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Application of the critical chain method as a way to reduce the time of construction project implementation

The paper considers the problems of modern development companies in a complex and unstable economic environment. In the current conditions, the question arises about the stability of the functioning of construction enterprises, which are forced to look for new methods, approaches and tools in the conditions of competition, complex economic and market conditions to maintain the efficiency of operational processes, as well as to maintain the relevance and economic efficiency of construction projects. In the paradigm of these conditions, traditional ways of working on projects for developers require modernization and updating, taking into account modern methods of management, control, and the system of internal and external interaction between organizations. At the same time, attention is focused not on the approach of changing and applying new tools or introducing digital or AI tools, but on the basis of changing the internal fundamental methods of the organization. To clearly formulate the problem, the concept of a project, the features of construction projects were given, the methods of planning along the critical path and along the critical chain were analyzed. The study proposes a modification of project planning and control based on the critical chain method. The critical chain method, in comparison with the traditional critical path method, takes the safety time to buffers located at the end of the critical chain and the ends of the feeder chains. Based on this, the study proposes a modification of the method adapted to domestic realities, which assumes an increased total reserve of time in buffers, and proposes the introduction of a contract buffer for the performance of fixed volumes of contract work. For the viability of the modified method, it is proposed to use contracts with "reward" instruments for early completion of work. At the same time, the described method has flexibility in the framework of time estimates in the performance of tasks for its adaptation to specific conditions contained in various construction projects.
Keywords: *construction, construction project, project management methods, project execution control, critical chain*

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INTRODUCTION

Project management is a mechanism that has existed and developed for quite a long time, since 1917. In spite of more than 100 years of history, there have not been many milestones in this field. The main milestones starting with the invention of the Gantt chart can be considered the development of the critical path planning method in 1957 and the invention of the network planning schedule in 1958.

After that new approaches and methodologies to operational management were developed, but globally the planning and project management processes did not change from the methodological point of view.

All projects are based on three main factors: timing, budget and quality. In the current situation of high key rates and widespread use of project financing in construction projects, the decisive factor affecting the success of the project is the timing of project implementation. Each month of the project with the use of project financing is very expensive and has a huge impact on the budget and, as a consequence, on the level of profit.

Two factors also have a significant impact: changes in preferential mortgage lending programs in terms of expiration[1]; the national project "Housing and Urban Environment", which aims to annually increase the volume of housing construction up to 120 million square meters. by 2030, and this is without taking into account the construction of necessary infrastructure[2]. All this complicates the situation in the real estate market, in which developers have increased risks. Not only the usual approaches to the implementation and internal component of construction projects [1, 2], but also the sustainability of enterprises in the construction sector may be under threat.

In such conditions, the success of the project largely depends on the timely completion of the project without loss of quality. The key influence on the success of the project and organizations is definitely the correctness of management. Digitalization, artificial intelligence and other modern technological capabilities are only tools, not a panacea in the implementation and management of projects.

A construction project is a multifactor stochastic system. That is, planning predicts a certain set of activities that are necessary to achieve the final goal, and these activities can be disrupted by the influence of uncertainty factors generated by the multifactor environment. This applies to all works of the investment stage of the project: preparatory, design and construction.

In the current economic situation, the author sees the main way to increase the liquidity of the project as a minimum in compliance with the set

[1] House of the Russian Federation. The Preferential Mortgage Programme ended on July 1, 2024. URL: https://xn--h1alcedd.xn--d1aqf.xn--p1ai/catalog/lgotnaya-ipoteka/ (Accessed: 06.03.2025).

[2] National goals and strategic objectives for the development of the Russian Federation for the period up to 2024 : Decree of the President of the Russian Federation of May 7, 2018 No. 204.

Factors limiting the production activity of construction organizations

Factors/Period	IV quarter 2019, %	II quarter 2020, %	IV quarter 2023, %	II quarter 2024, %
High level of taxes	41	36	33	31
Lack of work orders	25	29	20	17
High cost of materials, structures and fabrications	29	28	45	46
Insolvency of customers	22	23	15	13
Competition	26	22	20	21
Lack of funding	24	21	13	12
Lack of skilled workers	17	15	24	31
High rate of interest on commercial loans	16	14	14	15
Weather conditions	13	12	11	12

deadlines for implementation (as the failure to meet the deadlines is a ubiquitous factor in most construction projects) fixed in the financial model of the project, and as a maximum their reduction. This is justified by the fact that the transformation in the methods of project management as a way to meet or reduce the required deadlines practically does not require additional financial costs.

THEORY AND METHODS

According to the data of the Federal State Statistics Service, construction companies emphasize the most significant factors limiting production activities, mainly those related to finance[3,4]. The results of the specimen survey with the distribution of responses of construction companies in percent are shown in Table.

In the course of the work we analyzed the postponement of scheduled delivery dates of apartment building construction projects. The analysis is based on the project data of more than four hundred developers[5]. This indicates that large companies have a large resource and financial reserve to create capacity reserves for all necessary supply lines, such as: project team, special equipment, workers and crews, construction materials and products. The relationship between construction volumes and average carryover is shown in Fig. 1.

Thus, the average value of postponement is 5.98 quarters, which is 17.94 months or one and a half years. There is also a clear increase in the postponement of deadlines with a decrease in the number of realized objects, i.e. in essence the scale of organizations. In such a case, the most effective method of improving construction efficiency is methodical changes in project management approaches and principles.

At the moment, the vast majority of organizations use the critical path method for planning and management. The author suggests using the critical chain method as an alternative. Within the framework of the research the sequence of work when using each of the methods is not described in detail, there is a lot of scientific literature on this topic [3–6].

Within the framework of analyzing both methods, the main differences between them were identified, they are as follows:

- mandatory resource leveling and elimination of multitasking;
- estimation of the duration of works with 50 % probability;
- supplementing the critical chain (critical path) and the work sequences included in it with buffers — time reserve for work execution.

The first point within the construction project refers more to the planning of design works, because in this case the resources are directly people — architects, designers, engineers, etc. In the framework of the research, the main focus is on the works of

[3] Factors limiting the production activities of construction companies in 2019–2020. URL: https://rosstat.gov.ru/storage/mediabank/tASKTSkO/Stroitelstvo_2020.pdf (Accessed: 25.03.2025).

[4] Factors limiting the production activities of construction companies in 2023–2024. URL: https://rosstat.gov.ru/storage/mediabank/Stroit_2024.pdf (Accessed: 25.03.2025).

[5] The average delay in the construction of residential complexes of construction and development companies in Moscow and the Moscow region. URL: https://msk.stroykontrol.info/companies (Accessed: 21.03.2025).

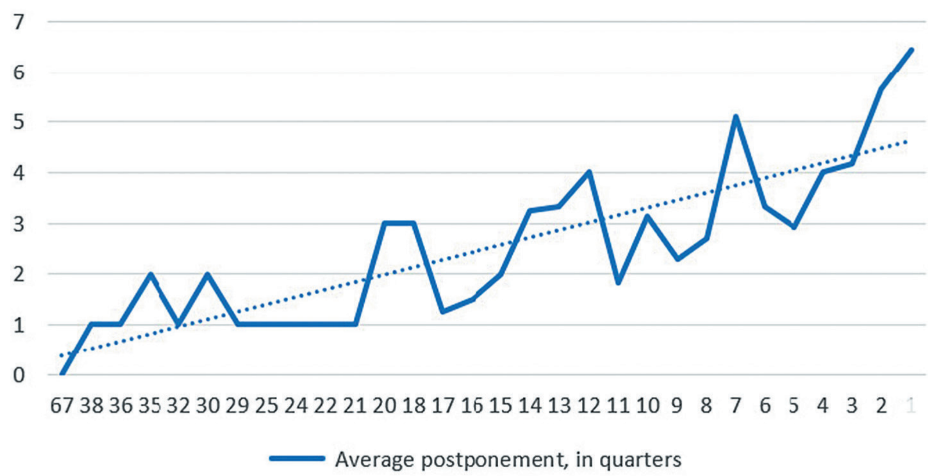

Fig. 1. Dependence of average postponement of delivery date and number of objects

the construction phase of the project, where the resources are mainly contracting organizations. This stage includes differences numbered 2 and 3.

In considering these differences and the theoretical basis of the critical chain method, it is necessary to take into account the duality inherent in the contracting organization in the performance of work. On the one hand for the project it is a separate independent resource, on the other hand the units performing the work are individual people. The latter fact substantiates the effectiveness and validity of this method within the framework of estimating the duration of work with 50 % probability, since this part is based mainly on psychological traps described in the method [5]. In the framework of the research, project planning and management is considered from the side of ACA organizations, management company or general contracting organization, which do not directly control the performers of works within subcontracting organizations.

The effectiveness of applying the critical chain method to construction projects is confirmed by the following sources [7–9]. In practice, taking into account the above-described features of work on construction sites mainly by contracting organizations, the problem of reducing deadlines is revealed. Within the framework of tender procedures for the performance of certain types of work, potential organizations of performers offer their commercial proposals, which contain the terms and cost of work. These conditions are in fact already minimal for them, because each contractor interested in the execution of works forms in the commercial offer the most balanced conditions for itself taking into account the following parameters: maximum profit — minimum term — minimum risks. Taking this into account, a half reduction of the planned terms initiated by the customer is not favorable conditions for the contractor. This problem makes it impossible to apply the critical chain method in its original form.

As a tool of adaptation to the realities of the construction industry and contracting procedures established in the domestic construction market, the author proposes the synthesis of the critical chain method with motivation tools within the contractual relations of the parties. This will make it possible to cover potential risks on the part of the contractor from the reduction of terms, and at the same time really increase his interest and motivation to conclude a contract with a shortened period of realization.

Taking into account that the share of apartment building projects with the use of project financing according to the Central Bank's data for the 3rd quarter of 2024 exceeded 97 %[6], and the weighted average rate on loan agreements throughout the Russian Federation is 9.89 % according to the Bank of Russia as of February 1, 2025[7]. It should be taken into account that the data of the Bank of Russia are based on all project finance projects currently being implemented. Most of these projects started when the key rate was much lower. Currently, the rates on project finance contracts are about 27–31 % (the key rate is 21 + 6–10 %). On this basis, an increase in the cost of work contracts as an incentive for contractors is reasonable. It is economically efficient from the project›s point of view to contract works that are on the critical chain, as their delay will lead to the failure of the intermediate and final deadlines of the project, which will entail additional costs to cover the project financing debt. The motivation tools used for each individual project should be selected through local expert assessments, taking into account the reliability of the contracted contractor, the existing relationships, the importance of working within the schedule, etc. Such methods are described in the following sources [10–13].

This adaptation of the application of the critical chain method in synergy with motivational tools in contracting requires additional methodological transformations in the theoretical foundations of the method. First, this approach should be communicated to the contractor (in this case the person or persons on the contractor's side who are responsible for carrying out and handing over the work under the contract) at the stage of preliminary agreement, so that everyone will operate with the same data and clearly understand the control structure. It also obliges the person on the client's side to ensure that the required scope of work is delivered in a timely manner. Secondly, the approach to calculating the project buffer should be changed.

MAIN RESULTS

In the original method, buffers are placed at the end of the critical chain and in the places where parallel non-critical chains of works (feeding) merge with the critical chain. Due to the fact that the critical chain consists of several types of works performed by different organizations, or by different subdivisions of the same organization, with which contracts are signed for the performance of specific volumes, a new way of calculating and placing buffers in the work schedule is proposed as an adaptation. There are many ways to calculate project buffers: the fifty percent method, simple and modified mean square error methods, the method of adapted procedures, and the method of fuzzy numbers[8]. For adaptation we use the most common method of RMS error, it takes into account the difference in the potential complexity of the work performed and allows us to adjust the size of the buffer with the help of expert judgment. The basic formula for calculating the design buffer is as follows:

$$2\sigma = 2\sqrt{\left(\left(\omega_1 - a_1\right)/2\right)^2 + \left(\left(\omega_2 - a_2\right)/2\right)^2 + \ldots + \left(\left(\omega_n - a_n\right)/2\right)^2}, \quad (1)$$

where σ — project buffer size (buffer per critical chain);

ω_n — the worst estimated duration of the work, in our case the volume under one contract with a particular contractor. The maximum estimate, i.e. the worst case, is proposed as 90 % of the work duration;

a_n —average duration of work, also from the volume per contract. Proposed as 50 % of the duration.

In this formula ω_n and a_n are taken from the original estimated duration of the works with the safety net time embedded inside the works.

The essence of the proposed calculation method is to allocate a part of the total project buffer to intermediate — contractual buffers for individual works. It is necessary to distribute the time of safety net from the buffer to the works in progress, and at the same time to preserve the project buffer in order to secure the total project completion time. In the original formula, when using in all works a maximum worst case estimate of 90 % and an expected average

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[6] Project financing of housing construction in the third quarter of 2024. Bank of Russia. URL: https://www.cbr.ru/Collection/Collection/File/54851/pf_2024_Q3.pdf (Accessed: 06.03.2025).

[7] Information on project financing: concluding loan agreements with developers using escrow accounts for settlements under equity participation agreements, and opening escrow accounts for settlements under equity participation agreements. URL: https://www.cbr.ru/banking_sector/statistics/?cf.date.time=Any&cf.tagid=167 (Accessed: 06.03.2025).

[8] Behzad Montazeri, Comparing Critical Chain Project Managemenet with Critical Path Method: A Case Study. Western Kentucky University, Master Thesis. URL: https://digitalcommons.wku.edu/cgi/viewcontent.cgi?params=/context/theses/article/2939/&path_info=montazeri__behzad_800980779_thesis.pdf (Accessed: 06.03.2025).

duration of 50 %, the average size of the buffer results in an average of 23 % of the time margin from the reduced to 50 % completion time. In the author›s opinion this is not sufficient, since the contractor's estimated duration of the work is already optimistic.

Thus, the following formula is proposed for calculating contractual buffers:

$$\sigma_n = 2\sqrt{((\omega_n - a_n)/2)^2} \quad (2)$$

and to calculate the project buffer:

$$\varphi = \sqrt{((\sigma_1/2)/k_1)^2 + ((\sigma_2/2)/k_2)^2 + \ldots + ((\sigma_n/2)/k_n)^2}, \quad (3)$$

where σ_n — project buffer size (buffer per critical chain);
ω_n — the worst estimated duration of the work, in our case the volume under one contract with a particular contractor. The maximum estimate, i.e. the worst case, is proposed as 90 % of the work duration;
a_n — average duration of work, also from the volume per contract. Proposed as 50 % of the duration;
φ — project buffer size;
k_n — a coefficient showing the weight of a job, i.e. the ratio of the duration of a particular job to the duration of the critical chain.

The k_n coefficient is calculated using the following formula:

$$k_n = v_1/\Sigma vi, \quad (4)$$

where k_n — a coefficient showing the weight of a job, i.e. the ratio of the duration of a particular job to the duration of the critical chain;
v_1 — critical chain operating time;
Σvi — total duration of all critical chain operations.

Thus, the proposed calculation method incorporates the flexibility to estimate the probability of average and worst-case duration of the work through expert judgment, taking into account the unique factors for each project, while providing sufficient buffer time for both the work within the critical circuit and for the entire project.

The buffer calculation for feeder circuits should be performed using the method of RMS error given in (1) or the fifty percent method, where half of the total time of the work sequence is used as the buffer.

With the Critical Chain Method, managers have a transparent way to monitor progress through buffers. The important thing is that it is preventive. In the traditional format with the application of the critical path method, the assessment of work progress does not imply the possibility of applying preventive actions to prevent tardiness, because the time margin is built into each specific work of the schedule and the fact of tardiness is fixed too late to prevent it.

The present method proposes to control the progress of work execution by measuring the buffer consumption. Since a buffer is included in the schedule, overdue tasks do not start shifting all the following tasks in the schedule to the right. The overdue work only starts eating up the days put into the buffer by the contract, or in the worst case by the project. And it is the degree of buffer consumption that determines the status of work execution. Anexample of the diagramis shown in Fig. 2.

As soon as the buffer flow rate leaves the white zone upwards (as in Fig. 2), it means that it is time to take decisive actions to accelerate the completion of current tasks, reinforce the preparation of work fronts, technical and resource support, etc.

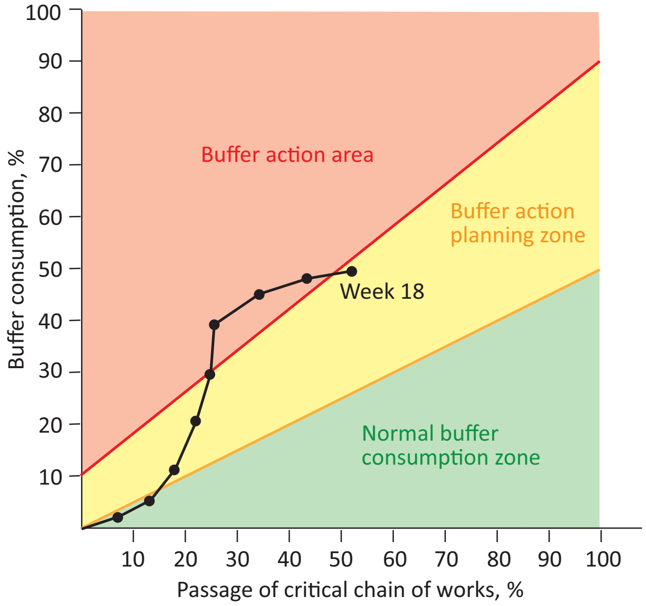

Fig. 2. Example of buffer consumption diagram for a project

CONCLUSIONS

The paper analyzes the current economic situation and its impact on the construction industry. A modification of project planning and control based on the critical chain method is proposed as a way to increase the probability of timely completion of the project, or to reduce the time of project execution. The stated method assumes a larger aggregate time reserve in buffers than in the original, proposes the introduction of a contract buffer for the fulfillment of fixed volumes of contractor work. As a way of motivation for contractors it is supposed to use contracts with “reward” instruments for early completion of works. At the same time, the outlined method has flexibility within the framework of time estimates in the performance of tasks for its adaptation for specific conditions contained in various construction projects. This approach will allow to increase competitiveness, to manage uncertainty more flexibly within the framework of multifactor stochastic system of the construction project, to build direct trustful relations with contractors and to control the progress of the project with the possibility of applying preventive measures to prevent failure of the project terms.

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Применение метода критической цепи как способ сокращения сроков реализации строительного проекта

В статье рассмотрены проблемы современных девелоперских компаний в условиях сложной и нестабильной экономической обстановки. В нынешних условиях ставится вопрос о стабильности функционирования строительных предприятий, которые вынуждены в условиях конкуренции, сложных экономических и рыночных условий искать новые методы, подходы и инструменты для сохранения эффективности операционных процессов, а также для поддержания актуальности и экономической эффективности строительных проектов. В парадигме этих условий традиционные уклады работы над проектами для застройщиков требуют модернизации и актуализации с учетом современных методов ведения, управления, контроля, системы внутреннего и внешнего взаимодействия между организациями. При этом заостряется внимание не на подходе изменения и применения новых инструментов или внедрения цифровых или ИИ инструментов, а на основе изменения внутренних фундаментальных методов работы организации. Для четкой постановки проблемы было дано понятие проекта, особенности строительных проектов, проанализированы методы планирования по критическому пути и по критической цепи. В рамках исследования предложена модификация планирования и контроля проекта на основе метода критической цепи. Метод критической цепи, в сравнении с традиционным методом критического пути, выносит время подстраховки в буферы, расположенные в конце критической цепи и концах питающих цепей. На основе этого в исследовании предлагается адаптированная под отечественные реалии модификация метода, которая предполагает увеличенный совокупный запас по времени в буферах, и предлагает введение контрактного буфера на выполнение фиксированных объемов подрядных работ. Для жизнеспособности модифицированного метода предлагается использование контрактов с инструментами «вознаграждения» за досрочное завершение работ. При этом изложенный метод обладает гибкостью в рамках временных оценок в выполнении задач для его адаптации для конкретных условий, содержащихся в различных строительных проектах.

Ключевые слова: *строительство, строительный проект, методы управления проектами, контроль выполнения проектов, критическая цепь*

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