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METHOD FOR SELECTING A COST-EFFECTIVE OPTION OF THE SEQUENCE OF CONSTRUCTION OF BUILDINGS AND STRUCTURES IN A COMPLEX

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Abstract

When developing a justification for investment in the construction of facilities in accordance with regulatory documents, alternative studies and calculations should be carried out in order to determine the effectiveness of investments.

This article offers a method for assessing the economic efficiency of options for the sequence of construction of a complex of buildings and structures. The method is based on the income approach (the net income generated by the complex of facilities is calculated) and on the cash flows discounting. At the same time, the economic effects for the investor are taken into account: effects from the reduction of discounted costs at the stage of construction of the complex, and effects in the field of operation of individual buildings and structures for the period of the calculation horizon.

Keywords: pre-design stage, construction organization project, complex of buildings and structures, construction phase, sequence of construction, financing schedule, discounted costs.

МЕТОДИКА ОЦЕНКИ ЭКОНОМИЧЕСКОЙ ЭФФЕКТИВНОСТИ ВАРИАНТОВ ОЧЕРЕДНОСТИ ЗАСТРОЙКИ КОМПЛЕКСА ЗДАНИЙ И СООРУЖЕНИЙ

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Реферат

При разработке обоснования инвестиций в строительство объектов в соответствии с нормативными требованиями должны выполняться альтернативные проработки и расчеты по определению эффективности инвестиций.

В данной статье предлагается методика оценки экономической эффективности вариантов очередности застройки комплекса зданий и сооружений, основанная на доходном подходе (рассчитывается чистый доход, приносимый комплексом объектов) и дисконтировании денежных потоков. При этом учитываются экономические эффекты от сокращения дисконтированных затрат на стадии возведения комплекса, экономический эффект в сфере эксплуатации отдельных зданий и сооружений, введенных за период горизонта расчёта, для инвестора.

Ключевые слова: предпроектная стадия, проект организации строительства, комплекс зданий и сооружений, очередь строительства, последовательность застройки, график финансирования, дисконтированные затраты.

Introduction

The pre-design stage in accordance with the Decree [1] is part of the life cycle of most construction projects. It serves to substantiate the decision to implement an investment project in terms of its necessity, technical feasibility, economic benefits, and environmental impact. At the same time, TCP 45-1.02-298-2014 indicates the need at this stage to carry out alternative studies and corresponding calculations of the investment efficiency for the full life cycle of the project (pre-investment, investment, operational and liquidation stages), to determine, if necessary, the sequence of construction, to make proposals on the organization and duration of construction [2].

Variant studies should cover all decisions: space-planning, constructive, organizational and technological decisions, and also take into account the social and environmental consequences of the construction and operation of the facility. It should be noted that it is rather problematic to take into account the full life cycle of the project in the calculations of the investment efficiency due to the lack of information on the operational stage [3].

When implementing an investment project, which includes a complex of buildings and structures, an important role in determining the efficiency of investments is played by the choice of the optimal sequence for the construction of its individual parts. The investor (customer, developer), when determining the order of construction, takes into account the sources and conditions for financing the construction of individual phases and start-up complexes, basic technological solutions for production facilities, decisions of the general layout and the possibility of organizing construction sites for the residential complexes (quarters, housing estates).

Changing the sequence of development entails changes in the schedule of capital investment distribution. The economic effect is achieved from the implementation of a more rational financing schedule and, as a result, a reduction in discounted costs.

The aim of this study is to develop an algorithm for the choice of an optimal option of the sequence of development of a complex consisting of several buildings and structures, which will maximize the net present value (NPV) for the investor.

The state of research in the area under consideration

In the 80s, a significant amount of research was carried out, a regulatory framework [4, 5, 6] and software were developed to determine the optimal sequence of development and calculate the cost efficiency of Construction Organization Project (COP).

The basis for determining the comparative effectiveness of design solutions for organizing the construction of production facilities was the Instruction [7], in accordance with which the best option is considered to give the minimum value of the reduced costs. At the same time, the effect of reducing the duration of construction was taken into account.

When comparing the options for the order of development of housing estates with urban planning complexes, the volume of work in progress for engineering equipment of the territory was taken as the basis for comparison [5, p. 16]. For each urban planning complex, the communications necessary for putting the buildings of this complex into operation were determined, considering that this site was commissioned first. The lengths of the networks and the roads were used to calculate the cost of engineering equipment for it. The first construction phase was the site for which the unit costs for engineering equipment per 1 m^2 of residential area were the lowest. Then, this site was excluded from consideration (it was assumed that engineering networks were laid to it) and the calculations were repeated for the remaining sites.

Today the economic system and project management methods have changed, which makes it impossible to apply previously developed algorithms. At the same time, there is a revival of interest in solving the problem of determining the optimal sequence of construction of buildings and

structures within the complex. There are two main approaches to solve this problem:

1. Choosing the best option for the sequence of construction in terms of organizational criteria, for example, reducing breaks between works, minimizing the number of workers, reducing the total duration of construction (Bolotin S.A., Velichkin V.Z., Chelnokova V.M., Morozova T F., etc.).
2. Choosing the best of the pre-developed options of sequence in terms of cost efficiency criteria.

Examples of the implementation of the first approach:

- formation of a schedule of the flow development of the territory using the method of undefined resource coefficients [8]. The method makes it possible to solve the problem of incompleteness of the initial data on the duration of work at the early stages of planning the development of the territory by urban planning complexes. Resource coefficients are values that are inversely proportional to the number of resources required to perform some work. To solve the problem, classical linear programming algorithms are used. Maximizing the objective function allows you to reduce organizational breaks between works;
- application of the branch and bound method in solving the problem of organizing residential quarter development [9]. As an objective function, the minimum duration of construction of all buildings of the quarter, a minimum of downtime for teams of workers, or a minimum of the duration of the work of teams on a quarter development can be used. Limitations - the deadlines for the construction of individual buildings and the entire complex, the total downtime of teams, the methods of flow organization of work on individual buildings and the complex as a whole (flow organization by the critical path method, by the rank method, by the continuous labor and technical resources employment method, by the continuous development of work fronts method);
- joint use of BIM-modeling programs (such as Revit) and project management programs (Project Expert, Microsoft Project) to determine the optimal sequence of construction of buildings included in the urban planning complex [10];
- breakdown of projects for Integrated Development of the Territory into urban planning complexes (several residential buildings provided with social infrastructure, landscaping and greening) and scheduling of flow construction [11, 12, 13]. At the initial stage, variants of matrices of the flow organization of work for individual facilities are calculated using the basic methods [14]. The corresponding object flows are formed. Then the matrices of complex flows of the following main types are calculated: Complex Compacted Flow, Complex Aggregated Flow, Complex Combined Flow. The variants are analyzed and the most appropriate for the construction conditions is determined;
- application of a heuristic algorithm for enumerating resource profiles for peak loads based on statistical modeling methods [15]. As a result, the resource peak (the maximum number of workers) and the corresponding area of temporary buildings are reduced. The economic effect is calculated as a reduction in the cost of temporary buildings.

Thus, when using the first approach, options are determined that are optimal from the point of view of organizational criteria, that is, from the point of view of a contractor or developer carrying out construction on their own. In practice, the interests of the investor and the contractor may differ significantly, and the investor will not choose finance options that are not optimal for him. Therefore, at the stage of development of predesign documentation and COP, it is advisable to make decisions that are effective primarily for the investor, and at the stage of organizational and technological design, when the contractor develops a Work Production Project - effective for the contractor, within the framework of COP decisions and the terms of the construction contract. Accordingly, it becomes necessary to develop different techniques for different stages of organizational and technological design.

When implementing the second approach, dynamic criteria of cost efficiency (on a discounted basis) are applied, classical calculations of the net present value, the profitability index are performed to select the best schedule option from the presented ones. At the same time, the described algorithms [16] use a somewhat simplified approach that does not take into account the differences between commercial and non-commercial facilities. Hence, it becomes necessary to concretize the methods for calculating the indicators of cost efficiency.

Assessment of the cost efficiency of options for the sequence of construction of a complex of buildings and structures in the development of pre-design and design documentation

Variants of technological and organizational solutions during their implementation do not affect the area of operation of the commissioned ed facilities. Therefore, the costs of their implementation are determined only in one area - the sphere of construction production. As for design solutions, the comparison of organizational and technological options should be carried out subject to certain conditions that ensure their comparability. These conditions include: compliance with work technology, high-quality performance of work, comparable working conditions.

The design of alternative construction schedules should be carried out under the following conditions:

- the option with the maximum duration does not exceed the prescribed or standard term for the construction of the complex;
- if it is possible to fulfill the above organizational and technological conditions, the sequence of construction of buildings in the flow is taken from longer in terms of construction duration to shorter ones. This allows you to reduce organizational breaks between the stages of building construction (underground, aboveground part, finishing and special works, installation of equipment);
- it is assumed that investment costs are incurred at the beginning of each considered time period, and investment results are obtained at the end of the period;
- when determining the duration of the construction of facilities in the schedules, one should proceed from at least two-shift work when using the main construction machines, without using - on average, 1.5 shifts, taking into account the regulatory requirements [17];
- the calculation horizon for economic comparison is taken as the duration of the construction of a complex of buildings, structures according to the option with a longer duration (except for cases of the same duration for options).

The main goal of the investor (customer, developer) will be the receipt of the maximum income, expressed in the growth of the net present value (NPV), which is the total difference between discounted income cash flows and discounted outcome cash flows (investments) for the entire considered period of the project (calculation horizon).

Thus, the economic effect for the investor (E_{inv}) from the choice of the option of organizational decisions is calculated as the difference between the NPV values of the best ($NPV_{inv}^{\min}$) and other options ($NPV_{inv}^{\max}$).

The economic effect of using a more profitable organizational solution includes:

- economic effect at the construction stage due to the reduction in discounted capital costs (E_{inv}^{C}), rubles;
- economic effect at the stage of operation, due to income from the use of the object for the period from the commissioning of a particular building to the end of the calculation horizon (E_{inv}^{O}), rubles:

$$E_{inv} = NPV_{inv}^{\min} - NPV_{inv}^{\max} = E_{inv}^{C} + E_{inv}^{O} \quad (1)$$

In accordance with the legislation [18], a construction object may consist of one or more buildings, structures and their parts, engineering and transport communications and other real estate objects.

As part of a construction object, design documentation can identify construction phases and start-up complexes.

The construction phase is a part of a main-purpose facility, which can be independently operated and ensure, among other things, the safety of its functioning, product release, production of work, provision of services.

If the object is a complex of buildings, structures, then, taking into account their purpose and the degree of autonomy of functioning after commissioning, the following options are possible:

- during the construction of a complex of buildings, structures, including residential, public, retail, administrative and other buildings for cultural and domestic purposes, each building with the infrastructure necessary for its functioning is a separate completed construction phase, which can generate income for the period from its commissioning into operation until the end of the calculation horizon;
- during the construction of a complex of industrial buildings and structures, representing a single property complex of the enterprise, the following options are possible:

1) the construction is carried out without the allocation of phases or start-up complexes, then when comparing the options according to the described method:

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- ✓ for an option with a shorter construction duration, income is taken into account from the moment the complex is put into operation according to this option until the end of the calculation horizon;
- ✓ for an option with a maximum duration equal to the calculation horizon, income is not taken into account;

2) the construction is carried out in several construction phases (start-up complexes) with the commissioning of each of them separately, after which the receipt of income from the commissioned phase begins until the end of the calculation horizon.

The economic effect of reducing discounted costs at the stage of construction of the complex:

$$E_{inv.}^{C} = \sum_{i=1}^{n^{I}+1} PV_{i}^{Inv^{I}} - \sum_{i=1}^{n^{II}+1} PV_{i}^{Inv^{II}} = \\ = \sum_{i=1}^{n^{I}+1} \frac{Inv_{i}^{I}}{\left(1+R_{inv}^{calc}\right)^{i-1}} - \sum_{i=1}^{n^{II}+1} \frac{Inv_{i}^{II}}{\left(1+R_{inv}^{calc}\right)^{i-1}} \quad (2)$$

where I and II – indices of the corresponding options;

i – number of the calculation period;

Inv_i – amount of capital investments (cash outflow, investment costs), mastered in the i-th calculation period of construction (month), rubles;

n – number of calculation periods during the calculation horizon;

$\boldsymbol{R}_{inv}^{calc}$ – real discount rate for the calculating period for the investor.

If the compared options for the construction of a complex of buildings and structures have the same duration, then the economic effect can be achieved from a more rational financing schedule and, as a consequence, a reduction in discounted costs.

If the duration of the construction of a complex of buildings and structures for both options is the same ($n^{I} = n^{II}$) and construction for both options is carried out without allocation of construction phases, then $E_{inv}^{O} = 0$.

If the duration of the construction of a complex of buildings and structures for both options is the same ($n^{I} = n^{II}$), the number of construction phases is the same ($m^{I} = m^{II}$) and the duration of the construction of phases is the same ($n_{j}^{I} = n_{j}^{II}$) for all $j = 1, 2 \ldots m$, then $E_{inv}^{O} = 0$.

The real discount rate for the calculating period for the investor is determined by the formula [19]:

$$R_{inv}^{calc} = \frac{R_{inv} \cdot t_{calc}}{360} \quad (3)$$

where t_{calc} – duration of the calculation period, days;

$\boldsymbol{R}_{inv}$ – annual real discount rate:

$$R_{inv} = \frac{r - in}{1 + in} \quad (4)$$

where in – inflation rate;

r – nominal weighted average discount rate:

$$r = r_{e} \cdot \alpha_{e} + r_{d} \cdot (1 - \alpha_{e}) \quad (5)$$

where r_e, r_d, – nominal interest rates of the investor's equity capital and debt capital;

α_e – share of equity in the total volume of capital investments.

The nominal interest rate r_e is calculated as follows:

- when financing the construction of commercial facilities, it is taken in accordance with the value of the return on invested equity capital:

$$r_{e} = \frac{NP^{r}}{E^{r}} \quad (6)$$

where NP^{r} – net profit for the reporting period, rubles;

E^{r} – equity in the reporting period, rubles;

- when financing the construction of non-commercial residential buildings by individuals, it is taken equal to the nominal interest rate on a long-term deposit r_{ld} or long-term government and bank bonds r_{lb};
- when financing the construction of non-commercial facilities by the state, it is taken to be equal to the standard coefficient of investment efficiency, determined by the ratio of net profit to invested capital on average per year.

The r_e value must not be lower than the refinancing rate of the National Bank of the Republic of Belarus.

If the planned share of equity capital in the total capital investment α_e is unknown, then the nominal weighted average discount rate for the investor r when financing commercial objects is equal to the return on invested total capital:

$$r = \frac{NP^{r}}{IC^{r}} \quad (7)$$

where IC^{r} – total amount of investor's capital in the reporting period, rubles.

When the construction phase is put into operation during the calculation horizon, the investor will receive additional income for this period. The economic effect of the investor in the area of operation from the functioning of the facility for the period of early commissioning is determined by the following formula:

$$E_{inv}^{O} = \sum_{i=n_{h}^{I}+1}^{n^{I}+1} PV_{hi}^{NI^{I}} - \sum_{i=n_{h}^{II}+1}^{n^{II}+1} PV_{hi}^{NI^{II}} = \\ = \sum_{i=n_{h}^{I}+1}^{n^{I}+1} \frac{NI_{hi}^{I}}{\left(1+R_{inv}^{calc}\right)^{i}} - \sum_{i=n_{h}^{II}+1}^{n^{II}+1} \frac{NI_{hi}^{II}}{\left(1+R_{inv}^{calc}\right)^{i}} \quad (8)$$

where h – index of the construction phase;

i – numbers of calculation periods in which net income is received, in the range from the moment of commissioning the h-th construction phase of the object according to the option to the moment of the end of the calculation horizon;

n_h – the moment of commissioning the h-th construction phase, calc. periods;

NI_{hi}^{II} is the investor's net income from the operation of the h-th construction phase in the i-th calculation period, rubles / calc. period.

When determining net income, the following options can be distinguished, depending on the purpose of real estate objects:

1) commercial objects:
- income can be received only after the commissioning of the entire complex of buildings and structures (the object as a whole);
- income can be received after the commissioning of a separate construction phase (part of the object that can be independently operated and generate income);

2) non-commercial objects:
- net income of a commercial investor (except for the state) after the commissioning of each construction phase (for example, a residential building with infrastructure);
- net income of the investor (state) after the commissioning of each construction phase (administrative building, school, etc. with infrastructure).

The net income for the option will be determined on an accrual basis as the construction phases are accepted into operation within the calculation horizon.

The investor's net income for commercial objects is determined as follows according to [19]:

$$NI_{hi} = NP_{hi} + DE_{hi} \quad (9)$$

where NP_{hi} is the net profit from the operation of the h-th phase as part of the construction object for the i-th calculation period, rubles / calc. period;

DE_{hi} – corresponding depreciation expenses, rubles / calc. period.

$$NP_{hi} = R_{o}^{calc} \cdot EC_{hi} \quad (10)$$

where $\boldsymbol{R}_{o}^{calc}$ is the real profitability of objects in terms of net profit for the calculating period;

EC_{hi} – the estimated cost of the j-th building, structure as part of the h-th construction phase, rubles.

You can take the real profitability of the object in terms of net profit at the level of the real discount rate for the investor (formula (3)).

Depreciation expenses for the *h*-th construction phase in the *i*-th calculation period:

$$DE_{hi} = \left(\sum_{j=1}^{N_h^b} \frac{EC_{jh}^b}{T_{jh}^b} + \sum_{j=1}^{N_h^{eq}} \frac{EC_{jh}^{eq}}{T_{jh}^{eq}} \right) \cdot \frac{t_{calc}}{360} \quad (11)$$

where, EC_{jh}^b, EC_{jh}^{eq} is the estimated cost of construction and installation work of the *j*-th building (structure, infrastructure element) in accordance with the consolidated estimate, or the *j*-th unit of equipment, respectively, rubles; ,

T_{jh}^b, T_{jh}^{eq} is the standard service life of the *j*-th building (structure, infrastructure element) or the *j*-th type of equipment as part of the *h*-th construction phase, respectively, years;

N_{jh}^b, N_{jh}^{eq} – the number of buildings, structures, types of equipment, respectively, in the *h*-th construction phase.

Investor's net income (except for the state) from the operation of a non-commercial residential building:

$$NI_{ji} = I_{ji}^A + D_{ji}^{CR} \quad (12)$$

where I_{ji}^A – is the alternative income from the operation of the *j*-th building for the *i*-th calculation period, rubles / calc. period;

D_{ji}^{CR} – deductions for capital repairs for the *j*-th building in the *i*-th calculation period, rubles / calc. period.

We consider deductions D_{ji}^{CR} as expenses that will lead to an increase in the value of the complex of buildings in the future, which is tantamount to earning income.

An investor's alternative income for non-commercial residential buildings is defined as savings in rental costs for similar residential buildings:

$$I_{ji}^A = RR_j \cdot S_j^t \cdot \frac{t_{calc}}{30} \quad (13)$$

Where RR_j is the rental rate for the *j*-th building, rubles / m²·month;

S_j^t – the total area of living quarters in the *j*-th building, m².

For residential buildings that are built without the participation of state budget funds (at the expense of future apartment owners), the rental rate is taken at the level of the market weighted average in the region according to the Internet.

For residential buildings under construction at the expense of the budget funds, the rental rate is determined as the base rate of payment for the use of public rental housing:

$$RR_j^{st} = 0,2 \cdot BV \cdot C_{im} \quad (14)$$

where BV is the base value, rubles;

C_{im} – is a coefficient determined by the regional executive committees and the Minsk city executive committee, taking into account the degree of improvements and the district where the residential premises are located.

Deductions for major repairs for the *j*-th residential building in the *i*-th calculation period:

$$D_{ji}^{CR} = d_j^{CR} \cdot S_j^t \cdot \frac{t_{calc}}{30} \quad (15)$$

where d_j^{CR} – is the standard of deductions for capital repairs for the *j*-th building, rubles / m² month.

The investor's (state's) net income from the operation of a non-commercial facility is calculated using the following formula according to [19]:

$$NI_{ji} = E_{ji}^n + D_{ji}^{CR} \quad (16)$$

where E_{ji}^n is the normative effect from the use of the ***j***-th object (construction phase) in the ***i***-th billing period (a non-commercial object brings a social or environmental effect that can be expressed in monetary terms), rubles / calc. period: ,

$$E_{ji}^n = R_{inv}^{calc} \cdot EC_j \quad (17)$$

where R_{inv}^{calc} is the real discount rate for the accounting period for the investor, in accordance with formulas (3) and (4);

EC_j – the estimated cost of construction of the ***j***-th object, rubles.

Conclusion

The method has been developed for assessing the cost efficiency of options for the sequence of construction of a complex of buildings and structures, based on an income approach (the net income brought by a complex of facilities is calculated) and discounted cash flows.

This takes into account the economic effects of reducing discounted costs at the stage of construction of the complex, and the economic effects in the field of operation of individual buildings and structures, commissioned over the period of the calculation horizon, for the investor. This technique is currently relevant and complies with the rules for the development of business plans for investment projects [20].

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