airplane, continually used, may release 18 to 20 terrestrial machines, 4 towed trailers and 24 to 30 men.

Agricultural aviation's actions are involving a substantiation and an operational method, both as much scientific as possible. Also, the solutions adopted with regard to the flying materiel are prerequisitely bound to a series of research and development activities, as the only way to approach an opti mal settling.

The problem of the flying materiel intended to agricultural and forest uses has a complex character. Especially, some of the specifications are frequently having conflicting effects, while in the aggregate they must furnish a high technical and economic efficiency.

At a global level, the problem has been treated with a large diversity. At the present moment, nearly 20 types of aircraft are used, at which :

— *power* varies between 135 HP (Hollandair HA-001) and 1000 HP (Antonov AN-2) ;

— *total weight* goes from 1000 kgs (the Argentinian SA-46) to 4740 kgs (AN-2) ;

— *loading capacity* begins with 176 kgs (soviet PO-2) and reaches 1000 kgs (AN-2) ;

— *maximum speed* allows 125 kms/h to Piper PA-25 up to the 236 kms/h of Percival EP-9 ;

— *start/landing length* requests 215/137 metres, respectively, to Auster Agricola, and falls to 100/40 metres, ditto, for the Roumanian IAR 818.

Although the Roumanian flying materiel proved to be satisfactory up to now, being also favourably considered in foreign countries, the actual production is no longer fit to satisfy the growing necessities of our country's agriculture and forestry.

Therefore, the new problem is to conceive and produce a new flying materiel, using our industry's forces and, in the same time, to optimize the specialized agricultural equipment to be mounted on. And all these, having in view that, instead of a single type, two types of aircraft are needed, with distinctly different characteristics and performances.

* * *

If, in a general mood, research and development for aeronautics cannot be limited to the theoretical basic branches of science, agricultural aviation is precisely a domain who involves all the disciplines drawn by its different forms and stages.

On the other hand, production technology for aeronautics demonstrates a fast progress, its products appearing to be more and more complex. A new phenomenon comes also into sight, the reversal of the relation between „creation time" and "operation time", entailing wide and important implications.

With these considerations in mind, we deemed that a rational way could be the use of the critical path method for organizing and coordinating the scientific research activities related to utility aviation. In view of a conclusive and efficient solution, a modified variant of the critical path method has been used.

1. METHODOLOGICAL PRINCIPLES

In the last time, an ever larger diffusion has been given to various applications of the "graph's theory", in organization, management and planning activities. Among these, the most frequently met is the *critical path method*, the efficiency of which has been proved in a series of scopes.

The use of the critical path method for rationalizing different complex processes (of industrial production, civil engineering, design, a.s.o.) assumes the drawing up of a graph, representing the model of the process that has to be optimized.

Proceeding to the graph's elaboration according to the *arc activity* principle, each activity of the network analyzed process is represented in the form of an arc, and the begining and ending terms of the various activities are marked by the graph's events, after which will be determined the path of maximum duration (called the critical path) and be analyzed all possible economic solutions for the reduction of the path, under a strict observance of the method's principles.

One must have in mind that every calculus and "conjectures" needed for optimization should be based on the premise that a clearly determined process is already existing. By this, it must be understood that the structure and the succession of the process' activities are well known and relatively unchanging. We have expressely used "relatively unchanging", because situations may arise when a certain succession, considered as logically rational at a given moment, could be modified due to new conditions created by the technical progress.

This premise is compulsory in every critical path method's variants, indifferently if using a single duration value for each activity (in the case of CPM) or using aleatory duration (as with the PERT method).

Accordingly, if for all other scopes, as construction planning, the management of design works, rationalizing of the organization for production and repair's technological processes, coordination of various military problems, a.s.o., a clearly specified methodology is already existing for a network analysis, for scientific research this method must be modified and adjusted.

To ensure an expositional uniformity and for avoiding possible confusions, we have to specify that we understand by *research process* the totality of *research activities* carried with a view to the solution of a *research project* (theme). Thus, each activity will be marked by an oriented arc, the sum of these arcs forming a graph which represents the process leading to the project's solution.

In the case of research processes, reality requires the start with the hypothesis that, even if for some activities one may establish certain durations, respectively terms, for other activities their achievement is itself under the mark of interrogation, which could lead to a cessation, viz. the suppression of an entire path.

In fact, the analysis of any scientific research process, in any domain will show that — at its launching moment — the results are not assuredly known or at least not known are the results and the solutions to be furnished by the variant taken into consideration. It has been found that the critical path's methodology should have particularly in view such conditions of uncertainty, in which the modeled process' activities will be carried on.

Consequently, a scientifical research process does not permit the construction of a graph with a precisely determined succession of arcs, because the results and conclusions pertaining to certain research activities cannot be previously known. In other words, only after the actual termination of one or more research activities one may see if the followed path is, or not,

the good one. Also, only then it will be possible to find which variant must be assumed and followed, and which of them have to be abandoned. It results that, after the end of such research activities, there will appear in the graph the decision moments corresponding to certain events.

1.1. The decision box

We will call these events, decision boxes, and their characteristic will consist in the fact that the multitude of arcs, externally incidents with themselves ($U_{\bar{d}i}^{+}$), will not be uniquely determined, but rather of an aleatory dimension, varying as a function of the conditions arisen during the development of the activities marked by the arcs internally incidents with themselves ($U_{\bar{d}i}$).

To differentiate into the drawing the normal nodes towards the decision boxes, the last ones will be marked by triangles (see figure 1).

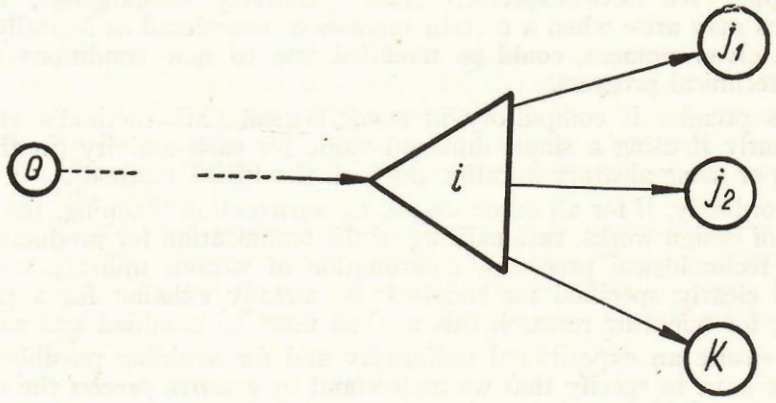

Fig. 1

For the rest of characteristics, the decision boxes are entirely similar to the common nodes, being simple stages and marking various terms (times). We defined more precisely this, so as no error be commited in the sense of the ellaboration or the emission of a certain decision at a decision box. The choice of a certain variant, or the formulation or ellaboration of a decision, are taking place on the course of the activities (arcs) ending at the decision box.

1.2. Conjunctive and disjunctive arcs

When elaborating the graph of a scientific research process, hence before the actual proceeding at the research proper, one cannot know the results of these research activities permitting the choice of a path (variant) for the process' continuation. Thus, the graph's elaboration phase requires the provision, in its limits, of all possible variants that could arise in the course of the scentific research process. Yet, on the course of the scientific process represented by the graph, certain arcs and even paths initially taken into consideration but subsequently found as unsuitable — will be eliminated.

We see that certain variants (arcs) are going to mutually remove themselves, these being designated in the foreign specialized literature as *disjunctive arcs*, while others will follow a parallel development, for which we accept the designate as *conjunctive arcs*.

In what concerns the organization and coordination of the research team's activity, attention should be drawn to the conjunctive arcs, as they presume a splitting of the researchers effective depending on the number of these arcs (parallel actions).

1.3. The numbering system used for the conjuctive and disjunctive variants' nodes

To distinguish the conjunctive variants from the disjunctives, and also with a view to the premises requested by a possible machine processing of the graphs containing decision boxes, we adopted the following numbering of nodes, thus delimiting the conjunctive and disjunctive arcs respectively:

1.3.1. *Conjunctive arc nodes have been given different numbers (for instance, nodes j and k in figure 1)*;

1.3.2. *Disjunctive arc nodes have the same numbers, a distinction between them being obtained by indexes attached to the digits (as with nodes* j_1 *and* j_2 *in figure 1)*.

We adopted this numbering system because in the calculations aiming to find the critical path, disjunctive variants — those mutually removing themselves — will be considered each separately, being independent one of another. It will result, thus, the obtention for each disjunctive variant of a subgraph with his own critical path; using this procedure, one variant's node numbering cannot be confounded with another.

For variants being conjunctive between themselves, the situation will be totally reverted, these variants forming a single common subgraph. This was the reason we choosed a distinct numbering of nodes, so as to avoid confusions.

1.4. The problem of activities precedent to the disjunctive variants

Occasionally, research activities scheduled to be started after a decision, hence those activities the validity or nonvalidity of which will appear only in the decision box from where they proceed, need the performance of other preliminary activities, having no direct contingency whit the decision box (*see figure 2*).

In the example from figure *2*, such activities are marked by nodes (f_1, h_1); (h_1, j_1) afferent to variant (i, j_1), respectively (f_2, h_2); (h_2, j_2) corresponding to variant (i, j_2).

The problem is if there is rational that these activities be commenced before the settling term of the decision box. If not, figure *2* is transformed as follows (*see figure 3*):

Such a case implies an extension of the term for the whole research process.

Sometimes, researchers are forced to accept this situation; at other times, due to the extremely fast progress of science in our time, this retardation may involve a series of costly consequences.

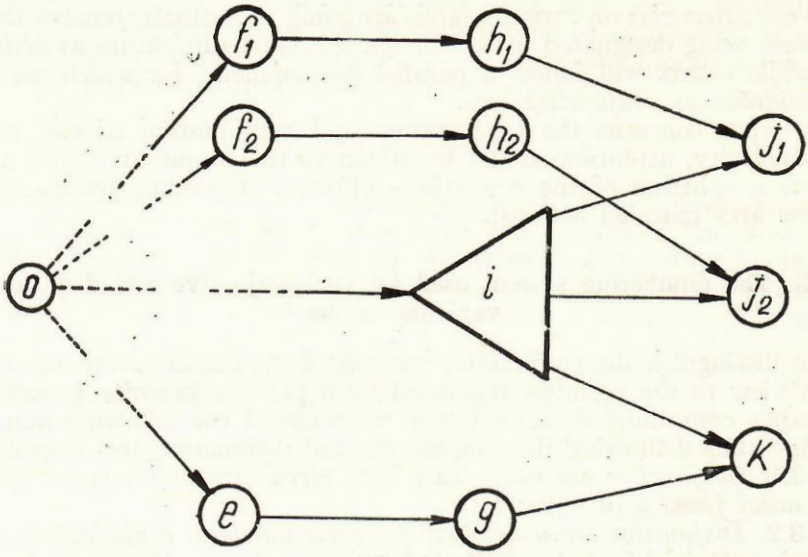

Fig. 2

1.5. The duration problem of the research activities

"It si well known" — was saying comrade Nicolae Ceaușescu at the december 1965 session of the Grand National Assembly of the S.R.R. — "that research cannot be always related to a fixed date, but also cannot be spread out without a definite prospect. In science, the time factor plays a particularly important rôle, that of shortening the duration of research work, allowing to keep pace with the development rate of world's science. In the international scientific competition, a country holds herself faster and becomes richer if her researchers succeed to a more quickly solution of problems, to a sooner practical application of the acquired findings."

One may encounter certain cases when, even with the clear hazard of spending for some activities who will be further found as wasteful for that research, it may appear as efficient the "untimely" launch of these activities preceding disjunctive variants.

Nevertheless, the measurement of an "untimely" lauch's economic efficiency constitutes a particularly complex problem, the precise solution of which has'nt been found yet. And this, because even if one may assess the time reduction for the entire research process, the ascertainement of relatives economies obtained by applying the research's results is dependent upon a series of factors who cannot be influenced by the researcher.

It is quite evident that when the activities preceding disjunctive variants are including a very large duration, and the *necessary* means for their execution are scarce, an "untimely" launching may be adequate, but also inversely.

If more variants intervene, being disjunctive in front of the precedent respective activities, we consider that to determine the urgency of these activities and of their launching terms it may be useful the settling of shares, from the viewpoint of the respective activities' needs in the research process. The settling of these orientational shares will be stipulated in the frame

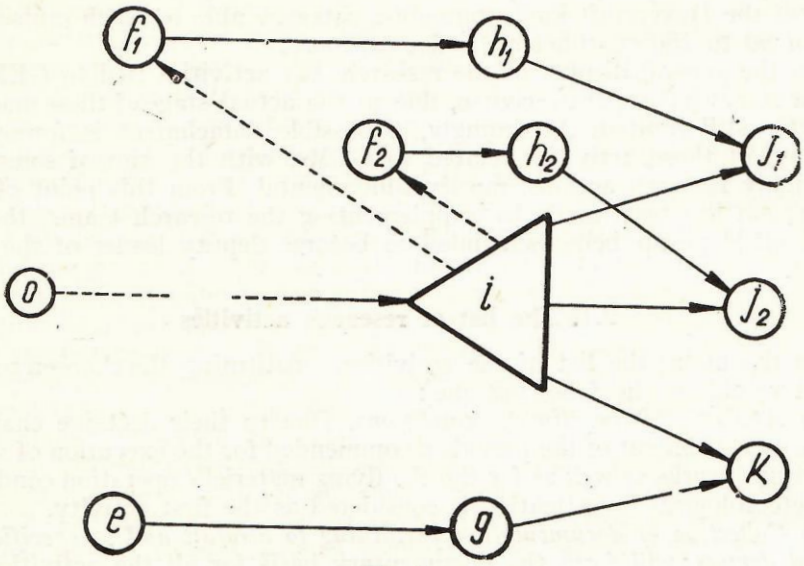

Fig. 3

of a research activity, as corresponding as possible to the fulfilment of such an evaluation, and the respective research activity being integrated in one of the paths leading precisely to the decision box involved.

In what concerns the majority of research projects having an "applied" character, one can estimate their component activities duration. In this case, the prepared graph model permits a determination of the critical path and a capitalization of all inferences deriving, with a view to the research process' optimization.

For the research projects with a "basic" character, to whom the activities' duration cannot be estimated, the prepared graph model, although not allowing a determination of the critical path, could be still useful for a more accurate analysis and organization of the logical sequence of various component activities

2. ORGANIZATION AND COORDINATION OF THE RESEARCH PROCESS.

To attain the objective, the determination of an optimal type of agricultural aircraft, the investigations (and also the series of studies and research actions) are endorsing all categories of utility aircraft, together with all categories of afferent engines, namely :

— "classical" airplanes, STOL, VTOL, helicopters, autogyro combinations, and GEMs;

— piston engines, propjets, and turbofans.

It is well known that VTOL aircraft may be conceived with :

— fixed wing, incorporating turbofans in the wings;

— fixed wings, with special aerodynamic guiding and lifting devices;

— mobile (tilting) wing, with propjets in the wings and with airscrews of a diameter greater than normal.

In what concerns the GEMs, we would like to state that our concept regards a category of craft somehow different from the "air cushion vehi-

cles" (of the Hovercraft kind), namely a category able to reach cruising heights of 90 to 150 centimetres, and even more.

In the general display of the research, the activities tied to GEMs will have a somewhat separate course, due to the actual stage of these machines, presently still limited. Accordingly, a possible detachment is foreseen, on the way, of those activities related to GEMs, with the aim of some more thoroughly research actions, mostly fundamental. From this point of view, a provision has been made by supplementing the research teams, the head of the GEM group being scheduled to become deputy leader of the whole project.

2.1. The list of research activities

In the main, the list of the activities constituting the choosen research project would be the following one :

1) *Analysis of the climatic conditions.* Due to their decesive character, for the establishment of the periods recommended for the execution of various agricultural works as well as for the the flying materiel's operation conditions, the meteorological investigation is considered as the first activity.

2) *Collection of documentation pertaining to aircraft and to specific agricultural devices*; will form the documentary basis for all the activities comprised in the research.

3) *Analysis of the kind of works to be done, of the periods recomended for their execution, and also of the share of various categories of soil* (flat, slope, a.s.o.), allows a specification of the kind of necessary works, and of the times they have to be carried on, together with a percentual settling of the categories of agricultural soils, as treatable by air action.

4) *Study and choice of the aircraft's recommended parameters,* including maximum speed at sea level, maximum speed in the air, medium recommended speed, maximum height (altitude), cruising height, and the specifical heights recommended for dusting, spraying, and seeding. The study will have as basis the documentation, and the choice of parameters will be related to the results obtained from activities 1 and 3.

5) *Processing of the documentation specific to aircraft* (including GEM).

6) *Processing of the documentation specific to board agricultural devices.*

NOTE : activities 5 and 6 are making up a selection of the information existing on achievements obtained in foreign countries.

7) *Preliminary analysis of the distribution of shares on various kinds of aircraft*; will be carried in relation to the programme of agricultural works, as derived from activity 3.

8) *Comparison of the results obtained in agricultural work by various aircraft existing in the world,* so as to permit the establishment of certain general indicators.

9) *Calculus of the theoretical necessary output* (the load, and the land area to be covered during one mission).

10) *Comparison between the results obtained with the first four categories of aircraft, and the results obtained by the use of terrestrial means,* both performing similar missions.

11) *Study and establishment of the recommended technical parameters for the specific board devices* (see 6), meaned to constitute the board agricultural apparatus of the aircraft (for dusting, spraying, and seeding).

12) *Analysis of the characteristics of foreign utility aircraft* (operational), *and of the stage reached by the studies on Gems*, in relation with the specific conditions of our country, and with their economic efficiency.

13) *Refreshment of the documentation*, with the purpose of completing the information as against the former activities requesting precisions.

14) *Choice of the kind of aircraft.* This activity has the character of a crucial point for the future orientation of the research. One considers compulsory the participation of the project leader, together with delegates empowered by the agricultural customer, by the aircraft construction industry, and by the air services company. Having in view the land categories and the types of crops specific to our conutry, together with the characteristics of the first four categories of aircraft considered, it would be impossible to limit the choice at a single kind of aircraft, being necessary to make it constantly with two categories. The conjunctivity conditions and/or those of disjunctivity, in this essay, will be the following : airplane and helicopter, or airplane and VTOL, or STOL and helicopter.

15) *Systemic correlation and processing of the documentation regarding the constructional formulae* of the first four categories of aircraft (less the GEMs).

16) *Settling of the conditions intended to the choice of the constructional formula for the selected aircraft* (criteria, raw values, a.s.o., regarding the aircraft's layout and useful load).

17) *Studies pertaining to the creation of board agricultural devices, corresponding to GeM's specific conditions.*

18) *Studies pertaining to the creation of a GEM*, corresponding to agricultural specific needs.

19) *Theoretic studies on the results hypothetically obtainable with a GEM.*

20) *Comparison of the data obtained in the studies related to GEMs, with those obtained through activity 10*, with the aim of an accurate definition of the possible position of a GEM in air services for agriculture, provided the existence of actual possibilities of normal achievement.

21) *Studies on the aerodynamic solution due to a GEM, as intended for agricultural services.*

22) *Studies pertaining to the solution required by the engine destined to an agricultural working GEM.*

NOTE : activities 17 to 22 (incl.) are not intersecting the sequence of the other activities meaned for the four aircraft, being listed at their above positions due to the fact they will take place concomitantly.

23) *Researches related to the calculus of the global output of the engines*, separately for each of the four categories of aircraft, completed with the choice of the kind of engine.

24) *Decision regarding the engine's necessary rating* (HP), *and the number of engines.*

25) *Aerodynamic studies on the proper family of profiles* for the lifting surfaces.

26) *Studies related to the hypothesis of a propjet VTOL*, as required by the choice of fixed or tilting wing.

27) *Studies connected to lift*, in case of the choice of fixed wing VTOL.

28) *Ditto*, in case of the choice of tilting wing VTOL.

29) *Systemic correlation of the documentation* regarding reciprocating engines.

30) *Ditto*, regarding projets.

31) *Ditto*, regarding turbofans.

32) *Economie efficiency's calculus* for each kind of aircraft, as well as for GEMs.

33) *Comparison between economic efficiency calculations*, as applied to the variants proven to be conjunctive. Elaboration of the *final statement* of the research project.

34) *Elaboration of the formal act of recommendation* for the use of ensuing design activities. This action will be performed by the entire research team.

35) *Orientational* technical and economic *studies* regarding the *aircraft and engine's construction process.*

36) *Ditto*, regarding the *GEM's construction process.*

NOTE : activities 35 and 36 to be achieved with the aditional participation of the aircraft industry's representative.

In principle, research is virtually ended by activity 34. But, due to the very complex problems entailed by the construction of a modern utility aircraft, and with regard to every category of machines — including GEMs, supplementary activities 35 and 36 have been enclosed, so as to allow a more realistic constructional answer.

These activities have the specific characteı of the transitional actions occuring between „research development" and "design" phases, yielding a direct contribution to a better technical and economic substantiation of the efficiency calculations related to the agricultural use of utility aviation.

2.2. Transposition of the research activities in a graph model

The graph's working out phase demands a special attention owing to the importance it has for the future coordination of research. During this phase, attention should be centred on the concatenation of the activities into a logically rational sequence. The graph will have the aspect shown in fig. 4.

With the aim of an easier identification of the listed research actions with the arcs shown in figure 4, we show a comparative table comprising in the same time the groups of specialists required to carry each activity, and the durations, in days.

Table 1

Showing the agreement between the research activities' inventory and the graph's arcs

Activity nr.	Arc.	The speciality of the research personnel	Number of researchers	Duration (days)
1	(0,1)	— navigator or senior pilot — agrotechnical researcher	1 1	10
2	(0,2)	— documentalist — aerotechnical documentation — aerotechnical specialist	1 1	30
3	(1,3)	— agrotechnical researcher — aeronautical researcher specialized in agricultural problems	1 1	30

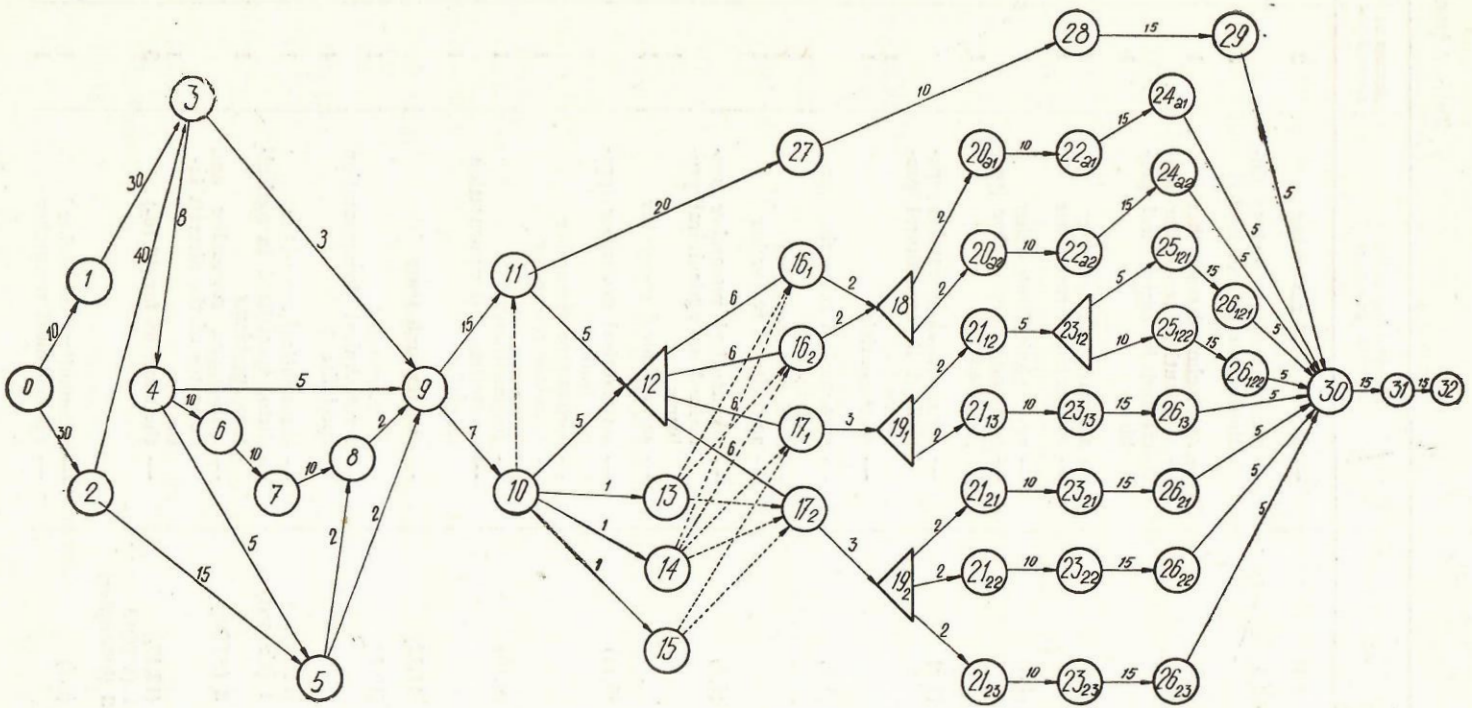

Fig. 4

Table 1 (continuation)

Activity nr.	Arc	The speciality of the research personnel	Number of researchers	Duration (days)
4	(3,4)	— aeronautical researcher	2	8
5	(2,3,)	— aeronautical researchers (including the project leader)	3	40
6	(2,5)	— agrotechnical researcher	1	
		— aeronautical researcher specialized in agricultural problems	1	15
7	(3,9)	— aeronautical researcher	2	
		— agrotechnical researcher	1	3
8	(4,5)	— agrotechnical researcher	1	
		— aeronautical researcher (project leader)	1	5
9	(4,9)	— aeronautical researcher specialized in agricultural problems	1	
		— mathematician	1	5
10	(5,8)	— aeronautical researcher (project leader)	1	
		— economic researcher	1	
		— agricultural researcher	1	2
11	(5,9)	— aeronautical researcher specialized in agricultural problems	1	
		— agrotechnical researcher	1	2
12	(9,11)	— aeronautical researcher (project leader)	1	
		— aero-engine researcher	1	
		— economic researcher	1	15
13	(9,10)	— documentalist	1	
		— aerotechnical documentation specialist	1	7
14	(11,12)	— the research team		5
15	(10,12)	— documentalist	1	
		— aerotechnical documentation specialist	1	5
16	$(12,16_a)$	— aeronautical researcher	1	
	$a = 1$ (aircraft)	— ditto, specialized in agricultural problems	1	
	$a = 2$ (STOL)	— aero-engine researcher and delegates of the aircraft industry.	1	6
	$(12,17_i)$	— the same as for $(12,16_a)$	3	6
	$i = 1$ (VTOL)			
	$i = 2$ (helicopter)			
17	(6,7)	— aeronautical researcher	1	
		— agrotechnical researcher	1	10

Table 1 (continuation)

Activity nr.	Arc	The speciality of the research personnel	Number of researchers	Duration (days)
18	(4,6)	— aeronautical researcher (de-		
		(deputy project leader)	1	
		— aeronautical researcher specialized in agricultural problems	1	
		— aero-engine researcher	1	10
19	(7,8)	— aeronautical researcher specialized in agricultural problems	1	
		— aero-engine researcher	1	10
20	(8,9)	— aeronautical researcher (project leader)	1	
		— aeronautical researcher specialized in agricultural problems	1	
		— agrotechnical researcher	1	2
21	(11,27)	— aeronautical researcher (deputy project leader)	1	
		— aero-engine researcher	1	20
22	(27,28)	— the same as for (11,27)	2	10
23	(16_a, 18)	— aeronautical researcher	1	
	$a = 1,2$	— aero-engine researcher	1	2
	(17_i,19_i)	— the same as for (16_a,18)	2	3
	$i = 1,2$			
24	($18,20_{aj}$)	— the same as for (16_a,18)	2	2
	$a = 1,2$			
	$j = 1$ —MP	*Note*: MP = piston engine,		
	$j = 2$ — MTP	MTP = propjet		
	(19_i,21_{ij})	— the same as for (16_a,18)	2	2
	for $i = 1$; $j = 2,3$;			
	for $i = 2$; $j = 1,2,3$	*Note*. MTV = turbofan		
	$j = 3$ — MTV			
25	(20_aj,22_aj)	— aeronautical researcher	1	10
	$a = 1,2$			
	$j = 1,2$			
	(21_{ij},23ij)	— aeronautical researcher	1	10
	for $i = 1$; $j = 3$			
	for $i = 2$; $j = 1, 2, 3$			
26	(21_{12},23_{12})	— acro-engine researcher	1	
		— aeronautical researcher	1	5
27	(23_{12},25_{121})	— the same as for (21_{12},23_{12})	2	5
28	(23_{12},25_{122})	— the same as for (21_{12},23_{12})	2	10
29	(10,13)	— documentalist	1	
		— aerotechnical documentation specialist	1	1

Table 1 (continuation)

Activity nr.	Arc	The speciality of the research personnel	Number of researchers	Duration (days)
30	(10,14)	— the same as for (10,13)	2	1
31	(10,15)	— the same as for (10,13)	2	1
32	(29,30) for GEM	— aeronautical researcher (deputy project leader)	1	
		— mathematician	1	
		— economic researcher	1	5
	$(24_{aj},30)$ $a = 1,2$ $j = 1,2$	— aeronautical researcher	1	
		— mathematician	1	
		— economic researcher	1	5
	$(26_{12k},30)$ $k = 1$ — fixed wing $k = 2$ — mobile wing	— the same as for $(24_{aj},30)$	3	5
	(26ij,30) for $i = 1$; $j = 3$ for $i = 2$; $j = 1,2,3$	— the same as for (24aj,30)	3	5
33	(30,31)	— aeronautical researcher (project leader)	1	
		— aeronautical researcher (deputy project leader)	1	
		— economic researcher	1	
		— mathematician	1	
		and delegates of the aircraft industry		15
34	(31,32)	— The entire team less the documentalists		15
35	(28,29)	— aeronautical researcher and delegates of the aircraft industry		15
36	$(22_{aj},24_{aj})$ $a = 1,2$ $j = 1,2$	—aeronautical researcher and delegates of the aircraft industry	1	15
	$(23_{ij},26_{ij})$ for $i = 1$; $j = 3$ for $i = 2$; $j = 1,2,3$	— the same as for $(22_{aj},24_{aj})$		15
	$(25_{12k},26_{12k})$ $k = 1,2$	— the same as for $(22_{aj},24_{aj})$		15
Dummy activities	(10,11) $(13,16_a)$ $a = 1,2$ $(13,17_2)$ $(14,16_a)$ $a = 1,2$ $(14,17_i)$ $i = 1,2$ $(15,17_i)$ $i = 1,2$	These arcs represent only logical conditions, proving the dependency between various activities. They don't need time (duration) nor research personnel, and have been depicted as dotted lines.		

2.3. Calculation of the critical path and network analisis of the research projest's development

The calculations for the critical path's settling have been effected by using the table lower down (but they could be also carried with other methods as the duration' matrix, Ford's algorhytm, a.s.o.).

The notations used in the Table represent, for each activity:

$t_i^{(0)}$ — the soonest possible term of beginning,
$t_j^{(1)}$ — the latest allowable term of beginning,
$t_i^{(0)}$ — the soonest possible term of ending,
$t_j^{(1)}$ — the latest allowable term of ending,
R_m — the maximum slack time,
R_l — the free slack time.

The maximum slack time is calculated according to formula

$$Rm(ij) = t_i^{(1)}(i, j) - t_i^{(0)}(i,j)$$

in time that the free slack time is obtained with formula

$$Rl(i, j) = t_i^{(0)}(j, k) - t_j^{(0)}(i, j)$$

In the case event j is placed on the critical path, then Rl = Rm.

Is an example, we show only an excerpt of Table 2.

Table 2

Showing the durations, terms and slack times, as parts of the graph

Activity	Duration	$t_i^{(0)}$	$t_i^{(1)}$	$t_j^{(0)}$	$t_i^{(1)}$	*Rm*	*Rl*
0,1	10	0	30	10	40	30	0
0,2	30	0	0	30	30	0	0
1,3	30	10	40	40	70	30	30
2,3	40	30	30	70	70	0	0
2,5	15	30	91	45	106	61	38
⋮							
$23_{12},25_{121}$	5	146	150	151	155	4	0
$23_{12},25_{122}$	10(9)	146	146	156 (155)	155	0	0
⋮							
31,32	15	191 (190)	190	206 (205)	205	0	0

Accepting the hypothesis according to which the activities have been correctly appreciated, the analysis of the data from column 3 and 4 of the Table allows the following findings:

1. If one agrees as a solution the VTOL variant with mobile tilting-wing and propjet propulsion, the critical path through this variant will amount 206 days, passing by events 0,2, 3, 4, 6, 7, 8, 9, 11, 12, 17_1, 19_1, 21_{12}, 23_{12}, 25_{122}, 26_{122}, 30, 31, 32.

2. If this variant will be abandoned in the course of the research, which can be ascertained when reaching decision boxes 12, 19_1 or 23_{12} (see figure 4) the critical path will be determined by the activities pertaining to the

GEM, on a track totalizing 205 days. This critical path will pass by events 0, 2, 3, 4, 6, 7, 8, 9, 11, 27, 28, 29, 30, 31, 32.

The network analysis will be carried out, considering the critical path with a duration of 205 days (the path going through the GEM specific activities). We accept this because the difference between the two path's durations is a minimum one, and also because there is a relatively small probability for the acceptance of the tilting wing VTOL variant. This one is passing by three decision boxes, whilst the activities pertaining to the GEM don't involve any decision box.

Once this hypothesis accepted, we must resort to a small expedient, reducing a day from the duration of one of the tilting wing VTOL variant' specific activities (see digits in parenthesis, Table 2), with a reserve of eventually taking again this day, should the variant be approached. The reduction will be operated at the activity marked by arc $(23_{12}, 25_{122})$.

Using, on one hand, the data from columns 7 and 8 of Table 2, namely the slack times, and on the other hand comparing the researchers' speciality column (table 1) with figure 4, we will pursue the achievement of the main objectives of this study:

a) to determine an effective of researchers as reduced as possible,

b) to carry on the research in the shortest delay.

It is quite evident that these two objectives are leading at contrary effects. By reducing the strength of researchers, it is generally presumed an extension of the research duration, and vice versa. This is the reason why one must carry, beforehand, a sound analysis of the general trend concerning the application urgency of the research' effects. Depending on this, one of the above-mentioned objectives must be selected as the prevailing one.

Due to the fact we had not the data needed to evaluate the practical acuteness of the research project's results, we will proceed to analyze, commencing by a determination of the necessary strength of researchers, following as much as possible a uniform distribution of their tasks and trying to reduce as much of the research process' duration.

3. DETERMINATION OF THE STRENGTH OF SPECIALIZED RESEARCHERS.

To determine the necessary effective of personnel, by speciality branches, we applied the following method:

3.1. A new analysing table *(Table 3)* hase been constructed, the "predicate" of which were the indicators from Table 2.

3.2. The "subject" of the new *table (3)* was formed by the speciality and the number of researchers participating to the various research activities.

3.3. Approaching each time a single speciality (researcher), one had entered every activity where the specialized researcher was participating, together with the indicators from Table 2, corresponding to each activity.

3.4. After the new Table has been completed with every speciality, Gantt graphs have been built for each separate researcher, using as far as possible the slack times, so as to form specialized research teams, as limited as possible.

3.4.*1*. It is recommended to start this operation with the researchers of the speciality considered as the most difficult to be covered with the desired number of specialists. In our case, we begun with the aeronautical researchers.

3.4.2. Each time, after the solution of a problem of effectives regarding the researchers of a certain speciality, one have to report every term's modifications also to the other specialities collaborating in those activities subjected to modifications.

3.5. This procedure must be repeated step by step, until all specialities are exhausted, thus obtaining a minimal team corresponding to the given conditions.

Table three's structure will be :

Researchers		Activities								Remarks
Speciality	Number of	Arc	Duration	t_i^0	t_i^1	t_j^0	t_j^1	Rm	Rl	

Upon analysis of the data contained in this Table (which cannot be exposed, due to the limited space available), the following team of researchers has resulted :

— aeronautical researchers (including the project leader and his deputy, the last being also responsible form the GEM group)	3
— aeronautical researchers specialized in agricultural problems (one of which will be used to support the above-mentioned, at peak periods)	2
Aeronautical researchers, in all	5
— aero-engines researchers (one of which being specialized in specific GEM propulsion problems)	3
— agrotechnical researcher	1
— economic researchers	2
— mathematicians	2
— aeronautical documentation specialist	1
— documentalist (bibliographer)	1
General effective of researchers	15

— air navigator (or senior pilot) having a limited activity, he may be placed in a consultant position, without being counted in the permanent research personnel.

Once established the effective of researchers, one must include in Table 2 all restrictions (alteration of terms) imposed by the shape of the research team, and one may proceed to the reduction of the research process.

4. ACTIONS TENDING TO OBTAIN A SHORTEST DELAY FOR THE ACCOMPLISHMENT OF THE RESEARCH.

The analysis already performed leads to the conclusion that, indifferently of the choosen disjunctive variant, one must reduce the research process' duration until node *11*. For instance, the durations of activities (0,2)

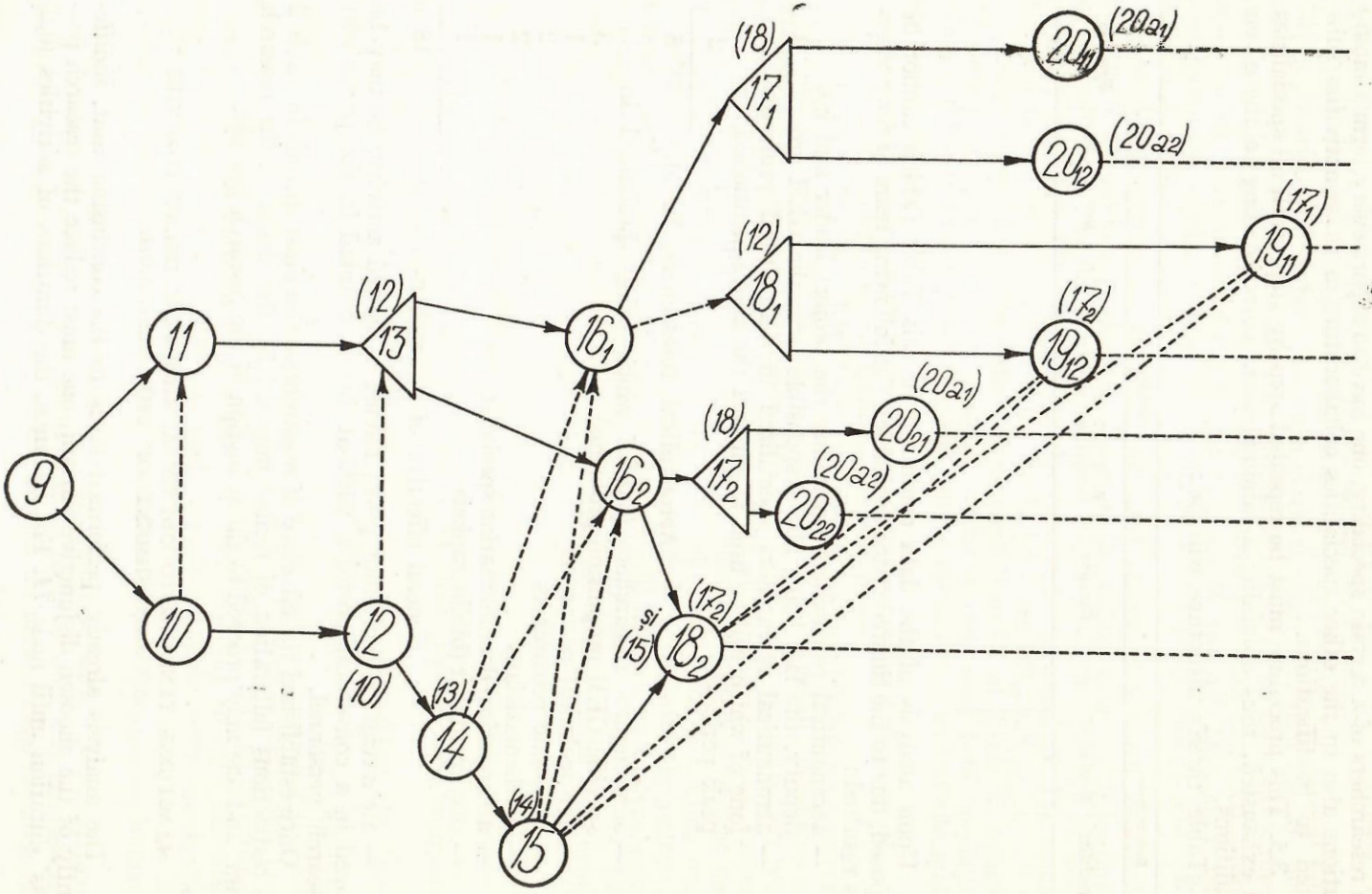
9
11
10
12
(10)
13
(12)
14
(13)
15
(14)
16₁
16₂
17₁
(18)
17₂
(18)
18₁
(12)
18₂
(17₂)
(15)
19₁₁
(17₁)
19₁₂
(17₂)
20₁₁
(20a₁)
20₁₂
(20a₂)
20₂₁
(20a₁)
20₂₂
(20a₂)

Fig. 5

and (1, 3) may be reduced by using, for activity (0,2) aeronautical researchers and for activity (1,3) mathematicians. For both activities, economic researchers are especially recommended, due to their education.

With regard to the of specialization profile problem of the professional researchers, one must underline that a sound analysis of reduction opportunities of the research process' duration may be carried out only after a complete knowledge of the research team's qualitative structure.

Anyhow, one considers that by using certain professional researchers also in other activities, for whom they were not definitely designated, one may obtain economies of about 20...30 days, so that the entire research process' duration could be limited to 157...185 working days.

However, attention must be drawn on the fact that the graph's structure will be modified, if acting in the hypothesis that due to the lack of specialized personnel — a parallel performance of the conjunctive variants will be impossible. This regards especially the activities included between nodes 12 and 30 which, according to Table 1, are using personnel of the same branch (speciality).

This altered position of figure 4 graph is presented in figure 5, together with the modification given to the documentation activities' sequence. To offer a better representation of the alterations' correspondence, we retain also the early counting of nodes, put in parenthesis. This last regrouping of activities involves an elongation of the research process' duration, that may vary between 25 to 30 days, depending on the acceptance, or the reject, of the mobile wing VTOL variant.

BIBLIOGRAPHY

1. Andrejszyn S. şi Olenski J., *Aplicarea metodei drumului critic în condiţii de nesiguranţă.* În Conducerea, organizarea şi aprovizionarea întreprinderilor, I.D.T. Caiet selectiv 8, nr 11, nov. 1965 (traducere din Ekonomika i Organizacja Pracy, nr. 6, 1965).
2. Jackson R. P. şi Longton P. A., *Operational Research and Aviation Management,* part. I. In Journal of the Royal Aeronautical Society, 1965, nr. 656 (aug.).
3. Thumb N., *Die Netzwerktechnik* (partea III-a). *In Zeitschrift für wirtschaftliche Fertigung,* 60, nr. 4, apr. 1965.
4. Potoţchi A., *Metode noi de raţionalizare a proceselor complexe.* În Studii şi cercetări economice, vol. IV, 1965.
5. * * * *Metodologia folosirii drumului critic la raţionalizarea proiectelor de investiţii şi a proceselor complexe de producţie,* Bucureşti, IDT, 1965.
6. Dyment J. T., *Tools of Airline Management.* In Journal of the Royal Aeronautical Society, 1965, nr. 649 (ian.).
7. Falkenhausen H., *Prinzipien und Rechenverfahren der Netzplantechnik.* In A.D.L. Nachrichten, nr. 30 (ian.-mar. 1964), nr. 33 (iul.-sept. 1964), nr. 34 (oct.-dec. 1964), nr. 35 (ian.-mar. 1965).
8. Oroveanu M. I., *Elementul ştiinţific în aviaţia civilă.* În Revista transporturilor, 1964, nr. 11
9. Iacovachi I. N., *Avionul YAR-818 în dotaţia aviaţiei militare.* În Revista transporturilor, 1964, nr. 7.
10. Lavaud G., *Relations entre le Ministère des Armées, l'université et l'industrie dans le domaine de la recherche scientifique et technique.* In Technique et Science Aeronautiques et Spatiales, 1964, nr. 4.
11. Marcu Al., *Productivitatea avioanelor utilitare în misiuni agrosilvice.* În Revista transporturilor, 1962, nr. 9.
12. Rado Gh., *Elicopter cu stabilitate proprie la punct fix.* În Studii şi cercetări de mecanică aplicată, 1962, nr. 2.

13. O'Brien M. P., *Right and Wrong Technological Planning*. In Technological Planning on the Corporate Leval. Harward University, Boston, 1962.
14. Oroveanu M. I., *Un nou mijloc de locomoție : vehiculele cu efectul solului*. În Revista transporturilor, 1961, nr. 9.
15. Weiffenbach J. F., *Structuring R|D Organizations*. În Researche and Development 1961, nr 6.
16. Patraulea N. N., Andrei St. şi Rado Gh., *Asupra calculului aerodinamic al vehiculelor utilizînd efectul solului*. În Studii şi cercetări de mecanică aplicată, 1960, nr. 6.
17. Bliss L. G., *Managing the Research and Development Activity*. In Top Management Handbook, McGraw Hill Co., New York, 1960.

L'ORGANISATION ET LA COORDINATION DES RECHERCHES SCIENTIFIQUES POUR LA DÉTERMINATION DU TYPE NÉCESSAIRE D'AÉRONEF UTILITAIRE AGRICOLE AU MOYEN DE LA THÉORIE DES GRAPHES

L'auteur présente une nouvelle variante de la méthode du chemin critique adaptée aux conditions spécifiques de la poursuite d'un processus de recherche scientifique. Cette nouvelle variante constitue au fond la représentation dans le réseau d'un processus complexe accompli dans des conditions d'incertitude. Le graphe au moyen duquel on modèle le processus respectif de recherche comprend plusieurs chemins disjonctifs et conjonctifs; les chemins disjonctifs sont ceux qui s'éliminent réciproquement en partant du noeud de décision respectif, tandis que les chemins conjonctifs sont ceux continués parallèlement (sans s'éliminer réciproquement).

De telles situations caractérisent les processus complexes de recherche scientifique, dans le cadre desquels le choix d'une des solutions prises initialement en considération peut être effectué seulement dans le cadre de la poursuite du programme de la recherche.

En vue d'illustrer cette méthodologie, l'auteur a exposé la recherche qu'il faut effectuer pour la détermination du type nécessaire d'aéronef utilitaire agricole.

En employant cette méthodologie, on a déterminé: 1) le programme de la poursuite de la recherche; 2) le nombre des chercheurs par profession, qui doivent accomplir la recherche respective; 3) la durée approximative du processus de recherche.

ОРГАНИЗАЦИЯ И КООРДИНАЦИЯ НАУЧНЫХ ИССЛЕДОВАНИЙ ДЛЯ ОПРЕДЕНИЯ НЕОБХОДИМОГО ТИПА СЕЛЬСКОХОЗЯЙСТВЕННОГО САМОЛЕТА ПРИ ПОМОЩИ ТЕОРИИ ГРАФОВ

Приводится новый вариант метода критического пути применительно к специфическим условиям развертывания отдельного процесса научного исследования. Этот новый вариант является, в сущности, изображением в сети комплексного процесса, выполняемого в условиях неуверенности. Граф, при помощи которого моделируется соответствующий процесс исследования, содержит несколько узлов решения, от которых исходит ряд дисъюнктивных и конъюнктивных путей; под дисъюнктивными понимаются пути, которые от соответствующего узла решения взаимно элиминируются, а под конъюнктивными путями понимаются пути, которые продолжаются параллельно (без взаимного элиминирования).

Подобные положения характеризуют комплексные процессы научного исследования, в пределах которых выбор одного из первоначально принятых в расчет решений мохно производить только в ходе выполнения программы исследования.

Для иллюстрации было выбрано исследование, которое следует провести для определения необходимого типа сельскохозяйственного самолета.

На основе применения вышеуказанной методики были определены: 1) программа проведения исследования; 2) профессиональный состав исследователей для выполнения данного исследования; 3) приблизительная длительность процесса исследования.