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DIAGNOSTICS AND CONDITION ESTIMATION PROCESS OF CONSTRUCTION OF THE SHIP ON SYSTEM PERT ON THE BASIS OF INTEGRATED CHARACTERISTICS

ABSTRACT

The method of diagnostics and an estimation of a condition of process of construction of a ship on the basis of integrated characteristics in PERT system is shown in the paper. The mathematical apparatus of the description of integrated characteristics and procedure of determination of their parameters is given. The technology of forming of the integrated characteristic of discrete production on the basis of Gantt chart and procedure of an estimation of a condition given process as object of management under the scheme "times-resources" is resulted. The result is illustrated by an example of construction of a ship of type "river-sea".

Keywords: diagnostics, the integrated characteristic, the control, PERT, technology,

INTRODUCTION

One of approaches to the decision of tasks of forecasting and an estimation of a condition of production processes of discrete type is the method of network planning and management of type "times-resources" (PERT). However, despite all advantages of this method, forming of procedures of the operative control and decision making on management of its means demands considerable time and enough difficult mathematical apparatus of modeling, considering specificity of construction of network schedules.

Development of technologies of the decision of tasks of the control and the analysis of a condition of real production processes for the purpose of construction of extremely simple mathematical models, is one of the central problems in any applied area. In this connection, in work it is considered by one of perspective approaches to construction of models of an estimation of

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a condition and forecasting of behavior of objects of discrete type: a method of integrated characteristics. The author offers this method for tasks of software of operational management and decision making on management of productions of discrete type which the shipbuilding concerns also.

1. FORMING OF INTEGRATED CHARACTERISTICS

Representing real object with sufficient accuracy, it is necessary to consider that its mathematical model should be whenever possible simple and adaptive. The further work with difficult model not only is inconvenient, but it can appear almost impossible. At formalization of real objects it is reasonable to be guided by mathematical models of a standard kind which are provided by the corresponding managing device and easily give in to integration by known methods [30]. Adaptation of graph-matrix representations in integrated characteristics (ICH) means of classical integr-differential mathematical apparatus [1] can be one of such decisions.

At development of network models rational degree of detailed elaboration of works, as it is known, gets out. The volume of a necessary resource for each work is allocated in a time interval determined by the moments of a fulfillment of initial and final events of this work. To consider real distribution of volume of each elementary work in the conditions of real production practically it is not real. With sufficient accuracy for practical calculations it is possible to accept this distribution either relay, or linear. Accuracy of approximation depends on number of events in a network. The linear model is closer to real and was more completely reflects a process course.

Average speed (intensity of accomplishment of elementary work) is determined from expression [1,2]:

$$q = \frac{dV}{dt} = \frac{de \cdot n \bullet Z \cdot t}{a+1}, \qquad (1)$$

where: de – duration of a working shift (hour/change);
n – average of the workers occupied in change on given work (hour/change);
Z – average coefficient of an over fulfillment of replaceable rates (change/rab.den);
t – number of working shifts in day (change/rab.den);
a – coefficient of not considered losses of time

According to topology of a network within an interval some elementary operations simultaneously can be carried out. Total speed of simultaneously carried out works in an interval is determined by expression:

$$q_j = \sum_{i=1}^{1} q_{ij} = \sum_{l}^{b} \frac{de_{jl} \cdot t_{jl}}{a_{jl} + 1} n_{jl} Z_{jl} \ , \tag{2}$$

where q_{jl} – speed of accomplishment l - elementary work on i - interval

$i = \overline{1, I}$, $l = \overline{1, L}$, $j = \overline{1, J}$.

The real characteristic of distribution of amount of works on time we will present in the form of linear – piecewise approximation which can be expressed the integrated sum [4]:

$$V^* = \sum_j V_j = \sum_j q_j \Delta t_j \ , \tag{3}$$

where: V_j – the amount of works which is carried out at j time interval

Δt_j – duration j time interval

At $j = J$ we will receive planned (most probable) amount of works:

$$V_{пл} = \sum_{j=1}^{J} V_j = \sum_{j=1}^{J} q_j \Delta t_j \ . \tag{4}$$

The considered approach is based on accounting of natural quantization of a time base by the moments of a fulfillment of all events of a network. Simple sequence of a chain of works, the moments of which fulfillment of events correspond to points of a break of the real characteristic of integrated distribution of amounts of works, we will specify as the equivalent model of a real network expressed by means of the classical mathematics (geometrically).

Limiting transition gives dependence:

$$V(t) = l \lim_{\Delta t_j \to \infty} \sum_j V_j = \int_0^1 q(t) dt \ . \tag{5}$$

This dependence approximates the linearly-piecewise characteristic that is represents it in the form of a continuous curve which can be interpreted known laws of the integr-differential description of linear functions by means of classical mathematics and «the method of integrated characteristics» (ICH) leads to methodology of an estimation of a condition and forecasting of the production process named the author.

Complete transition corresponds to casual infinite detailed elaboration of network model at

$$t = t_{пл}\,;\; V(t) = V_{пл}\,. \tag{6}$$

Let's notice that construction ICH is considered with reference to the determined networks, characteristic for technologies of shipbuilding.

Thus, we come to forming of three equivalent models which consistently transform production technology representation to model ICH under the scheme:

a) the initial network schedule;
b) equivalent network model;
c) the initial integrated characteristic.

2. THE DEVICE OF THE DESCRIPTION OF INTEGRATED CHARACTERISTICS

The made analysis of considerable number of network models in productions of the different types, that number and in shipbuilding, has allowed to remove sample ICH which are approximated by standard integr-differential characteristics (Fig. 1).

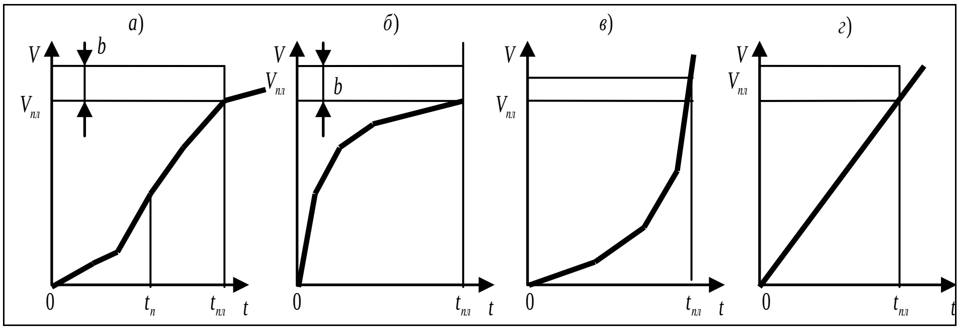

Fig. 1. Sample characteristics of integrated distribution

For integrated distribution the model of a kind (6) is removed:

$$V(t)=\begin{cases} 0, \quad npu \quad t<0 \\ V_{пл}, \quad npu \quad t>t_{пл} \\ (V_{пл}+b)\left(1-d_1 e^{-\frac{t}{T_3}}+d_2 e^{-\frac{t}{T_4}}\right) \quad , \quad t_{пл}\geq t\geq 0. \end{cases} \tag{7}$$

Here $d_1=\frac{T_3}{T_3-T_4}$; $d_2=\frac{T_4}{T_3-T_4}$;

T_3 and T_4 – constant coefficients, dimensional time.

The size «b» entered for increase of accuracy of approximation, is determined at $t=t_{пл}$ ::

$$b=\frac{V_{пл}\left(d_1 e^{-\frac{t_{пл}}{T_3}}-d_2 e^{-\frac{t_{пл}}{T_4}}\right)}{1-d_1 e^{-\frac{t_{пл}}{T_3}}+d_2 e^{-\frac{t_{пл}}{T_4}}}. \tag{8}$$

Thus we will receive a point of an excess of the integrated characteristic, having equated second half of derivative function to zero. Then we will specify an excess point as

$$V(t_n)=(V_{пл}+b)\left(1-\frac{T_3+T_4}{T_3}e^{-\frac{t_n}{T_3}}\right) \tag{9}$$

The point of an excess also determines type ICH. In Fig. 1 these characteristics are shown: with normal (a), to lobbies (b) and back (c) fronts of works. The type characteristic (d) is theoretical (predicted). It can be applied in extremely rare occurence – uniform job design on all front of accomplishment of production operations. Thus, the volume of carried out operations at production process of discrete type in actual practice will be:

$$V(t)=\begin{cases}0, & при \quad t<0,\\ V_{пл}, & при \quad t>t_{пл},\\ (V_{пл}+b)\left(1-e^{-\frac{t}{T_3}}\right) & при \quad t_{пл}\geq t\geq 0,\end{cases} \tag{10}$$

3. COMMUNICATION OF THE INITIAL DATA OF OBJECT WITH MODEL PARAMETERS

Let's find the dependences connecting the initial data with parameters of model. Having transformed expression (7), we will receive in relative units position of a point of an excess on time axis:

$$\frac{\varphi_{T_1}}{\varphi_{T_3}}-1=e^{\frac{-\varphi_{T_1}}{\varphi_{T_3}}}\left(\frac{2-\varphi_{T_1}/\varphi_{T_3}}{\varphi_{T_1}/\varphi_{T_3}-1}\right), \tag{11}$$

where $\varphi_{T_1}=\frac{T_1}{t_{пл}}$; $\varphi_{T_3}=\frac{T_3}{t_{пл}}$; $\varphi_{t_{пл}}=\frac{T_n}{t_{пл}}$.

Let's specify a condition of a finding of a point of an excess of an envelope on a site of a bit-straight-line characteristic which has the maximum inclination. Speed of course of process in an excess point we will specify as

$$Q_{\max}=\frac{V_{пл}+b}{T_3}e^{\frac{-t_n}{T_3}} \tag{12}$$

where

$$T_1=T_3+T_4=\frac{(V_{пл}-V_n)+b}{Q_{\max}}, \tag{13}$$

where T_1 – time necessary for accomplishment of a complex of operations with

In the maximum speed;

$\frac{V_{пл} - V_n}{Q_{\max}}$ – time necessary for accomplishment of the remained amount of works with the maximum speed;

$\frac{b}{Q_{\max}}$ – extra time of additional volume.

Let's present the decision in a dimensionless type:

$$\varphi_{T_1} = \frac{\delta_n}{\varphi_{Q_{man}}} + \frac{\varphi_b}{\varphi_{Q_{\max}}}, \tag{14}$$

where

$$\delta_n = 1 - \varphi_{V_n};\ \varphi_{V_П} = \frac{V_n}{V_{пл}};\varphi_{Q_{\max}} = \frac{t_{пл}}{V_n};\varphi_b = \frac{b}{V_{пл}}$$

If the equation of an approximating curve behind an excess point we will present in the operational form:

$$(T_1 \cdot S + 1)(V - V_n) = (V_{пл} - V) + b, \tag{15}$$

where V – current value of volume of carried out works.

The decision (15) for a point $(V_{пл}, t_{пл})$ we will write down in a kind:

$$(V_{пл} - V_n) = (b + V_{пл} - V_n)\left(1 - e^{-\frac{t_{пл} - t_n}{T_1}}\right), \tag{16}$$

whence after transformations

$$b = \frac{(V_{пл} - V_n)e^{-\frac{t_{пл} - t_n}{T_1}}}{1 - e^{-\frac{t_{пл} - t_n}{T_1}}} \tag{17}$$

Having passed to dimensionless sizes, we will write down a condition of passage of the integrated characteristic through a planned point in a definitive kind

$$\frac{\varphi_b}{\varphi_{Q_{\max}}} = \frac{\delta / \varphi_{Q_{\max}}}{e^{\frac{1-\varphi_{t_n}}{\varphi_{T_1}}} - 1}. \qquad (18)$$

To solve system of the transcendental equations resulted above, it is possible or a method of consecutive approach, or graphical.

Calculations have allowed to construct the nomogram for determination of parameters of a mathematical model of the integrated characteristic (Fig. 2). Thus, the mathematical apparatus of realization of a reference mode of functioning of object of management is developed by means of integrated characteristics.

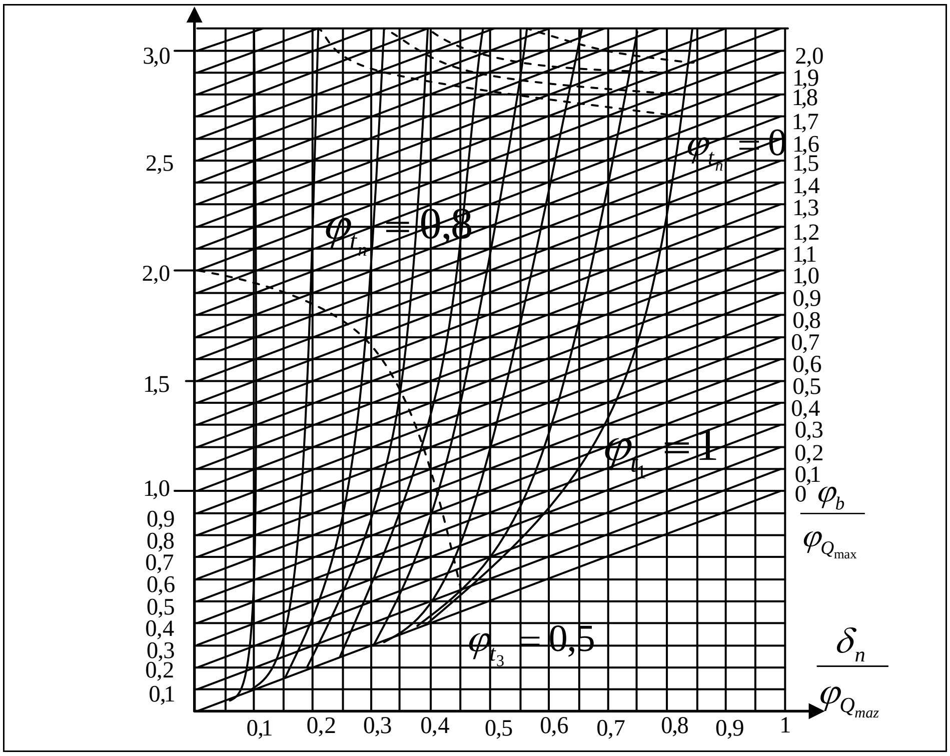

Fig. 2. The nomogram for parameters of ICH model.

4. AN EXAMPLE OF CONSTRUCTION OF THE INTEGRATED CHARACTERISTIC

The received results are illustrated by a concrete example.

The commission of experts, and organizers of production has arranged technologists

Technology of construction of a boat the river-sea of the project 576 in the form of a network schedule (Fig. 3).

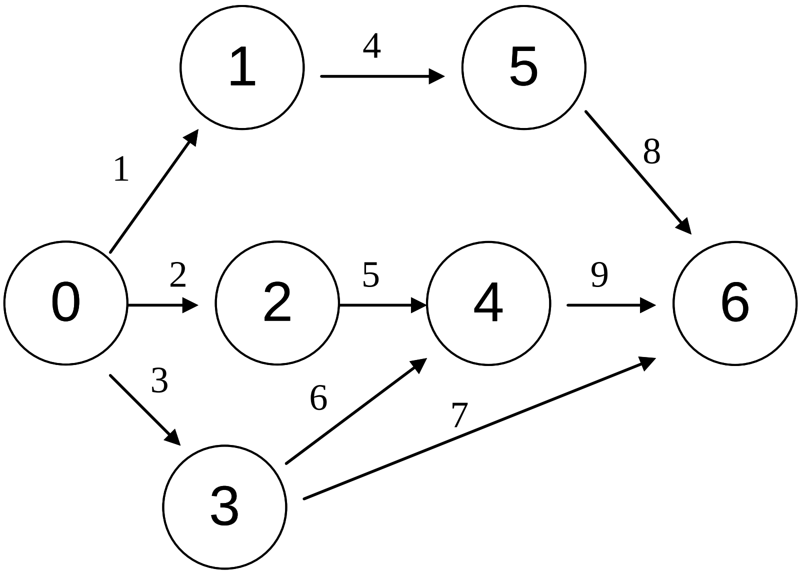

Fig. 3. The network schedule of construction of a boat the river-sea (the project 576)

Thus, base parameters of network model (a network schedule) have been tabulated. To construct ICH on these given by quite probably known computer methods (Fig. 6). We will complicate a task and we will construct ICH, having resorted to a variant of its forming on the basis of Gantt chart (Fig. 4). Business in that. That a number of ship-building productions has

Table 1.

The given constructions of a boat the river-sea (the project 576)

№	P	R	t	R/t
1	0-1	16	7	2,29
2	0-2	22	13	1,69
3	0-3	13	8	1,63
4	1-5	0	19	0,00
5	2-4	7	14	0,50
6	3-4	11	19	0,58
7	3-6	5	3	1,67
8	5-6	6	8	0,75
9	4-6	7	11	0,64

Source: own data

own cycles of specific complexes of operations, at planning and which forecasting it is used Gantt chart [3].

Such condition is dictated by necessity of distribution of elements of uniform process on production divisions, shops, the sites, considering their specificity and technological unity: production metallic - and tree, molding, assemblage (picking) of separate knots and items, installation, etc. For example, at boat building, its such elements as the case, moving complex, power installation, deck details and mechanisms are created by different production divisions (shops) with the specific equipment, equipment, shots and only then, on a building berth, are mounted as a unit an item – a boat. In this case just and it is convenient to apply Gantt chart, beginning its construction on separate ways of the network schedule for the purpose of effective control and management of separate kinds of production process not only on a complex indicator times-resources, but also on speed of use of the allocated resource on each operation (R/t). Table 1 contains all necessary data for this procedure: P – operation number it agree a network schedule. R – a resource on each operation, t – an operation lead time, R/t - speed of resource consumption on each operation.

Let's designate ways on graph on Fig. 1, which are only four: I: 1-4-8, II: 2-5-9, III: 3-6-9, IV: 3-7.

Now we will find total time for each way:
I: 7 + 19 + 8 = 34, II: 13 + 14 + 11 = 38, III: 8 + 19 + 11 = 38, IV: 8 + 3 = 11.
Critical path is the way with the maximum time, that is in this case it is ways number two and number three (II,III).

Let's calculate the sum of the resources necessary for realization of all program of construction of a boat of a class "river-sea" under Table 1.

$$\sum R = 16 + 22 + 13 + 0 + 7 + 11 + 5 + 6 + 7 = 87.$$

From the same Table 1 we will specify speeds of resource consumption on each of works R/t .

Having constituted generalized Gantt chart, it is easy to generate the integrated characteristic that in effect won't change its form as though it has been received by a traditional way by a technique stated above (Fig. 6).

On the basis of received given (Fig. 4) we will construct broken line ICH (Fig. 5) which we'll aproximate (will plan) in the form of the settlement characteristic. It полность coincides with already received before (Fig. 6).

In practice the engineering error of modeling ICH should be no more than 5 % - 7 %. If it hasn't occurred, reception ICH on Gantt chart is executed not precisely or with errors. These calculations are necessary to repeat. At forecasting of accomplishment of operations is usual pass to the relative units expressed or coordinates 1.0-1.0, or in percentage terms that, basically, same. In our case if for 100 % to accept all used resource and established time of production process we will receive that t is identical 100 % (t =1) and R are identical 100 % (R=1). Then linear ICH it is possible to present on a square field of decisions of tasks of the forecast and an estimation of a condition of production process (object of management) and to pass to the analysis of this object in relative units. For an illustration of the resulted statement the Fig. 6 is reversible for example.

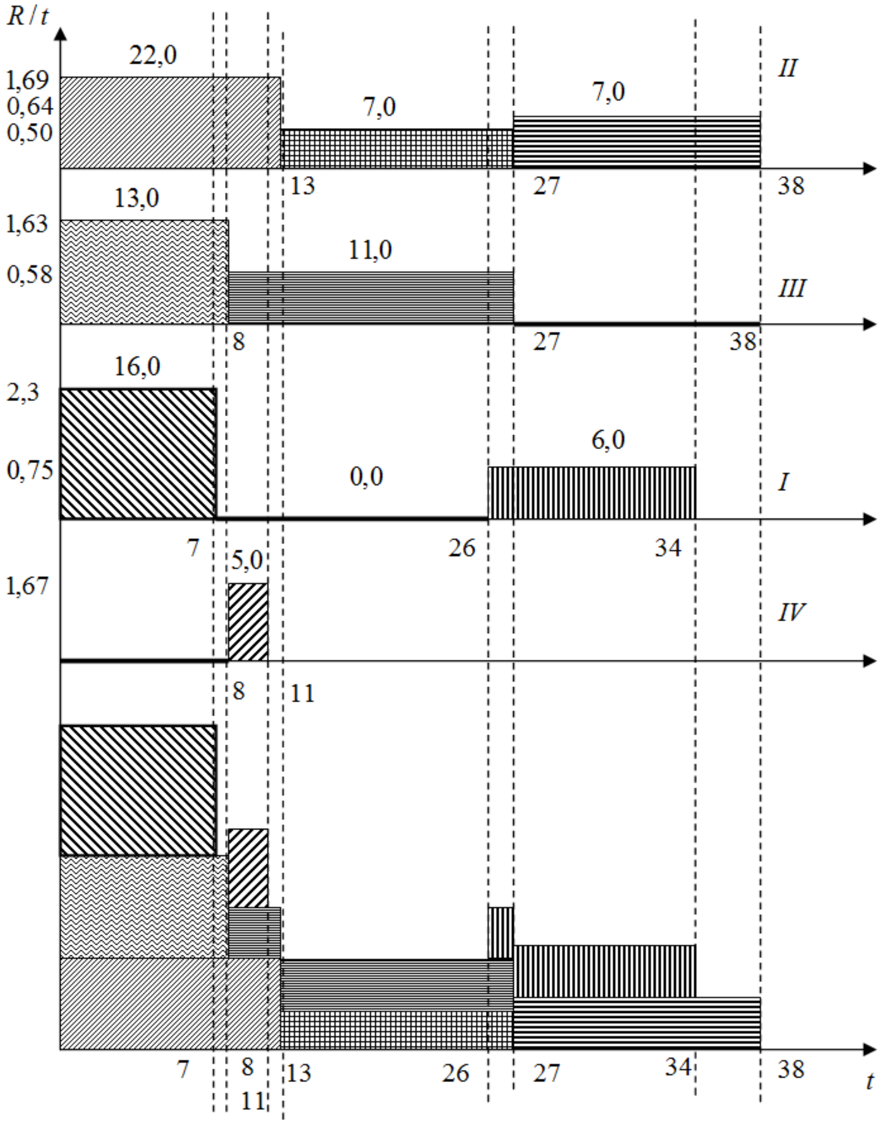

Fig. 4. Gantt chart constructions of a boat of the project 576

The analysis of forecasting of process of construction of a boat of a class "river-sea" 576 projects on the accepted technology (Fig. 1) shows that at 50 % of time of duration Production process it is necessary to spend 90 % of resources, and for development of 17 % of resources 10 % of time (Fig. 6) is required.

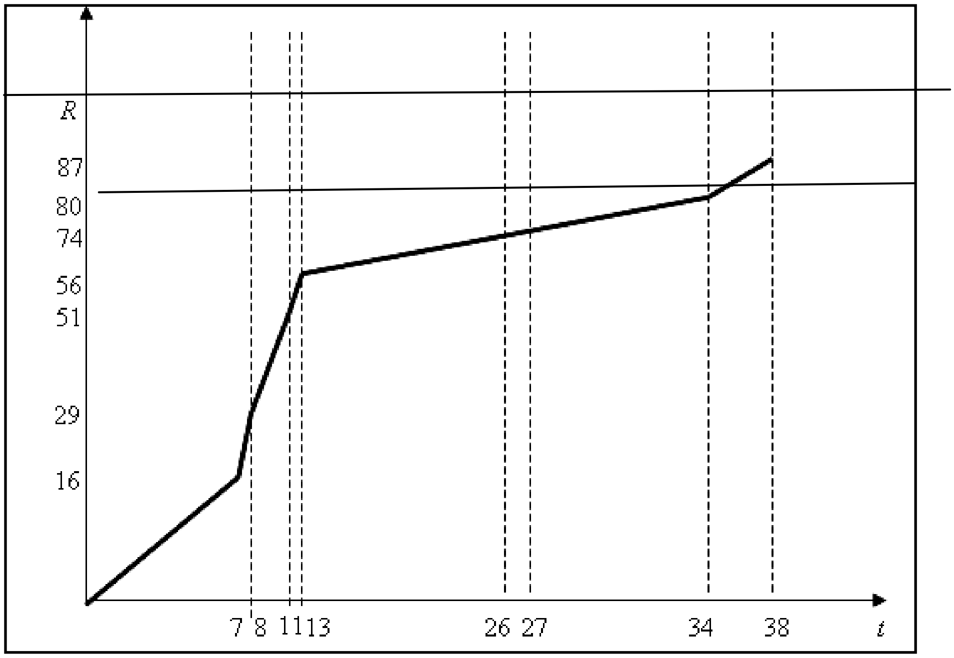

Fig. 5. Broken line ICH by Gantt chart (Table 1)

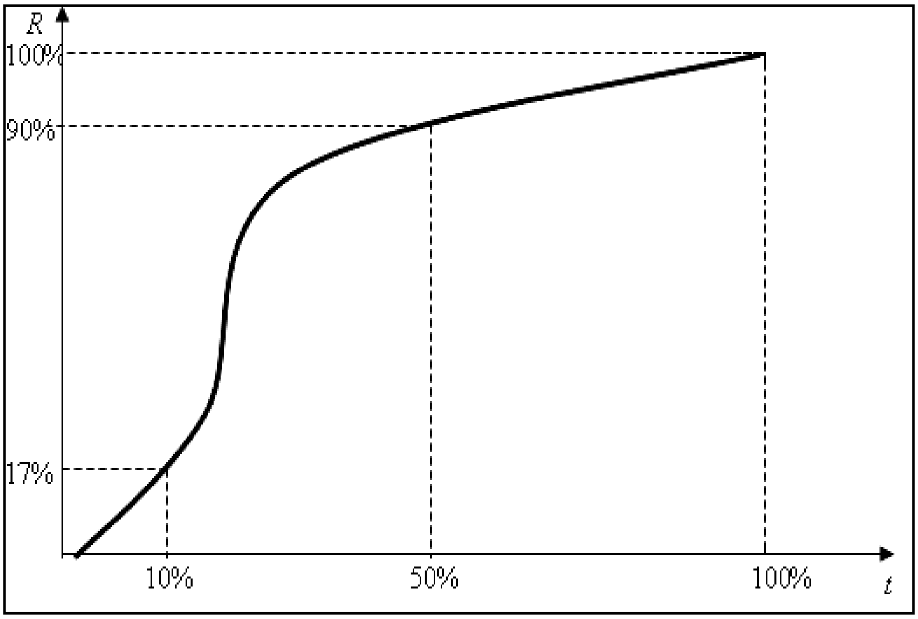

Fig. 6. Forecasting of a condition of production process of construction of a boat of the project 576 (river-sea)

CONCLUSION

In the present work technologies and organization models, methods of representation, the control, forecasting for support and decision making on management of objects of productions of discrete type on the basis of integrated characteristics in the environment of system PERT are offered.

Thus orientation to methods PERT containing in a basis the focused directed graph, allows to use widely the offered methodology for any process or the object which technology is described by system of causes and effect relationships and events. Almost all objects and processes concern the specified class of technologies continuous and discrete production, building, mechanical engineering, shipbuilding, instrument making, including assembly technologies.

BIBLIOGRAPHY

1. Arefyev I., *Model zarządzania procesem produkcyjnym na bazie charakterystyki integralnej*, Szczecin, AM, Zeszyty naukowe N 9 (8), 2007, s. 14-20
2. Arefyev I., *Adaptation of integral Characteristics Method for an Estimation of Critical Navigational Situations in Difficult Rout Sections* Vol.18,No.2A, 2009. p. 32-40
3. Арефьев И.Б., Новиков М.Н., *Метод построения интегральных характеристик и оценка допустимой области системотехнического объекта*. // Системный анализ в проектировании и управлении. 10–я Международная научно-практическая конференция. – СПб, Политехнический университет, 2006 г.,ч. 3 – с.53
4. Месарович М. Такахара Н., *Общая теория систем: математические основы*, - М: Мир, 1978 г. 600 с.