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INCREASING THE COMPETITIVENESS OF CONSTRUCTION COMPANIES IN THE FIELD OF HOUSING CONSTRUCTION BY OPTIMIZING THE FLEET OF CONSTRUCTION EQUIPMENT

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ABSTRACT

The research is devoted to the topical problem of Russian construction companies - increasing competitiveness. The article analyzes the factors constraining the development of production activities of construction companies (in housing construction). Correlation analysis revealed those factors that have the greatest negative impact on the activities of construction companies. The analysis showed that one of the most significant factors negatively affecting housing construction is the high wear and tear of construction machinery and equipment

To solve the problem, the article suggests an algorithm for optimizing the fleet of construction machines and equipment.

The proposed algorithm uses elements of dynamic programming that allow choosing the most correct variant of optimization of the fleet of construction equipment.

The approach proposed in the article is aimed at increasing the productivity of construction companies in the field of housing construction and, as a consequence, to increase the competitiveness of Russian construction companies.

This approach can be used by enterprises of different levels and sizes, as well as those involved in other areas of construction.

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Key words: housing construction, increasing competitiveness, negative factors, construction equipment.

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1. INTRODUCTION

The construction industry is one of the basic spheres of the economy of any type. The building complex is connected practically with all branches of the economy, hence the problems and development of various spheres of the economy, including, depend on the pace of development and the state of the construction industry enterprises.

The difficult condition of the construction industry in Russia, the lack of competitiveness of Russian construction companies dictates the need to search for new methods that increase the efficiency of construction companies. One of the basic directions of the construction complex is housing construction. Currently, there is not enough available housing stock in Russia, as evidenced by official domestic sources of information [1], as well as various foreign research [2, 3]. In this regard, particular interest is the analysis of the activities of construction companies in the field of housing construction. It is necessary to identify the most important factors hampering the development of production activities in construction companies in the housing sector, and suggest options for leveling this influence on the activities of enterprises. Thus, the volume of construction will increase, the productivity of labor will increase, and as a result, the level of competitiveness of construction enterprises will increase [4].

2. METHOD

Measuring the closeness and direction of the relationship between the socio-economic indicators being studied is an important task in the study of the quantitative measurement of the interconnection of socio-economic phenomena. Such an assessment of the tightness of the relationship between the signs implies the definition of a measure of the correspondence between the variation of the effective trait from one (in the study of pair dependencies) or several (multiple) factors. We used the classical correlation analysis, and, most importantly, the measurement of the tightness of the bonds using a linear Pearson correlation coefficient [5, 6].

In practice, various modifications are applied to the formulas for calculating this coefficient:

$$r = \frac{\overline{(x-\bar{x})\cdot(y-\bar{y})}}{\sigma_x \cdot \sigma_y}. \quad (1)$$

Using the mathematical properties of the mean, we obtain:

$$r = \frac{\overline{(x-\bar{x})\cdot(y-\bar{y})}}{\sigma_x \cdot \sigma_y} = \frac{\overline{xy}-\overline{\bar{x}y}-\overline{x\bar{y}}+\overline{\bar{x}\bar{y}}}{\sigma_x \cdot \sigma_y} = \frac{\overline{xy}-\bar{x}\bar{y}-\bar{x}\bar{y}+\bar{x}\bar{y}}{\sigma_x \cdot \sigma_y} = \frac{\overline{xy}-\bar{x}\bar{y}}{\sigma_x \cdot \sigma_y} \quad (2)$$

Transformations of the given formula allow to receive the following formula of the linear correlation coefficient:

$$r = \frac{\sum(x - \bar{x}) \cdot (y - \bar{y})}{n \cdot \sigma_x \cdot \sigma_y} \text{ или } r = \frac{\sum(x - \bar{x}) \cdot (y - \bar{y})}{\sqrt{\sum(x - \bar{x})^2 \cdot (y - \bar{y})^2}}, \quad (3)$$

n - the number of observations.

x, y – indicators between which it is necessary to determine the relationship

By calculating the final values of the original variables, the linear correlation coefficient can be calculated from the formula:

$$r = \frac{n \cdot \sum xy - \sum x \cdot \sum y}{\sqrt{[n \sum x^2 - (\sum x)^2] \cdot [n \sum y^2 - (\sum y)^2]}} \quad (4)$$

or

$$r = \frac{\sum xy - \sum x \cdot \frac{\sum y}{n_0}}{\sqrt{\left[\sum x^2 - \frac{(\sum x)^2}{n}\right] \cdot \left[\sum y^2 - \frac{(\sum y)^2}{n}\right]}}. \quad (5)$$

The correlation coefficient can be expressed in terms of the variances of the terms:

$$r = \frac{\sigma_x^2 + \sigma_y^2 - \sigma_{x-y}^2}{2\sigma_x \cdot \sigma_y}. \quad (6)$$

Formulas (4), (5), (6) are used in the study of sets of small volume ($n \leq 20 \div 30$). Between the linear correlation coefficient and the regression coefficient there is a definite relationship, expressed by the formula:

$$r = a_i \frac{\sigma_{x_i}}{\sigma_y}, \quad (7)$$

a_i - regression coefficient in the coupling equation;

σ_{x_i} - the standard deviation of the corresponding statistically significant factor sign

The above described procedure for calculating the correlation coefficients will be carried out using MatLAB packages and the standard package MS ECXELL.

3. RESULTS

3.1. Analysis of the influence of factors limiting the production activity of construction organizations (for example, housing construction)

In order to identify the most significant factors for the activities of construction organizations in Russia, we built a dynamic series of statistic indicators [1,7]. It should be said that in this paper we used the official data of the Federal State Statistics Service of Russia [1,7], however, there are other studies in this area, such as the HSE research [8].

Thus, according to the results of the study, almost half of the managers of construction companies considered the restrictions on demand for products (two criteria - "lack of orders" and "non-solvency of customers") are the main problem of development of construction activity in the survey program.

The main contribution to such assessments was made by the decrease in demand for the services of the industry from the private corporate sector and the population. More than a third of respondents (40%) reported a negative impact of the size of the tax burden. Over the past year, the frequency of mentioning the high cost of materials, structures and products (from 24 to 33%), lack of financing (from 24 to 26%), a high percentage of commercial credit (from 15 to 20%) has increased significantly. On the contrary, the pressure of the deficit of skilled workers dropped noticeably (this was noted by 14% of entrepreneurs against 20% a year earlier), unfair competition in the market (27% and 30% respectively) [8].

Deterioration of construction equipment is one of the causes of low labor productivity. Thus, according to the World Bank [9, 10, 11], the average level of construction work in the Russian Federation today "... is now 21% of ... the United States and 33% of the European level ... per year, one builder in the US accounts for 84 m^2 of housing, in Canada - 53 m^2, in Sweden - 51 m^2 and Russia - only 13 m^2 » [10,11]. In many respects, low productivity is due to physical wear and tear and obsolescence of the basic production assets of construction companies, the use of inefficient methods of organizing work.

According to official statistics [1, 7], the main factors constraining the production activity of construction companies are the following factors, see Table 1. Table 2 shows the statistics of the survey of executives in the construction sector (data collected over 16 years). These data (in%) reflect the number of heads of construction companies who consider these factors to be a negative influence on the construction company.

Table 1 Factors restraining production activity of construction enterprises and their designation

Designation	Factor name	Designation	Factor name
X1	Customer insolvency	X6	High percentage of commercial loans
X2	High level of taxes	X7	Shortage and deterioration of construction machinery and mechanisms
X3	Lack of work orders	X8	Lack of skilled workers
X4	High cost of materials, structures, products	X9	Weather
X5	Competition from other construction firms		

Table 2 Factors limiting the production activity of construction organizations, in % [1, 7]

	Год															
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
X1	60	61	58	42	36	33	26	23	43	39	28	30	27	27	31	31
X2	71	66	59	62	44	43	42	42	40	38	53	51	42	39	40	36
X3	27	36	33	24	16	14	13	10	28	28	19	19	17	18	16	29
X4	47	53	46	38	38	36	44	46	31	27	37	37	25	23	33	33
X5	29	31	29	39	36	34	32	32	32	33	35	36	28	29	27	23
X6	12	11	16	10	12	14	12	11	20	17	12	12	14	14	20	20
X7	16	14	14	13	5	5	5	6	3	4	2	2	2	2	1	3
X8	21	21	21	31	24	25	26	31	16	16	20	21	21	21	14	13
X9	9	7	11	23	15	20	18	12	12	12	13	15	12	12	12	10

According to Table 2, a histogram was constructed for the dependence of the volume of housing construction (built not at the expense of the population and mortgages) on factors constraining construction activity (Fig. 1).

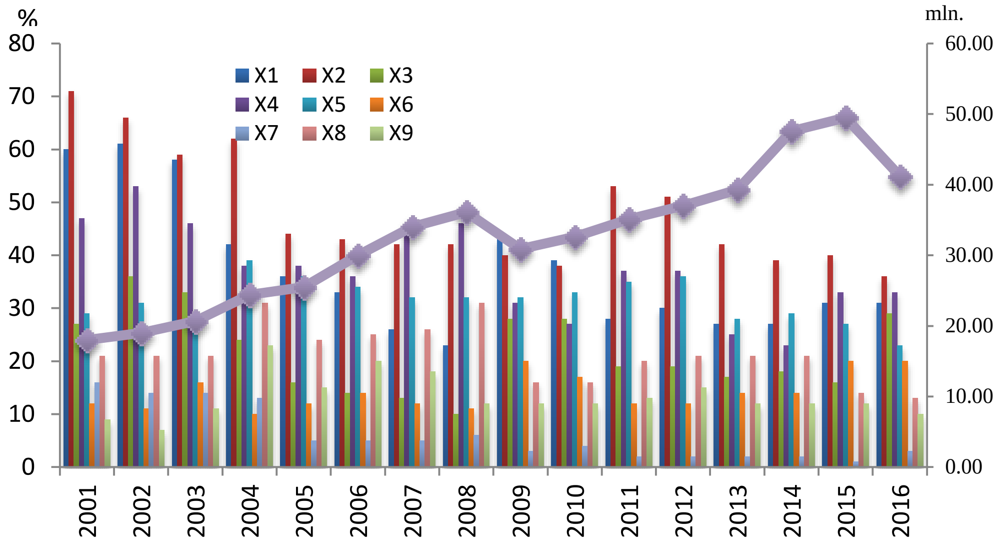

Figure 1 Dependence of housing construction on the negative factors affecting the activities of construction companies

Using the correlation research method described above, we found the following correlation dependencies between the indicators, see Table 3. Based on the results of the study, it can be seen that three factors influence the pace and volume of housing construction:

a. insolvency of customers (-0.81)

b. shortage and deterioration of construction machinery (-0.86)

c. high level of taxes

It should be said that all three factors have a dramatically negative impact on housing construction. Further calculations (the Pearson correlation coefficient) showed that the closest tightness of the relationship between housing construction and such a factor as "Shortage and deterioration of construction machines and mechanisms" is the Pearson coefficient of 0.73 (Table 3).

Table 3 The degree of dependence of housing construction on factors restraining the production of construction activities

Factor		Correlation coefficient	Pearson correlation coefficient
Insolvency of customers	X1	-0,81	0,66
High level of taxes	X2	-0,77	0,59
Lack of work orders	X3	-0,52	0,27
High cost of materials, structures, products	X4	-0,69	0,47
Competition from other construction firms	X5	-0,36	0,13
High percentage of commercial loans	X6	0,43	0,19
Shortage and deterioration of construction machinery and mechanisms	X7	-0,86	0,73
Lack of skilled workers	X8	-0,34	0,12
Weather	X9	0,00	0,00

Further we shall concentrate on a problem of optimization of a park of building cars and the equipment, as the basic problem restraining development of housing construction.

3.2. Features of the Assessment of the Competitiveness of Construction Companies

In today's market conditions, characterized by extreme instability, the dependence of the national economy on other countries and the strengthening of the role of international corporations, organizations and institutions, there is a rapid growth of competition between subjects of different levels (regions, industries, enterprises). M. Porter notes that states and regions do not compete directly, but through business entities producing products, while states create a competitive environment [12]. With respect to the level of enterprise research, competitiveness is a relative characteristic that determines its ability to fight for the market with other enterprises, and also to obtain new competitive advantages through the effective use of all types of resources [13].

For enterprises of the construction industry, working mainly in the national market, the influence of international global and cultural factors on competitiveness is insignificant. Technological, resource and innovation factors are much more important for construction. Potentially, the level of competitiveness of an enterprise in the construction market is determined by the number and importance of the existing competitive advantages that determine the key success factors that ensure stable and reliable operation. Such competitive advantages can include: high quality of construction and assembly works, short-term implementation of investment projects, reasonable cost of products, professionalism of employees, reputation, experience in construction, modern level of management and organizational development, etc. [14].

We analyzed the most common approaches to assessing the competitiveness of construction companies in the domestic market (Table 4).

Table 4 Groups of indicators for assessing the competitiveness of construction enterprises [14-21]

Indicators \ **Author, source**	**M.A. Shuvaev [19]**	**I.S. Stepanov [20]**	**E.N. Lysenko [15]**	**T.Ya. Silkina [21]**	**V.V. Asaul [14]**	**O.V. Lukinov [16]**	**I. E. Petrova [18]**	**B. Mandah [17]**
Market share	+							
The integral indicator of the qualitative characteristics of the enterprise					+	+		
Complex of economic, social and technical factors (integral indicator)		+			+			
Indicators of financial and economic reporting					+		+	
Participation in tenders		+	+			+		
Capitalization of the enterprise				+				
Consumer cost of production	+			+		+	+	
Factors of production								+
Competitive potential			+					
Innovative factors					+			+

Given the development of the construction market and the specifics of construction companies, it is advisable to use an integrated approach to assess their competitiveness, covering the analysis and evaluation of those aspects of activity that allow the company to win a stable market position, to be of interest to the customer by the price-quality ratio construction products. With this is the tendency to determine the competitiveness of a construction enterprise as a set of advantages that allow winning tenders for placing orders for contract work and enter into contracts for the construction, reconstruction and restoration of large objects [19].

Another fairly objective assessment of competitiveness is the "Number of won tenders", since for the victory in such trades the enterprise must prove its experience, availability of the necessary resources, offer the tender proposal (offer) that is most acceptable to the customer. With this approach, the competitiveness of a construction enterprise depends on its innovative, resource and technological potentials that allow it to conclude profitable contracts and find a rational ratio between the required quality of the erected object and its price, which should provide the necessary profitability and profit [15, 16, 20].

Considering the above, the most important criteria for the competitiveness of a construction company include:

- efficiency of use of production potential;
- financial and economic condition;
- effectiveness of the organization of marketing and promotion of finished objects;
- the quality level of construction products, its ability to meet customer requirements.

In the course of the analysis, the degree of influence of wear on construction machinery and mechanisms on the final assessment of the competitiveness of the construction company was studied. According to various estimates, the impact of wear on construction machinery and mechanisms on the competitiveness of a construction company is 5 to 15% [23].

3.3. Methods of Forming a Fleet of Construction Machines and Mechanisms (CMM)

In our opinion, this methodology should take into account the following main points:

- the need for building machines and mechanisms depends on the total amount of construction;
- it is necessary to divide the volume of construction works and types of work (land, installation, etc.), according to the timing and nature of the construction work from the point of view of implementation of various CMM;
- Calculation of the need for CMM for the established scope of work, should be done taking into account the available equipment (in working condition and being under repair);
- should be provided for various options for the acquisition of CMM (should be considered as a new technique, and second-hand);
- calculation of the feasibility of taking the CMM for rent

In view of the above, we propose the following algorithm (Figure 2), which makes it possible to meet the need for CMM in accordance with the declared volumes of construction. It is known that construction equipment eventually wears out, aging physically and morally. In the process of operation, as a rule, its productivity decreases, as well as the operating costs for the current remont. Over time, it may be necessary to replace construction equipment, as its further operation costs more than repairs.

In the proposed algorithm, the block "Simulation of the renewal of a fleet of construction machines" was singled out separately, which provides:

- purchase of equipment (options for new equipment and used equipment are considered);
- leasing out construction equipment not involved in construction;
- carrying out major repairs (current repair) of existing construction equipment.

The peculiarity of this approach is the modeling of the overhaul of existing equipment (block "B" in Fig. 2). It should be noted that the decision to overhaul or replace CMM should be made methodically and economically justified.

4. DISCUSSION

The methodical approach for making a decision on carrying out repairs, or acquiring new equipment, will look like this. In the process of work, construction equipment gives an annual profit, requires operating costs and has a residual value. These characteristics depend on the operating conditions and age of construction equipment. In any year, construction equipment can be saved, sold at a residual price and purchased a new one. If old equipment is maintained, operating costs increase and productivity decreases. When replacing, you need significant additional capital investments. The task is to determine the optimal replacement strategy in the planning period so that the total profit for this period is maximum.

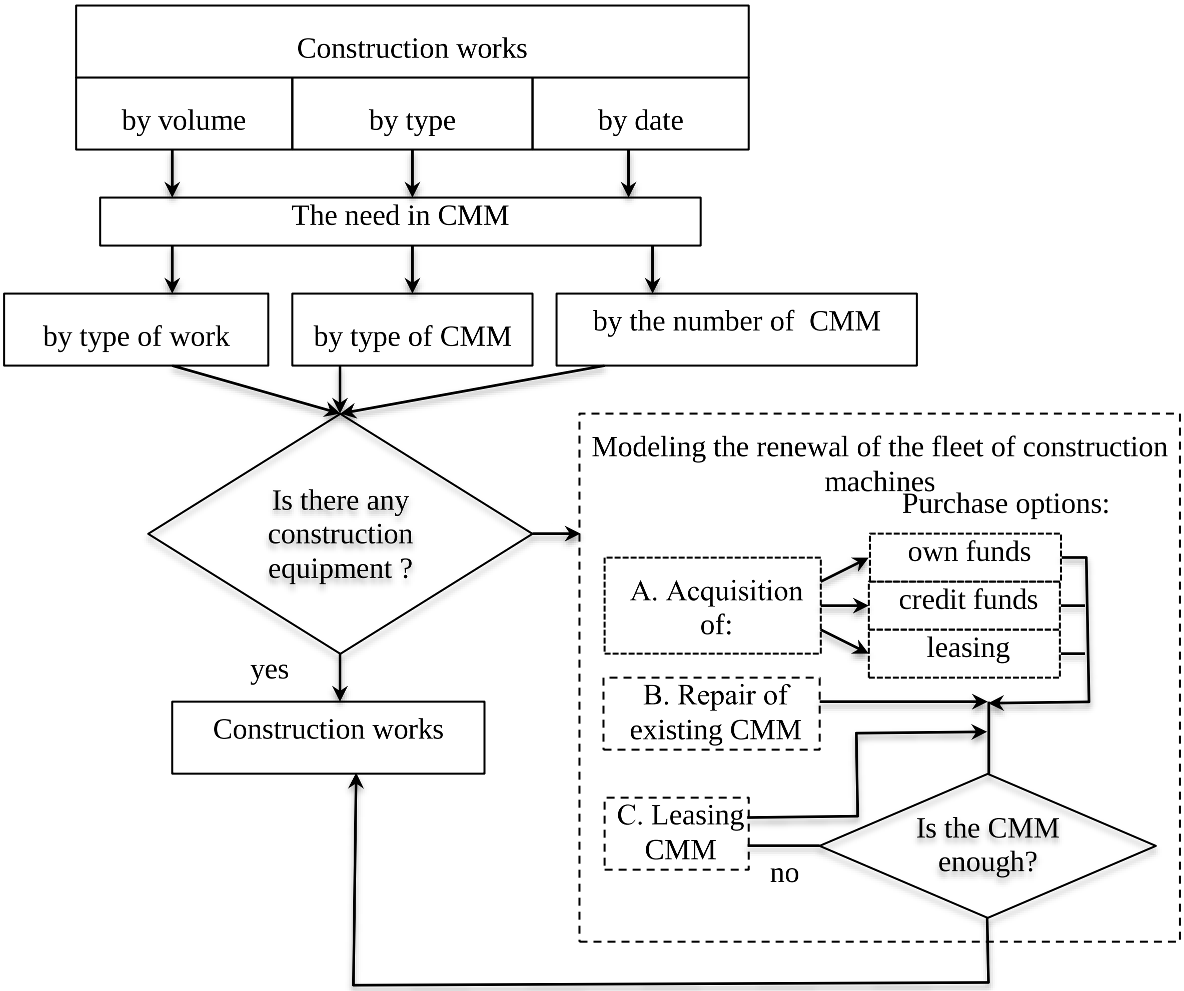

Figure 2 Algorithm for the formation of an optimal fleet of construction machines

To quantitatively formulate the problem, we introduce the following notation:

r (t) - the cost of products produced for a year on construction equipment age t years;

u (t) - the costs associated with the operation of this construction equipment;

s (t) - residual value of construction equipment of age t years;

p - purchase price of construction equipment;

t - duration of the planning period; t = 0, 1, 2, ... ,;

T is the number of the current year.

To solve the problem, we apply Belman's optimality principle [24, 25]. Consider the intervals (years) of the planning period in the sequence from the end to the beginning. We introduce the function of conditionally optimal values of the target function *Fk (t).* This function shows the maximum profit received from construction equipment age t years for the last k years of the planning period. Here the age of the equipment is considered in the direction of the natural course of time. For example, t = 0 corresponds to the use of completely new construction equipment. The temporary steps of the process are listed in reverse order. For example, for k = 1, the last year of the planned period is considered for k = 2 - the last two years, etc., for k = T - the last T years, i.e. entire planning period.

In this task, the system is a fleet of construction equipment. It condition is characterized by age. The control vector is a solution at the time t = 0, 1, 2, ..., T to save or replace equipment. To find the optimal replacement policy, you should analyze, according to the principle of optimality, the process from end to beginning. To do this, we make a proposal on the state of the equipment at the beginning of the last year (k = 1). Let the equipment have an age of t years. At the beginning of the T-th year there are two possibilities:

- To save construction equipment on the T-th year, then the profit for the last year will be r (t) - u (t);
- Sell construction equipment at a residual value and buy a new one, then the profit for the last year will be equal to s (t) - p + r (0) - u (0), where r (0) is the cost of products released on the new equipment. the first year of its entry; u (0) - operating costs this year.

It is advisable to deploy the process from the end to the beginning. For the last year (k = 1), the optimal policy from the point of view of the entire process will be a policy that ensures maximum profit only in the last year. Given the value of profit for a different mode of action (replacement or preservation), we come to the conclusion that the decision to replace construction equipment at the age of t years should be taken in the case where the profit from new construction equipment in the last period is greater than from the old one, that is, provided:

$$s(t) - p + r(0) - u(0) > r(t) - u(t) \quad (8)$$

If

$$s(t) - p + r(0) - u(0) \leq r(t) - u(t), \quad (9)$$

it is advisable to preserve the old technique. So, for the last year, the optimal policy and maximum profit F1 (t) is found from the condition:

$$F_1(t) = \max \begin{cases} r(t) - u(t) \ (preservation), \\ s(t) - p + r(0) - u(0) (replacement\ of\ equipment). \end{cases} \quad (10)$$

Let k = 2, that is, consider the profit for the last two years. We make an assumption about the possible state t of construction equipment at the beginning of the penultimate year. If at the beginning of this year a decision is taken to keep the construction equipment, then by the end of the year the profit *r(t)-u(t)* will be obtained.

At the beginning of the last year, construction equipment will go into t+1 state and with the optimal policy in the last year it will bring a profit equal to $F_1(t + 1)$.

Thus, the total profit for two years will be $r(t) – u(t) + F_1(t + 1)$.

If, at the beginning of the penultimate year, a decision is made to replace construction equipment, the profit for the penultimate year will be $s(t) – p + r(0) – u(0)$.

As new equipment is purchased, at the beginning of the last year it will be able to t = 1. Therefore, the total profit for the last two years with the optimal policy in the last year will be:

$$s(t) – p + r(0) – u(0) + F_1(1) \quad (11)$$

Conditionally optimal in the last two years will be the policy that delivers the maximum profit:

$$F_2(t) = \max \begin{cases} r(t) - u(t) + F_1(t+1) - reservation, \\ s(t) - p + r(0) - u(0) + F_1(1) - replacement. \end{cases} \quad (12)$$

Similarly, we find expressions for conditionally optimal profits for the last three years, four, and so on. The general functional equation takes the form:

$$F_k(t) = \max \begin{cases} r(t) - u(t) + F_{k-1}(t+1) - reservation, \\ s(t) - p + r(0) - u(0) + F_{k-1}(1) - replacement. \end{cases} \quad (13)$$

For $k = T$ we obtain $\max Z = F_T(t_0)$, and:

$$F_T(t_0) = \max \begin{cases} r(t_0) - u(t_0) + F_{T-1}(t_0+1) - reservation, \\ s(t_0) - p + r(0) - u(0) + F_{T-1}(1) - replacement. \end{cases} \quad (14)$$

Thus, unfolding the entire process from the end to the beginning, we get that the maximum profit for the planning period T is $Z = F_T(t_0)$. Because the initial state t0 is known, from the expression for $Z = F_T(t_0)$ we find the optimal solution at the beginning of the first year, then the optimal solution for the second year that follows from it, etc.

An example of calculations by this method is presented in Table 4.

Table 4 Example of the definition of the option of repair or sale of CMM

	Residual value (s (t)), million rubles	**Revenues per year (r (t)), million rubles**	**Expenses for repairs and maintenance (u (t)), million rubles.**	**Profit (Fk (t)), million rubles.**	**Original cost (p) million rubles**	**s (t)-p+r(t)-u(t)**	**r(t+1)-u(t+1)**	**Level of workload of CMM,%**
Excavator - 1 year	2,700	3,98	2,931	1,049	3	0,749	0,755	59,40%
Excavator -	2,295	4,023	3,268	0,755	3	0,050	1,159	61,50%

2 year								
Excavator - 3 year	1,951	3,998	2,839	1,159	3	0,110	0,940	57,78%
Excavator - 4 year	1,658	3,567	2,627	0,940	3	-0,402	0,887	61,23%
Crane – 1 year	4,5	7,887	4,524	3,363	5	2,863	2,871	62,01%
Crane – 2 year	3,825	6,872	4,001	2,871	5	1,696	3,521	66,62%
Crane – 3 year	3,251	8,883	5,362	3,521	5	1,772	2,103	63,31%
Crane – 4 year	2,926	7,982	5,879	2,103	5	0,029	1,402	69,31%

Analyzing the table 4 it can be concluded that the sale of the excavator and the crane is impractical, in this case it is more advantageous to repair the equipment, but here it is necessary to take into account both the level of equipment loading and the cost of the performed work. In this case, a drop in the load of MIW will lead to a decrease in the volume of products produced, and consequently to the emergence of a vari- ance in the sale of equipment. There can also be a situation that you-lease out the existing construction equipment.

Choosing one or another option to optimize the fleet of construction equipment, the company increases both the productivity of construction and competitive advantages in the market.

5. CONCLUSIONS

The methodical approach proposed in this article, aimed at reducing the influence of factors limiting the production activity of construction organizations in the field of housing construction, is applicable not only to reducing the wear of construction machines, but also to other factors. In addition, this approach can be applied both to the sphere of housing construction, and to the field of road construction, industrial construction, etc.

The technique of optimization of the fleet of construction equipment considered in the article makes it possible to increase the efficiency of the construction company and, as a consequence, leads to an increase in competitiveness in the housing construction market. The offered variants of optimization of the park of building machines allow not only to increase the efficiency and competitiveness of the enterprise, but also allow to predict the further position of the enterprise in the market.

In addition, it is recommended to use a multilevel system of indicators to assess the effectiveness of the implementation of a methodical approach, which allows for timely monitoring of changes in performance indicators for the use of construction equipment. The authors also recommend using a scenario approach to the analysis of factors constraining the development of construction organizations and adversely affecting the competitiveness of the construction enterprise.

Developed by the authors, methodological recommendations to increase the competitiveness of construction companies by reducing the impact of negative factors (for example, housing construction) have both scientific and practical importance.

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