Network Modelling of Resource Consumption Intensities in Human Capital Management in Digital Business Enterprises by the Critical Path Method

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Abstract
The article analyses the resource consumption intensities in human capital management in digital business enterprises by the critical path method. The article provides a critical review of the use of human capital development tools. The network of the IT project in representations "work-arc" and "work-top" is constructed. The time parameters of the project in these two views are calculated. The Gantt chart for the researched project is constructed, and also the histograms of intensities of consumption of human resources are constructed. The distribution of the researched resources within the calculated duration of the project and relatively increased by 10% relative to the calculated duration of the project has been optimized. The comparison of the values of the maximum intensities of resource use before optimization and as a result of its implementation is performed.

Keywords 1
Critical Path Method, Network Modelling, IT projects, Resource Consumption Intensities, Human Capital Management, Digital Business Enterprises

1. Introduction

Within the project team as an organizational structure of project management function project manager, project coordinator engineer, design manager, administrative and information services, groups of finance, accounting and analysis, marketing, management of construction works, logistics, work coordinator etc.

Man is the main figure of the project. Any project with any material and financial support without the people who carry it out is ineffective. The project manager must have a wide range of knowledge from different areas of activity. The project manager must know in detail all the life phases of the project. However, the most important area of its activity is effective cooperation with a large number of people: team members, company employees, project participants, the environment of direct and indirect influence [1, 2].

The priority of this area of activity is confirmed by the results of a survey of specialists-managers. Almost 80% of respondents put the factor of human relations in the first place of all factors influencing the successful implementation of the project. The human aspect of project management is manifested in all phases of the project, because negotiations, meetings, decision-making, conflict resolution and other relationships are integral procedures of the project.

2. Related Works Review

The project manager must understand people, evaluate and anticipate what can be expected of them in a given situation. Such knowledge helps the project manager to find contact with team members, company employees, customers and other project participants [2–4]. Understanding the psychology of people will allow him to take the right position in negotiations, meetings, in conflict, as well as to involve people in favor of the project with maximum effect.

Most people who have succeeded in various spheres of public life, were able to properly "program" their relationships and behavior in society, knew or guessed about the psychological patterns of human communication and influences on people, successfully applied them in practice. However, as a rule, these people did not receive special psychological training. There are only two reasons: work in critical situations and lack of time - it turned out to be enough to introduce psychology into the training plans of project managers, who work, as a rule, in conditions of constant stress.

There are many recipes and methods for achieving psychological stability and confidence, strategies for influencing the environment and shaping one's own destiny. It is expedient for everyone to know themselves, especially for managers, on whose actions the efficiency of subordinates' work depends. Knowing yourself, you can correct your own behavior, minimize shortcomings or even get rid of them, develop positive traits. Clearly knowing your strengths and weaknesses, you can choose the right line and form of behavior in different situations.

The behavioral basis of communication between people and their actions in various situations is the psychological characteristics of the individual. To determine it, there are many tests in practical psychology [3-6]. The most common of these are socionics tests, which divide people according to the manifestations of their emotions into extroverts and introverts. In extroverts, everything is "written on the face", they express their feelings (words, gestures, facial expressions) in such a way that it is very easy for the interlocutor to determine their reaction to their words and actions. Introverts, on the other hand, express their emotions very succinctly, as if they are turned inward; their reaction is usually impossible to recognize immediately. Only a psychologist on certain grounds can establish how his information is received and what can be expected in return.

There are tests that determine a person's emotional types by temperament (melancholics, phlegmatics, sanguine and choleric) and their role in the team (leader, performer, opponent, idea generator, critic, indifferent).

Consider the psychological characteristics of project team members and personally the project manager. Let's analyze what makes the work of a project manager effective.

You can suggest three criteria for the head:
• leadership traits (effective managers have some common traits);
• leadership styles (they use different styles);
• situational approach (effective managers adapt their style to the circumstances).

The human factor is a situation when people do something wrong or, conversely, do not perform any actions that are necessary. People's mistakes are often the basis for the physical causes we have already mentioned. For example, an employee violated the rules of use of equipment, so it refused [4-8].

First, the development of project management concepts requires constant theoretical and methodological improvement [9-13]. After all, changes in society and in production dictate new requirements.

Secondly, any management related to the human factor has always been and will be of interest to scientists in all fields [14-18]. Because personnel management needs to be constantly improved, taking into account the individual needs of each person. Third, the effective management of any project requires living people who create a team to perform the tasks. And the future of the project will depend on how effectively it will be formed.

The man is the central figure of the project. Any project with any material and financial support without human participation is dead. Therefore, the project manager by the nature of its activities must have knowledge in many special areas. But the most important thing in his work is cooperation with a large number of people: team members, company employees, project participants, the environment of direct and indirect influence. The priority of this area of activity is confirmed by the results of a survey of many specialists-managers: 82% of them consider the human factor to be the main among others in terms of its impact on the outcome of the project.

There is no doubt that the center of all modern concepts of management is man. The development and dissemination of human resource management concepts is becoming an important trend that is most closely related to other aspects of management evolution [5, 19-23].

In the context of restructuring economic relations, the formation of new organizational structures operating on the basis of various forms of ownership, the key to successful organization can be considered successful integration of human resources management and business operations, which dynamically takes into account internal and external situations. The evolution of society in the direction from industrial to information causes fundamental changes in the product "labour" [24-28].

As its carrier is increasingly the most skilled workers and employees, that is, the workforce becomes intelligent, information-rich, so its alienation from the owner is in a qualitatively new form. The variety of planning activities, the large number of participants involved and the rigid interconnectedness of all components of economic processes necessitates purposeful structuring of the processes of the organization, ie long-term regulation of the actions of managers [29-33].

The human aspect of project management is important in all phases of the project, as such factors as negotiations, meetings, decision-making, conflict resolution and others are integral procedures in the project implementation. Therefore, the project manager must have psychological skills to evaluate the person, predict in advance what and in what situation to expect from him, find contact with team members, company employees, customers and other project participants [34-38].

Understanding the psychology of people will allow the project manager to take the right position in negotiations, meetings, conflict situation, will provide opportunities to involve the necessary people in the project with maximum effect. Most people who have succeeded in various spheres of public life, were able to "program" their relationships and behaviour in society, learned the psychological patterns of human communication, influence on people, successfully applied this knowledge in practice [6]. However, these people, as a rule, did not have special psychological training.

Working in situations of non-directive communication and limited communication time, which are characteristic of the activities of project managers, necessitated the introduction of the subject of psychology in their training. Today there are many methods of achieving psychological stability and confidence, strategies to influence people and shape their destiny. But first of all, the project manager must follow the rule: "To know others better, know yourself!" This makes it possible to correct their behavior: shortcomings -reduce, if you cannot completely get rid of them, the advantages - to develop; By clearly understanding your strengths and weaknesses, you can choose the right course of action in various difficult situations in advance .

"It's better to straighten your hair by looking at yourself in the mirror." Such a mirror can be a psychological portrait, built on the results of testing. The most common is a test in which people are divided into two groups according to the manifestation of emotions: extroverts and introverts. In extroverts, everything is "written on the face", their feelings are expressed so vividly (words, gestures, facial expressions) that the interlocutor does not need to determine the appropriate reaction to their words and actions. Introverts, on the other hand, express their emotions very sparingly, they seem to turn inward, their reaction is often not immediately recognizable. Only an experienced psychologist on certain grounds is able to establish how his information is perceived and what to expect in return.

Continuing this topic, we recall the famous test to determine four emotional types of people by temperament: melancholic, phlegmatic, sanguine and choleric. There is a test that determines people by their role in the team: leader, performer, opponent, idea generator, critic, indifferent [7, 39].

The implementation of any project should meet the needs of hypothetical consumers and provide owners with economic benefits, among which the most important is profit. In solving these problems, managers at any level must be constantly guided by economic calculations, and on their basis to make informed decisions. Considerable attention of managers during project implementation should be focused on providing protection against certain risks. Among a number of risks, the risk of loss or lack of competitive advantage should be singled out.

It is the search for ways and reserves to strengthen the competitive status of the enterprise implementing the project, usually leads to an increase in social productivity, strengthening the human factor, humanization of society, creativity not only among managers but also among ordinary subordinates. This gives grounds to consider project management processes as rationally organized actions based on socio-economic components of the mechanism of saving live labour.

The project manager must have not only a set of professional knowledge, but also a number of natural qualities, among which it is worth noting confidence in their work. Responsibility for its results, the ability to manage the team. The manager of any level in the process of project implementation has significant powers delegated to him by the owner (customer) of the project, has a controlled influence on the behaviour of his team.

The influence of the manager on the team managed by him will be effective when the management is carried out on the basis of the application of scientifically sound methods, the optimal motivational mechanism and the leader's own example. Many economic sources, sources devoted to the problems of management, emphasize that the manager is also an experienced speaker. Thus, we can state with confidence that the effectiveness of the project, along with other factors, is determined by the level of public speaking of the manager of any level.

In addition, the manager must be an attentive listener, regardless of who addresses him. It is difficult to disagree with this opinion

Resource management in the project is the main task of the project manager. The importance of this task lies in the effective management and use of any project resources - time, cost, human and material. The main feature of human resource management in the project is the formation of a team and its effective management. The factor of human relations in project management is one of the main factors influencing the successful implementation of the project [8, 40].

The human resources of the project include all project executors, namely: the manager, the project management team and the project team. Project human resource management includes the following processes: organizational planning, staffing and teamwork [9, 41].

The project manager has to solve a number of specific tasks related to work motivation, conflicts, implementation, control, responsibility, communications, power, leadership, etc. Effective solution of these problems by the project manager will create favorable conditions for project work, help to overcome the psychological stress in the project team, arising in the process of finding, agreeing and implementing project solutions, will avoid conflicts and stress, which in turn can affect scientific technical level, timely execution of works and quality of the project [9].

Project human resource management includes the processes of organization, management and leadership of the project team [10].

The project team consists of people who have defined roles and areas of responsibility for project implementation. Project team members can have different skill sets, full or part time, and can be attached or removed from the team during project implementation.

Although project team members have specific roles and responsibilities, the participation of all team members in project planning and decision-making is valuable to the project. Involving team members allows them to use their experience in project planning and strengthens the team's focus on achieving project results. In order to effectively implement the project, its leader must prevent conflicts that may arise [10, 42].

To do this, the project manager needs the ability to manage the process of resolving a conflict situation until it grows into an open confrontation. For effective management of research projects in an unstable economy, it is necessary to pay close attention to human resource management.

In projects where the human factor is crucial, focusing only on human resource and staff management without regard to organizational and professional cultures, individual characteristics of team members and other poorly identified and measurable characteristics, often leads to conflicts, complications and low project efficiency. The philosophy of the organization, its culture, which includes national, corporate, organizational and professional, is much more important in the success of the project than technological and economic resources, organizational structure and compliance with project deadlines. Therefore, in order to create an effective project management team, it is necessary to harmoniously combine different systems of values, mentality and specifics of activities, which are carried by team members in the integrated space of the project.

In an "immature" organization, the influence of the "human" factor is noticeable, which is that the quality and outcome of project product development depend largely on the quality of specific performers and managers, and decisions are often improvised "on the fly".

In this case, the management is busy, mainly, "patching holes", and the probability of exceeding the limits and deviations from the requirements for the product of the activity is very significant.

In a "mature" organization there are clearly regulated and technologically organized (coordinated) procedures for achieving a quality product (project product), which at a high level of probability eliminates the negative impact of the human factor and ensures the independence of the activity from it.

In terms of project management, the management body's access to a sufficiently developed level of project maturity allows to systematically ensure a constant, independent of specific individuals, the focus of activities to meet the priority needs of the local community on a project basis.

An extremely important condition for the successful implementation of modern IT is to take into account the influence of the human factor, which is manifested in such areas as the culture of teamwork, the ability to learn and openness to innovation.

The transition from traditional to computerized information processing is especially difficult, which is associated with a significant reorientation of professional activities of staff, which can be interpreted as reengineering the business process. Therefore, technical and organizational adaptation and improvement of economic processes should always be consistent with training measures. Continuous training of employees should become an important component of the ongoing process of implementing new elements of ISM.

Staff training for new projects should begin at an early stage. Involving staff to participate in the process already in the planning phase gives a significant learning effect. As a rule, the introduction of a new IP means a radical departure from the traditional organization of labour [43, 44–55].

Even in the most favorable situation for the use of new IP requires intensive training, which should relate to understanding the mission of IP in general, the logic of using IP in each workplace, methods of using applications to solve professional problems.

Human resource management is an important part of project management in any field. In the activities of scientific institutions - this issue is even more important due to the fact that the process of implementing research projects is time consuming. The efficiency, timeliness and quality of his work depend on the psychological atmosphere in the research project team. In the process of forming a project team and recruiting staff, it is necessary to take into account the concepts of conflict and stress, as well as, if necessary, apply methods of conflict and stress management. Therefore, in the science of project and program management it is necessary to develop the direction of conflict management and stress of the project team.

The human problems discussed and the recommendations for solving them through the introduction of modern IT can be useful to those organizations that are rebuilding or moving to a new field of activity. The introduction of IT makes it possible to accelerate the formation of a full-fledged team several times by strengthening the capabilities of communication tools for business professional communication, joint use of the acquired knowledge base and software for integrated data processing.

3. Calculation of project parameters by the critical path method

In order to build the project network, the parameters of events (early and late completion, time reserves) and works (early and late start and end of works, full, free, independent and guaranteed time reserves) were calculated, and the critical path was determined. for a given ratio of precedence and deterministic durations of work by the method of CPM, to build histograms of resource allocation

2 types. Precedence ratio:
- A<I,F;
- B<E;
- C<A,B;
- D<G,E;
- E<F;
- G<H,J,K;
- H<F.

The duration of the work is summarized in table 1 - in the first row. The last two lines show the required resource costs of the 1st and second type.

In order to build a project network, it was set to determine the probability that the actual duration of the project will be 10% less than its average value using the PERT method.

Table 1

Duration of works and necessary costs of resources of the 1st and second type

A	B	C	D	E	F	G	H	I	J	K
5	9	9	4	17	9	6	11	17	6	4
12	9	9	8	10	18	12	22	10	12	8
8	9	12	16	12	12	8	14	20	12	10

Given relations of precedence, pessimistic - b, most probable - m and optimistic - a duration for each of the works. The duration of the work is summarized in table 2.

Precedence ratio:

- A<I,K,F.
- B<E;
- C<A,B;
- D<E,G;
- E<H,K;
- G<H,K;
- H<F;.

Table 2

The duration of the work

Duration	A	B	C	D	E	F	G	H	I	K
a	4	6	3	3	4	1	6	3	4	7
b	8	10	9	8	10	4	10	5	9	9
m	6	8	4	6	6	2	8	4	6	7

According to the given precedence relations, the project network was constructed in the "work-arc" representations, which is shown in Fig. 1 and "work-top", which is shown in Fig. 2. The time parameters of the project are calculated, where in table 3 the characteristics of network events are given, and in table 4 - temporary parameters of works in the network.
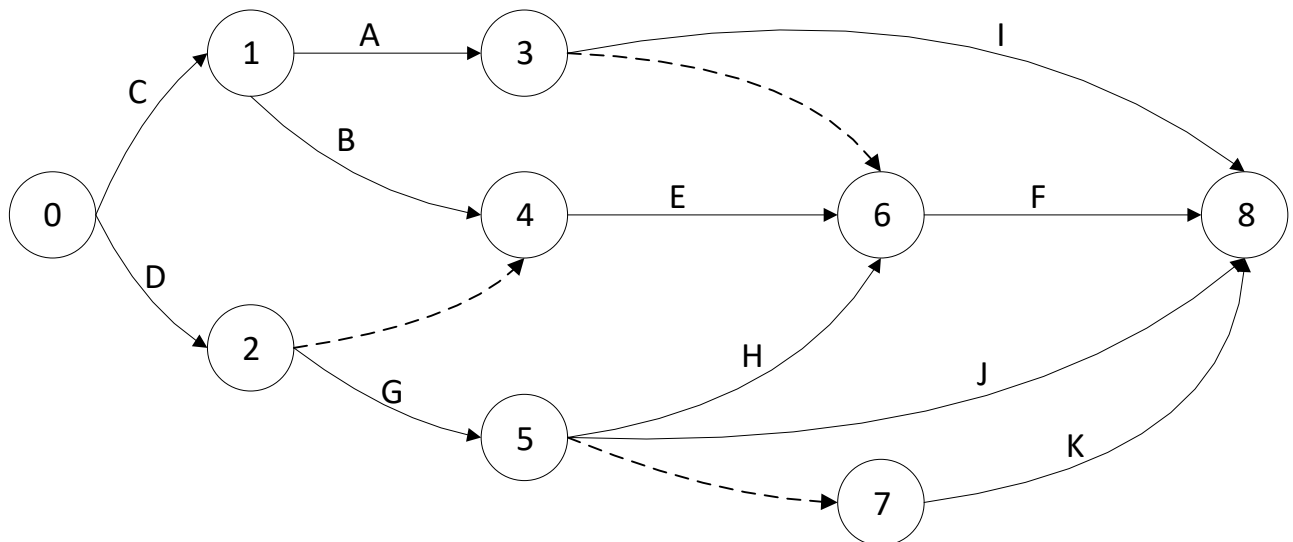
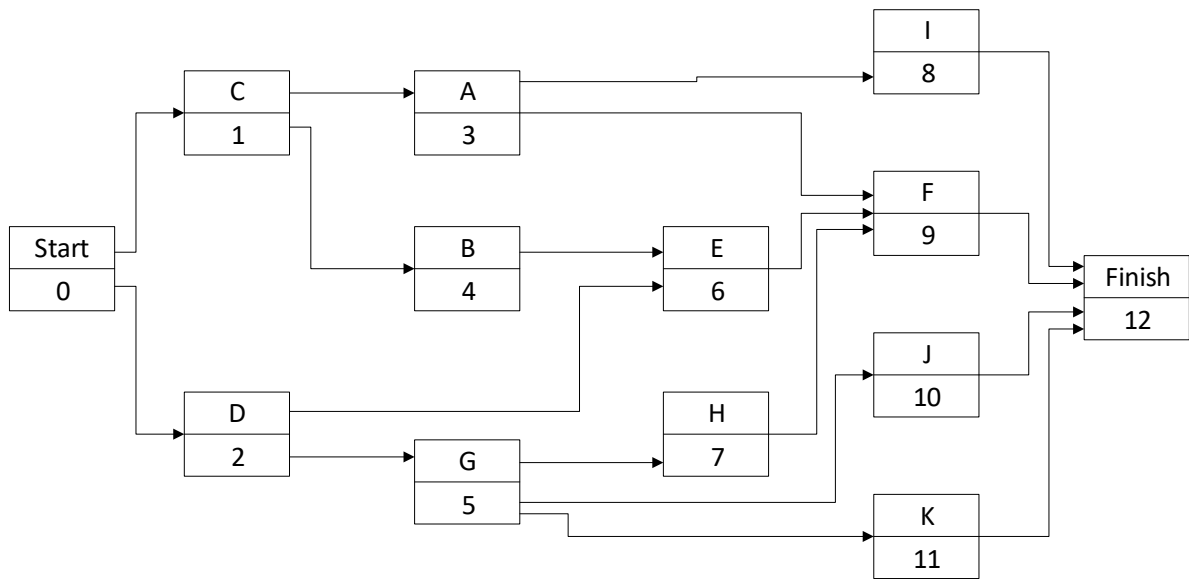**Figure 1**: "Work-arc" representation

Figure 2: Representation "work-top"

The time parameters of the project are calculated, in table 3 the characteristics of network events are given, and in table 4 - temporary parameters of works online.

Table 3
CPM network event characteristics

	0	1	2	3	4	5	6	7	8
t_i	0	9	4	14	18	10	35	10	44
T_i	0	9	18	27	18	24	35	40	44
R_i	0	0	14	13	0	14	0	30	0

Table 4
CPM network event characteristics

	t_{ij}	(i,j)	t_i	t_j	T_i	T_j	t_{ij}^{ra}	t_{ij}^{re}	t_{ij}^{pa}	t_{ij}^{pe}	r_{ij}^{a}	r_{ij}^{f}	r_{ij}^{u}	r_{ij}^{g}
A	5	1,3	9	14	9	27	9	14	22	27	13	0	0	13
B	9	1,4	9	18	9	18	9	18	9	18	0	0	0	0
C	9	0,1	0	9	0	9	0	9	0	9	0	0	0	0
D	4	0,2	0	4	0	18	0	4	14	18	14	0	0	14
E	17	4,6	18	35	18	35	18	35	18	35	0	0	0	0
F	9	6,8	35	44	35	44	35	44	35	44	0	0	0	0
G	6	2,5	4	10	18	24	4	10	18	24	14	0	0	0
H	11	5,6	10	35	24	35	10	21	24	35	14	14	0	0
I	17	3,8	14	44	27	44	14	31	27	44	13	13	0	0
J	6	5,8	10	44	24	44	10	16	38	44	28	28	14	14
K	4	7,8	10	44	40	44	10	14	40	44	30	30	0	0
M	0	2,4	4	18	18	18	4	4	18	18	14	14	0	0
N	0	3,6	14	35	27	35	14	14	35	35	21	21	8	8
P	0	5,7	10	10	24	40	10	10	40	40	30	0	0	16
	5	1,3	9	14	9	27	9	14	22	27	13	0	0	13

In Figure 3 shows the project network in the presented "work-arc" indicating the characteristics of network events. In fig. 4 shows the network of the project in the representation "work-top" with the

parameters of the work. The critical path that passes through the works is also determined: C – B – E – F.
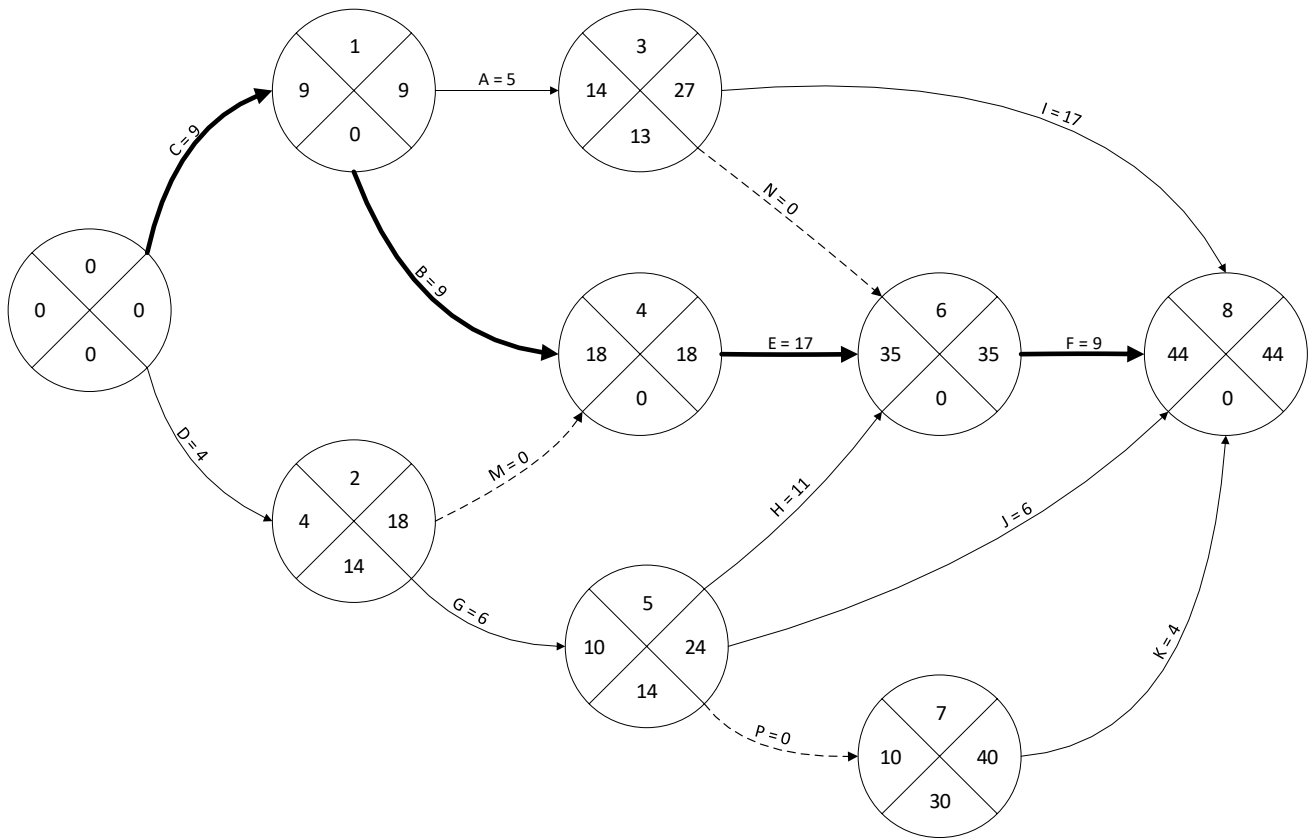

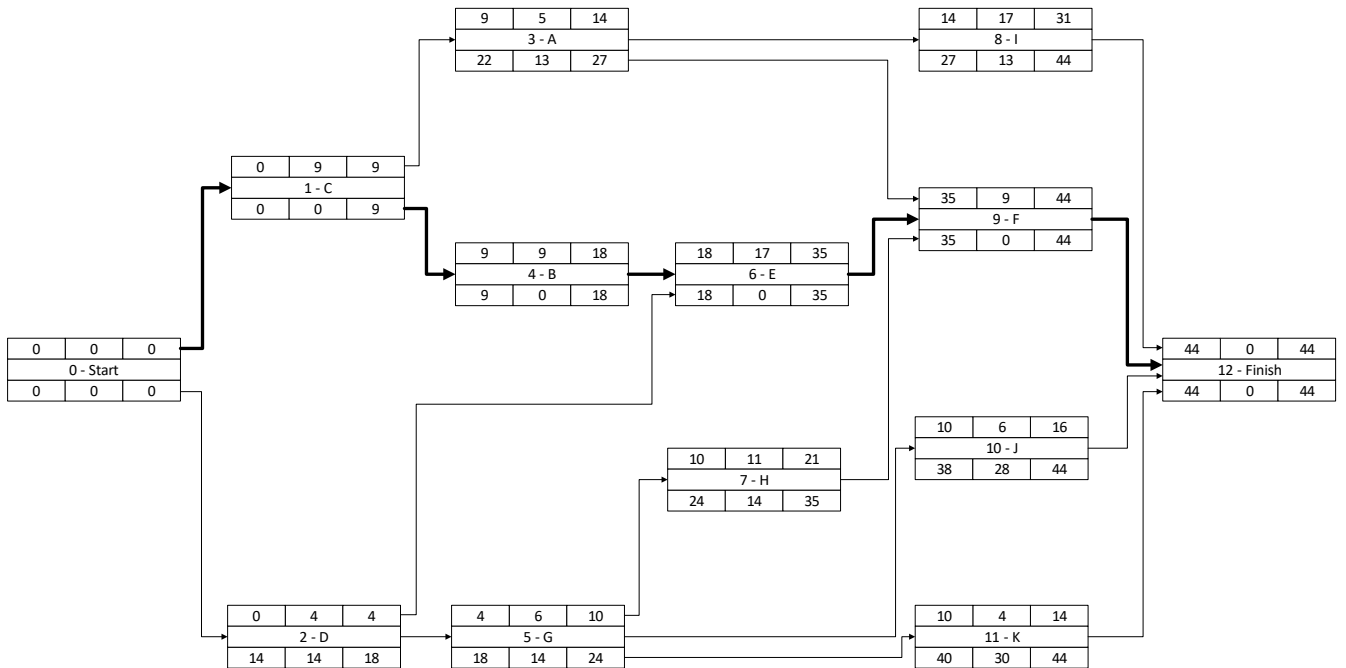**Figure 3:** Representation of "work-arc" with event parameters

Figure 4: Representation of "work-top" with parameters of works

A Gantt chart for the project is constructed, and histograms of resource consumption intensity are constructed, which is shown in Fig. 5. The Gantt chart is built for a 44-day project and all the work on it is posted early. Also optimized resource allocation within the calculated project duration, Gantt chart and optimized resource allocation are shown in Fig. 6.

Re-optimized resource allocation for increased by 10% relative to the calculated project duration, which is shown in Fig. 7, which contains a Gantt chart and resource histograms.

The maximum value of resource intensity before optimization was at the level of 9.4 and 8.37 for the first and second resource, respectively, during the 4 days of the project.

After optimizing the use of resources, these values changed to 5.4 for 1 day for the first resource and 5.33 for 4 days for the second resource.

And after performing the optimization with the increased duration of the project, new values of the maximum intensity of resource consumption were obtained, namely: 4.59 and 4.51 for the first and second resources, respectively, for 6 days.

As a result, it can be concluded that increasing the duration of the project leads to a greater opportunity to optimize the use of resources, although a sufficient effect can be achieved without increasing the duration of the project, but simply using the value of project time reserves.
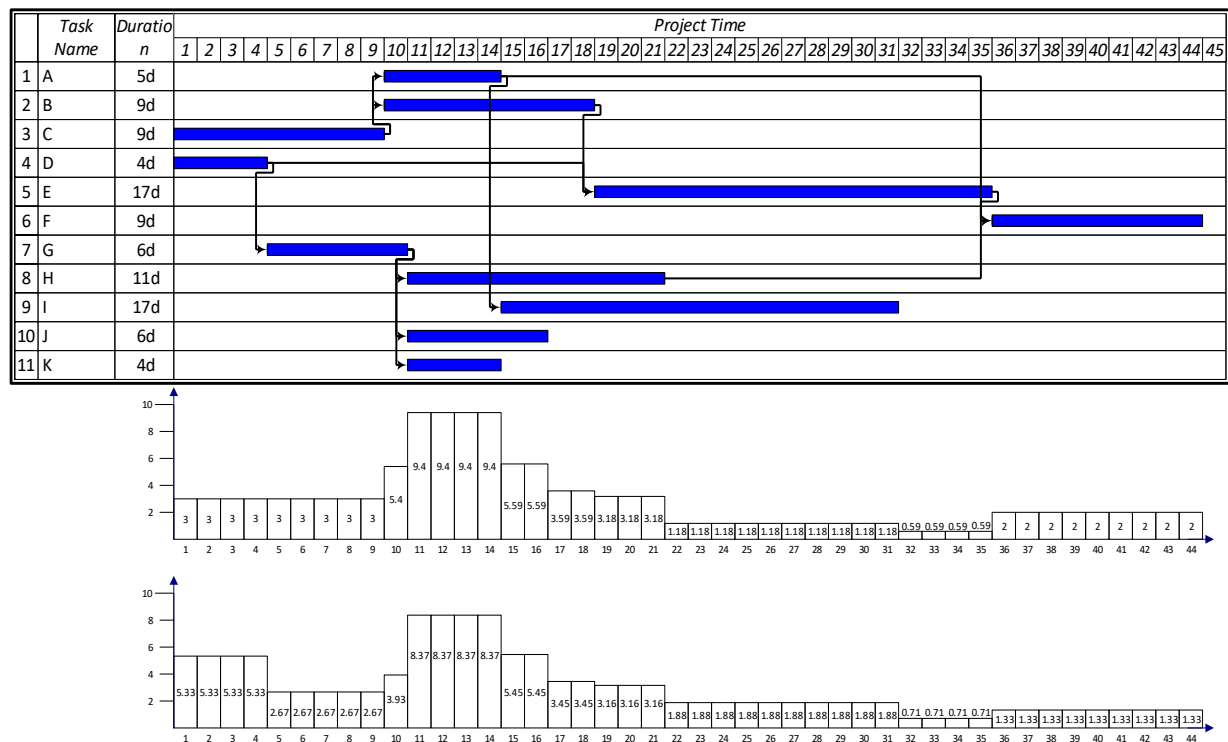

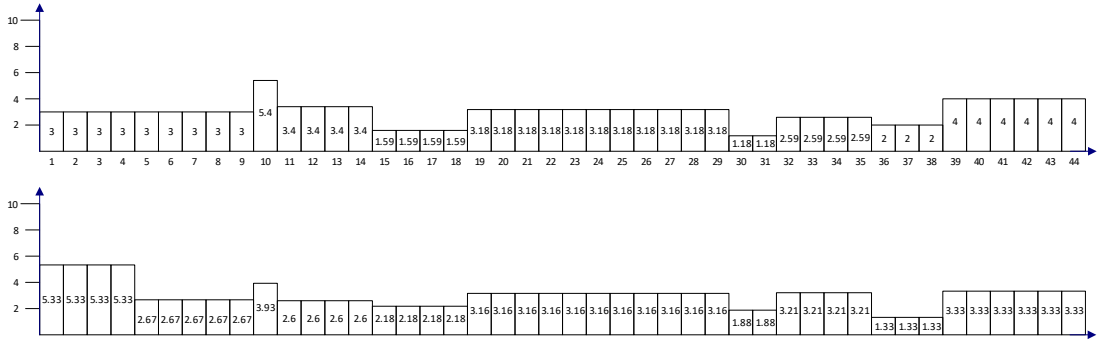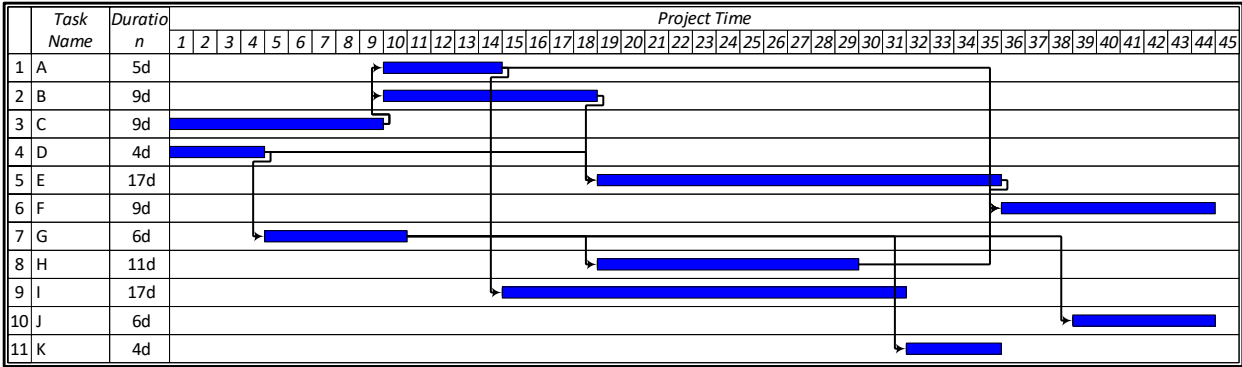**Figure 5:** Gantt chart and histograms of resource consumption intensity

	Task Name	Duration	Project Time
1	A	5d	
2	B	9d	
3	C	9d	
4	D	4d	
5	E	17d	
6	F	9d	
7	G	6d	
8	H	11d	
9	I	17d	
10	J	6d	
11	K	4d	

Figure 6: Gantt chart and optimized histograms of resource intensity

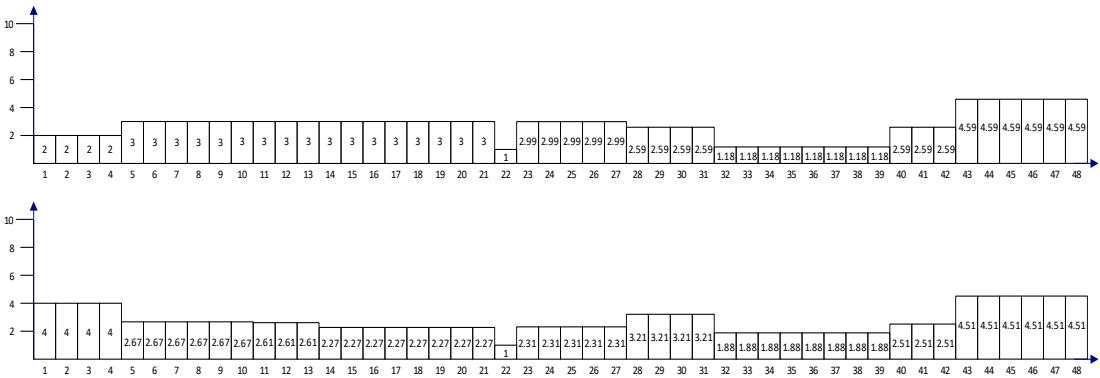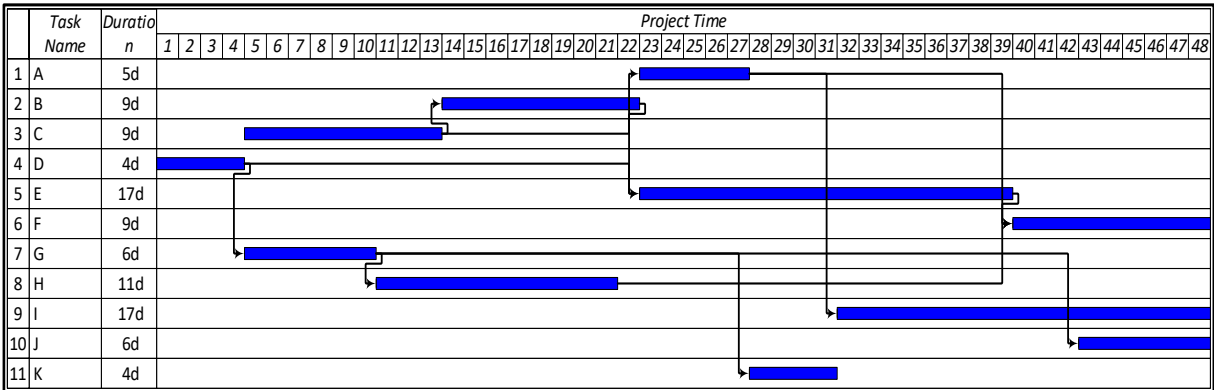|	Task Name	Duration	Project Time
1	A	5d	
2	B	9d	
3	C	9d	
4	D	4d	
5	E	17d	
6	F	9d	
7	G	6d	
8	H	11d	
9	I	17d	
10	J	6d	
11	K	4d	

Figure 7: Gantt chart and optimized histograms of resource intensity for increased duration

4. Calculation of project parameters PERT method

According to the given precedence relations, the project network is constructed in the "work-arc" representations, which is shown in Fig. 8 and "work-top", which he depicted in Fig. 9.
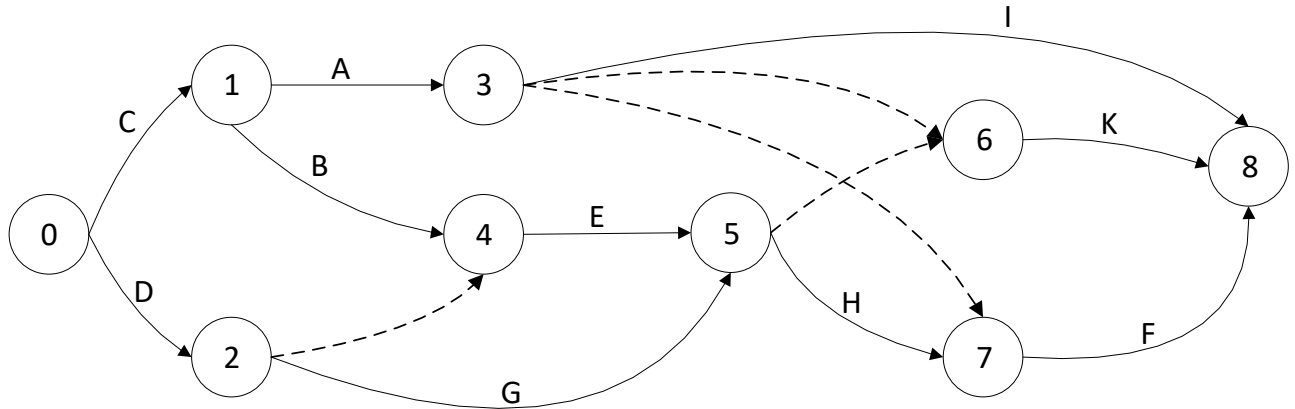

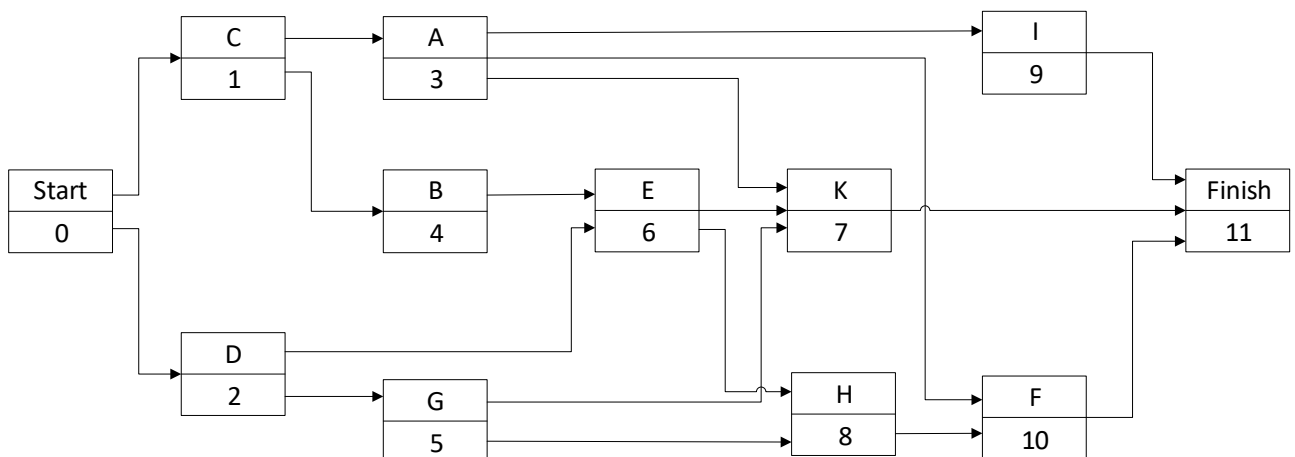**Figure 8**: View of the "work-arc" network

 Figure 9: Representation of the work-top network

The average durations and variance values for each of the network works were calculated according to the formulas $t = (a + b + 4m)/6$ and $D = (b - a)^2 / 36$. The result is shown in Table 5.

Table 5

Parameters of works

Tasks	Events	$M[t_{ij}]$	$D[t_{ij}]$
A	1,3	6	0,44
B	1,4	8	0,44
C	0,1	4,67	1
D	0,2	5,83	0,69
E	4,5	6,33	1
F	7,8	2,17	0,25
G	2,5	8	0,44
H	5,7	4	0,11
I	3,8	6,17	0,69
K	6,8	7,33	0,11

The critical path by the algorithm of the method is also calculated critical path (CPM) for the average duration of the project, which is shown in Fig. 10.

The critical path of the project is through works: C – B – E – K. The average duration of the critical path is 26.33. The variance of the critical path is 2.55.
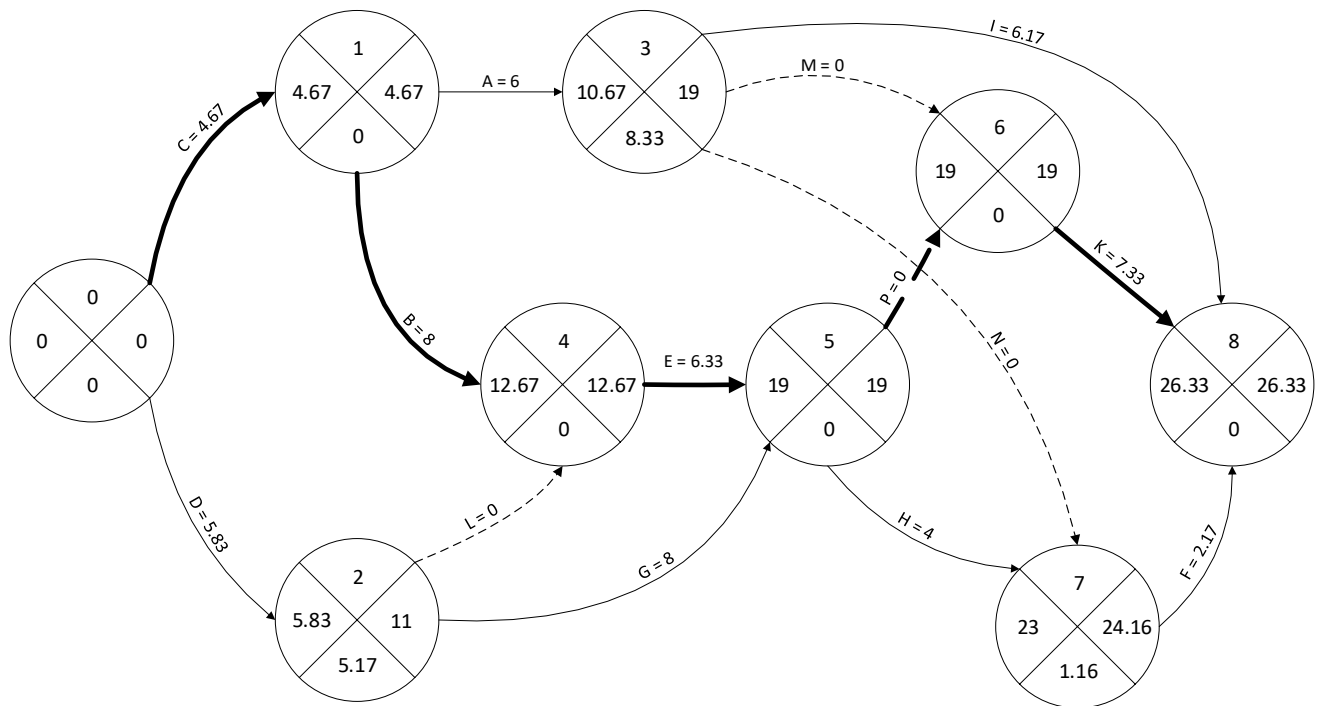

Figure 10: Representation of "work-arc" with a critical path

The results of the calculation are summarized in table 6, the value of the normal value of z is calculated and from the table of the normalized normal distribution law the probability is determined that the actual duration of the project will be 10% less than its average value.

The average duration of the project is 26.33. 10% less duration - 23.7. Probability: F (-1.64) = 1-F (1.64) = 1-0.949 = 0.051

Table 6
The results of the calculation

Event	Path	$M[t_j]$	$D[t_j]$	d_j	u_j	$P(t_j \leq d_j)$
8	0-1-4-5-6-8	26,33	2,55	23,7	-1,64	0,051

Thus, the probability that the actual duration of the project will be 10% less is 0.051.

5. Conclusion

The authors developed an approach to the analysis of resource consumption intensities in human capital management in digital business enterprises by the critical path method. A critical review of the use of human capital development tools provides. The network of the IT project in representations "work-arc" and "work-top" is constructed. The time parameters of the project in these two views are calculated. The Gantt chart for the researched project is constructed, and also the histograms of intensities of consumption of human resources are constructed. The distribution of the researched resources within the calculated duration of the project and relatively increased by 10% relative to the

calculated duration of the project has been optimized. The comparison of the values of the maximum intensities of resource use before optimization and as a result of its implementation is performed.

It is suggested that increasing the duration of the project leads to a greater opportunity to optimize the use of resources, although a sufficient effect can be achieved without increasing the duration of the project, but simply by using the value of time reserves of the project.

The project network is constructed, the values of average duration and variance for each of the network works are determined, using the set expert values. The critical path (CPM) for the average duration of work is calculated. Also, for the critical path, its average duration and variance are calculated, assuming that the critical path duration as a random variable is distributed according to the normal law. As a result, the probability of project duration was calculated using the PERT method.

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