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UDK 621.6

Existing Problems for Reducing Viscosity of Oil and Oil Products during Storage

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Key words and phrases: high-viscosity oils; oil; food supply; storage of viscous oils; viscosity reduction.

Abstract. The purpose of the article is to consider the existing problems of storage of high viscosity oils and petroleum products. The objectives of the article are to study and summarize the existing array of information to identify the most significant problems in the field of petroleum products. The study was based on descriptive and analyzing methods. The results obtained allow us to draw conclusions regarding the current situation in the field of reducing the viscosity of oil and oil products during their storage.

In general, the modern Russian complex for storage, heating, discharge, loading and transportation of viscous oils and petroleum products fulfills its task. Domestic oil depots install both Russian and imported equipment, look for ways to improve the efficiency of both storage and heating of highly viscous oils and petroleum products. Nevertheless, there are certain problems that remain in this segment of the oil and gas industry. We will describe the main ones.

Today, outdated models of steam and hot water boilers supplying heat-carrying media to coil heaters located on the bottoms of tanks continue to prevail in this segment. The use of this equipment does not significantly increase the heat transfer coefficient from coils to petroleum product, causes frequent interruptions in operation which reduces the actual load factor of heaters to 15–20 %, makes impossible the settling of petroleum products with simultaneous heating due to convective currents in heated petroleum product, makes it difficult to keep the heat-transfer surface properly clean since cleaning is connected with the discharge of petroleum products from tanks, involves labour intensive process of running external steam and condensate pipes to each tank. Steam and water heating boilers operate at high pressure which creates the risk of explosions and fires; additional safety measures make this equipment extremely bulky and heavy.

Discharge and loading of viscous petroleum products remain ineffective. The use of portable coil type steam heaters requires a significant investment of time, and working with “live steam” leads to the flooding of heated petroleum product. As a result, railway tanks with fuel oil and other dark oil products stand idle for a long time while being discharged, and cargo receivers pay fines to transportation companies.

Electric heating remains an extremely expensive procedure, especially during the cold season. Electric heating is a much more expensive way of heating compared to combined-cycle boilers, mainly because in Russia natural gas is still significantly cheaper than electricity.

The storage and heating system for petroleum products remains nontransparent: there is no reliable, open statistics on the scale and efficiency of storage and heating at oil depots. Strict reporting is carried out at each depot for transported, stored and shipped petroleum products, but on a regional and country scale it is extremely difficult to determine how much viscous oils and petroleum products are stored at oil depots and transported through them.

In general, the deduction of energy costs for storage and heating of petroleum products at oil depots remains difficult, since these costs are included in the general cost calculation of a company. Oil depots usually record the total energy consumption for a reporting period (month, quarter, year), but only rarely allocate the cost of heating tanks. This is related to the fact that boiler houses at oil depots operate not only for heating tanks, but also for heating storage and administration buildings. Under such conditions, breakdown of costs for production and utility needs often becomes difficult.

An important problem in optimizing the equipment and technologies for the storage and heating of viscous petroleum products is the efficiency criterion of their use. As of today, when choosing heating equipment, the following indicators in its technical passport are used: “efficiency factor” (%), “steam capacity” (t/h) and others. Such parameters define the “heat-generating” efficiency of this equipment, but they do not say anything about its final “rheological” efficiency, i.e. the ability to reduce the viscosity of liquids. That is quite understandable. When installing this equipment at oil depots, it is mounted in conjunction with a pipeline or panel infrastructure with its own “thermal conductivity” efficiency. Thus, the indicators of the heating equipment itself are integrated with the indicators of heat-supply devices mounted on tanks.

Assuming the viscosity of a petroleum product as a function of its heating cost, the final “rheological” efficiency of the heating equipment can be expressed through its derivative A, i.e. the rate of viscosity change (mm^2/s) of the given volume of petroleum product per unit increase in energy consumption (kWh). The reverse indicator of the heating cost is also correct: the equipment with minimum costs to reduce the viscosity of given petroleum product volume per specified value considered to be more efficient. These ratios require experimental test of equipment not in workshops and on testing grounds of a manufacturer, but “in the field” – at oil depots, in reservoirs and tanks.

Unfortunately, such experiments at our oil depots are very rare. The entire oil supply industry, including viscous petroleum products, remains technologically backward, and the reason for this is known. According to researchers, in the beginning of the XXI century, the oil supply system companies have the lowest level of technical equipment in the Russian oil industry since the funding of these facilities was carried out even back in the Soviet times with whatever remaining funds. This situation has not changed much today. Oil depots were privatized, but large oil companies that run petroleum product supply companies (“sales”) do not consider them priority, and therefore skimp on serious investments in their modification and upgrade.

The technological backwardness of petroleum product supply exists also because this industry virtually does not adopt any innovative methods to treat liquids in order to reduce their viscosity. At modern Russian oil depots, storage and heating of viscous petroleum products are still done by old methods developed in the second half of the last century, namely, steam treatment and electric heating. The analysis of industry regulatory framework shows the recognized validation of these two methods, and any deviations from them are risky. These rules do not contain provisions necessitate the search for innovative methods of such treatment for viscous petroleum products, methods to reduce energy costs for these operations, and the corresponding experiments.

Meanwhile, over the past decades, Russian and foreign petrochemical scientists, physicists, acousticians, engineers have accumulated vast experience in innovative treatment of oil and petroleum products in order to reduce their viscosity, i.e. improved steam treatment and electric heating, and non-standard methods of their treatment with electric, magnetic, electromagnetic, hydrodynamic ultrasonic fields as well as the use of renewable energy sources.

This article allows us to draw the following conclusions regarding the current situation in the field of reducing the viscosity of oil and oil products during storage. Firstly, it was shown that the sphere of oil supply in general demonstrates conservatism and technological backwardness. Secondly, over the past decades, oil and gas science has made great strides in the development of new methods for reducing the viscosity of oil and oil products: experiments are conducted using methods of exposure to liquids of electric, magnetic and electromagnetic fields, ultrasonic radiation, hydrodynamic effects, etc. An extremely interesting experience has been accumulated in creating experimental plants that reduce the viscosity of oil and petroleum products during their production, transportation, storage. However, these studies and experiments are limited, as a rule, to laboratories and experimental training grounds. In the literature, references to the experimental testing of various methods of reducing the viscosity of oil products at oil depots are extremely rare. This is explained by the closed nature of the petroleum product supply industry and its conservatism. Thirdly, we believe that there is an urgent need for an industrial experiment at oil depots in order to test methods and technologies for reducing the viscosity of oil products stored in tanks. Fourth, the analysis showed that the most vulnerable place in the theory and practice of reducing the viscosity of petroleum products is a costly approach. Researchers report a high percentage reduction in viscosity after applying their methods, but are silent about how much this reduction was obtained; tank farms do not isolate heating costs, i.e. work on a cost basis, etc. In our opinion, this trend can be reversed only if the objective of the experiment is not to reduce the viscosity of oil products at any cost, but to save energy, i.e. search for low-cost ways to achieve this goal.

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Существующие проблемы снижения вязкости нефти и нефтепродуктов при хранении

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Ключевые слова и фразы: высоковязкие нефти; нефть; снижение вязкости; сфера продуктообеспечения; хранение вязких нефтей.

Аннотация. Целью статьи является рассмотрение существующих проблем хранения высоковязких нефтей и нефтепродуктов. Задачи статьи: изучение и обобщение имеющегося массива информации для выявления наиболее значимых проблем в сфере нефтепродуктообеспечения. Основой данной работы послужили описательный и анализирующий методы. Полученные результаты позволяют сделать выводы относительно существующей ситуации в области снижения вязкости нефти и нефтепродуктов при их хранении.

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Suppression Coefficient as a Generalized Energy Suppression Criterion for Incoherent Radar Systems

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Key words and phrases: impulse; noise; power; radio-location system; suppression coefficient; signal.

Abstract. This paper considers the concept of the suppression coefficient and its further use as a generalized energy criterion capable of assessing the quality of a masking signal to suppress radar systems for various purposes. Particular attention is paid to the methodology for determining the suppression coefficient of radar systems with post-detector accumulation under interference conditions. As a result of the study, the expressions required for its calculation are given.

The purpose of the paper is to study radar systems with post-detection accumulation (incoherent systems),and the effectiveness of interference by determining their suppression coefficient. The main sources for this research were studies of electronic warfare and, in particular, radar systems for electronic suppression [3; 6]. This study is devoted to an urgent problem, since today the search and use of the suppression coefficient of incoherent radar systems in electronic suppression radar systems plays an important role in electronic warfare on the whole.

The suppression coefficient k_r is a quantitative characteristic of energy efficiency of suppression of some radio electronic equipment (**REE**) by one of the noise signals.

Even at the very beginning of the period when k_r was used as an energy criterion, there were some paradoxes in the suppression of some types of radar stations (radar) with the same assessment of the effectiveness of the noise signal. Thus for conventional pulsed incoherent radars and radars operating with complex signals equivalent in energy to the sounding signal and with the ability to suppress range selection, the values of the suppression coefficient differ from each other. More precisely, for a radar operating with complex signals, the value of k_{rdif} is a compression ratio kc times greater than for a conventional impulse incoherent radar [1]

$$k_{rdif} = k_r \cdot k_c, \tag{1}$$

where k_c is a compression coefficient equal to signal base d, $k_c = d$.

Difficulties and misunderstandings in the theoretical estimation of k_r were really strong due to the emergence of a new generation of radars – impulse-coherent, holographic, etc. Therefore, the practical need for an objective analysis of the advantages and disadvantages of

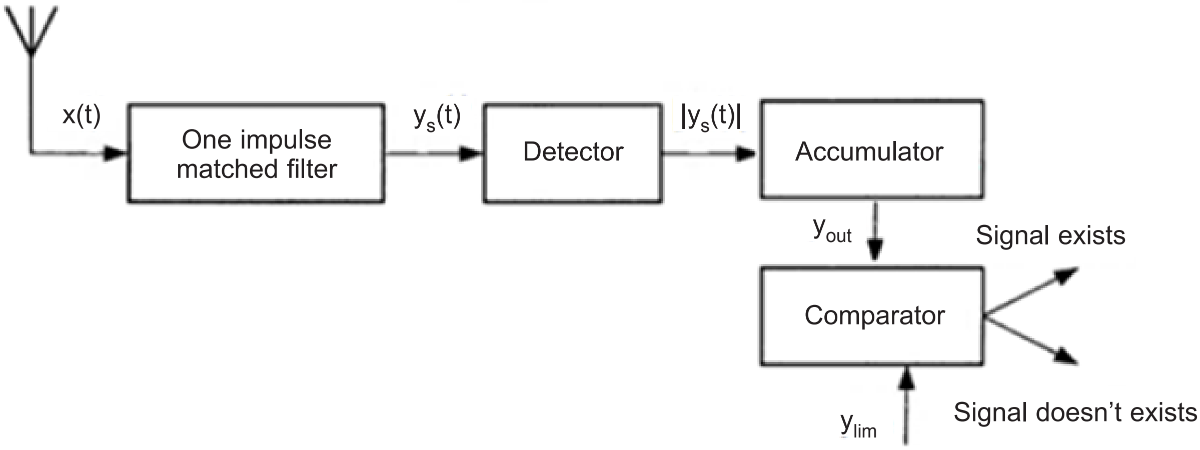

Fig. 1. A Simplified block diagram of a quasi-optimal receiver – a detector of incoherent radar

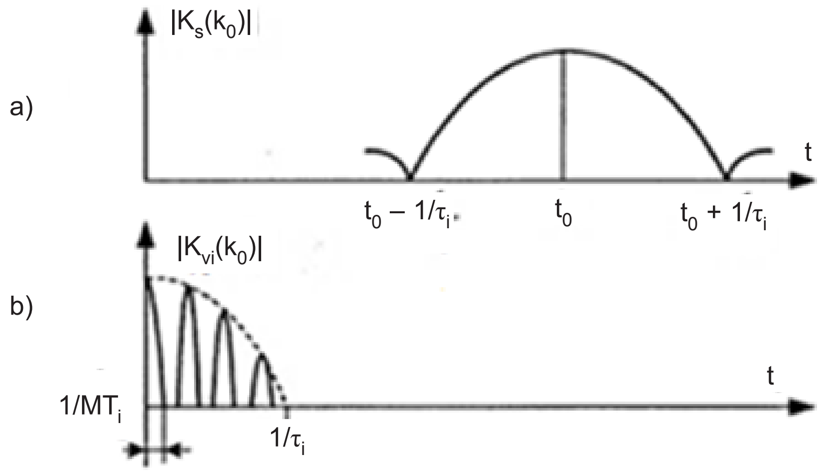

Fig. 2. One impulse processing by a matched filter AFC (a) buffer (b)

using k_r manifested itself as an energy criterion for the effectiveness of electronic suppression. In addition, it is necessary to find possible erroneous methods of theoretical and practical determination of k_r. But as for the main problem, it is necessary to find rules for using k_r for practical calculations related to the use of the electronic suppression equality [1].

Thus, all the equalities that determine the coefficient of suppression of an incoherent radar can be found from the following considerations.

In incoherent radar, information about the phase of the received signals is not used. A simplified block diagram of a quasi-optimal receiver – a detector of incoherent radar is shown in Fig. 1.

The processing of one train of *M* impulses by a matched filter can be depicted as an AFC in Fig. 2a. AFC of the buffer – $K_{vi}(j\omega)|$ is shown in Fig. 2b.

Compared to coherent reception, incoherent processing of the detected signal requires a higher signal-to-noise ratio at the input. This is due to the loss of energy by the useful signal during target detection. This loss is mainly related to the detection of a mixture of signal and noise.

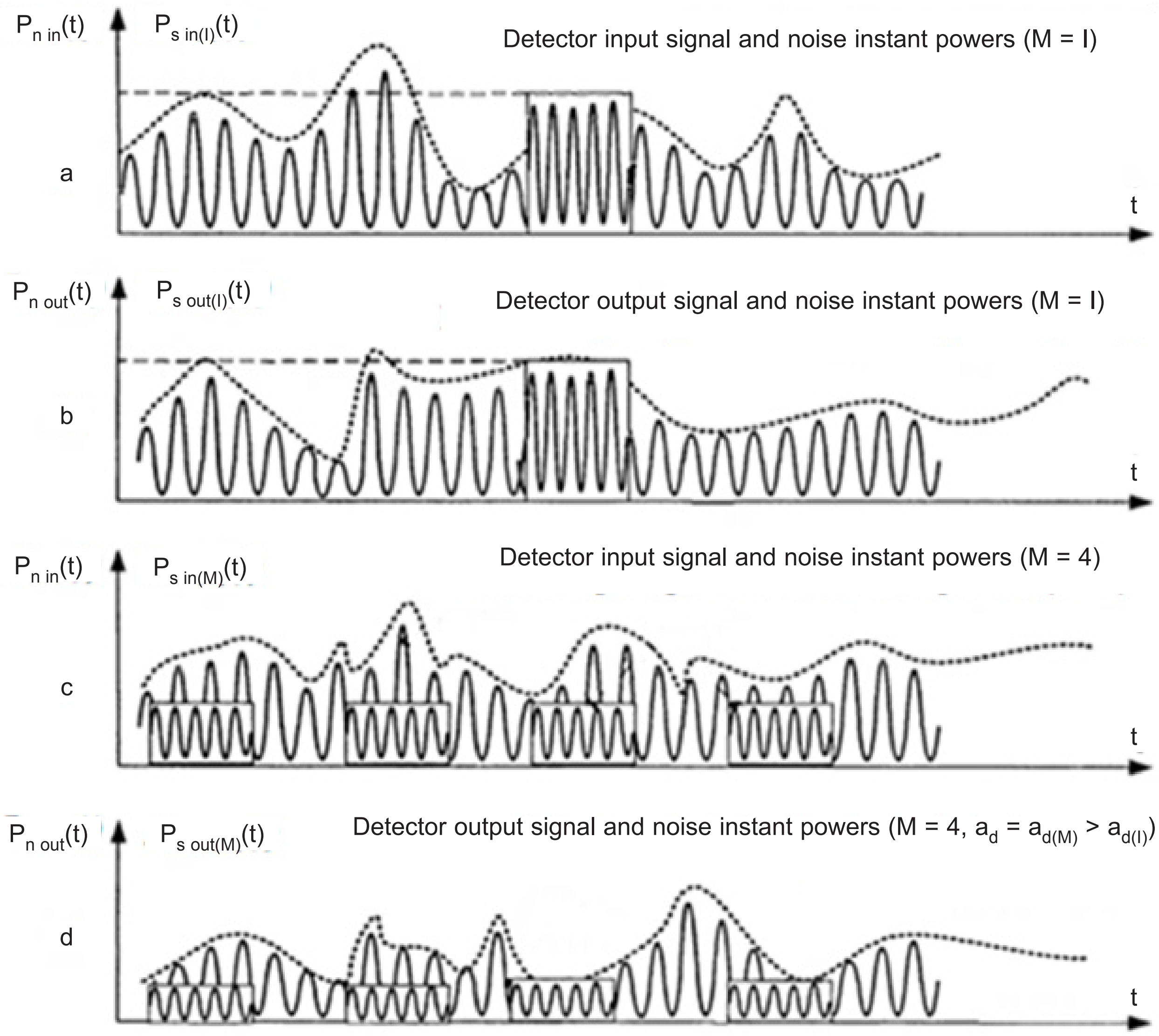

Fig. 3. Incoherent radar detector input and output signal and noise power

Amplitude detector (**AD**) as a nonlinear element reduces the signal-to-noise ratio. At its output, this ratio is related to the input as follows [2]:

$$k_{d\ out} = k_{d\ in}^2/(1 + 2k_{d\ in}), \tag{2}$$

where $k_{d\ in}$ is AD input signal and noise powers relation (as well as at the output of the linear part of the receiver).

As follows from (2), the presence of noise leads to a decrease in the signal-to-noise ratio at the detector output. This influence is especially pronounced in the case of an insignificant signal-to-noise ratio ($k_{d\ in} < 1$) and can be called the main reason for the energy influence.

It is really important to say that all considerations above can be looked through only as illustrative [2].

Detector loss should be accounted for using a loss factor that can be found using the method below.

For built-in impulse coherent radar, the limit value q_{lim} can be found using the detection curves taking into account the type of signal being processed (fully known signal, signal with arbitrary initial phase, signal with fluctuating amplitude and initial phase). For a train of M coherent impulses with total energy E, the value of the limitation $q_{lim}(M)$ is found from the graphs in Fig. 3 from [5].

Based on the following ratios:

$$q_{lim}(M) = 2E/N, \quad (3)$$
$$E = E_1 \cdot M = P i \tau_i \cdot M, \quad (4)$$

where E_1 is the energy of a single-impulse train, the limitation value $q_{lim}(1)$ of a single-impulse train will decrease very strongly. It does not follow from (4) that the signal-to-noise ratio, reduced by a factor of M, is required to detect one impulse with energy E_1. In this case, it follows from (4) that in order to detect a burst of M coherent impulses, the required value of the limitation value $q_{lim}(M)$ must increase M times in comparison with the value of the limitation $q_{lim}(1)$.

For incoherent radar, the detection of one impulse with a τ_i duration and E_1 energy due to energy losses requires a higher signal-to-noise ratio than that found from (3), and to be precise, it will be:

$$q_{lim\ inc}(1) = \alpha_d(1) \cdot q_{lim}(1), \quad (5)$$

where $\alpha_d(1)$ is one impulse energetic losses coefficient ($\alpha_d(1) > 1$) [3].

When processing a burst of M pulses, the loss factor increases. This is due to the following circumstances.

For incoherent radar, the processing of one impulse with energy E_1 and a burst of impulses with the total energy E from (4), as well as the instantaneous power of the received oscillation are shown in Fig. 3a and 3b.

When an impulse with energy E is decomposed into M impulses with the same total energy, the power of each impulse P_s in (M) decreases by a factor of M, as shown in Fig. 3c and 3d, while the noise power P_n remains unchanged, therefore, the energy loss increases due to a decrease in the signal-to-noise ratio.

The energy loss factor depends on the number M of integrated impulses. With increasing M, the coefficient $\alpha_d(M)$ also increases. This factor also depends on the value of the q_{lim} limitation. If $q_{lim} = 2E/N$ is low and $N = \text{const}(f)$, then this is equivalent to low energy signals. The detector perceives signal suppression by noise much stronger, which leads to an increase in the coefficient $\alpha_d(M)$. Here and earlier, q_{lim} is the value of the signal-to-noise ratio limitation given for an ideal (coherent) receiver.

Fig. 4 shows a relationship between the loss coefficient $\alpha_d(M)$ and the number M of processed impulses. A common parameter is the signal-to-noise ratio limiting value q_{lim}.

For incoherent radar, the signal-to-noise ratio limitation value $q_{lim\ inc}(M)$ can be found from the following formula

$$q_{lim\ inc}(M) = \alpha_d(M) \cdot q_{lim}(M), \quad (6)$$

where $q_{lim}(M)$ is the limitation value of the signal-to-noise ratio when suppressing an ideal impulse coherent radar. For example, it was assumed that an ideal impulse coherent radar stops working when $q_{lim}(M) = 9$ dB in case of processing $M = 100$ impulses, we can find loss

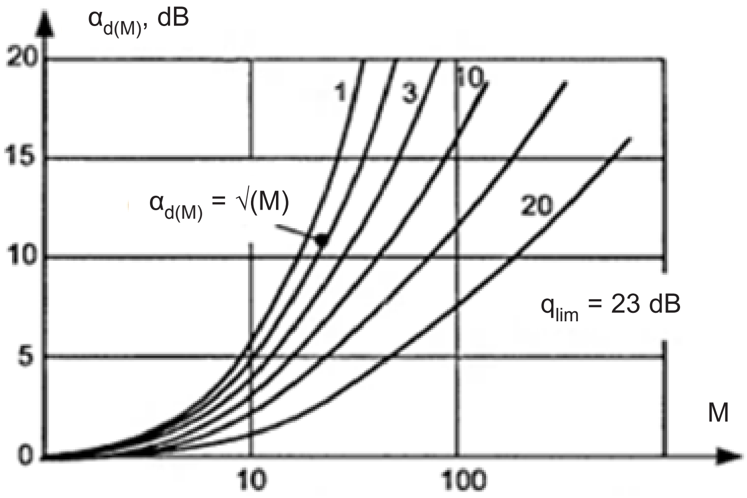

Fig. 4. The relationship between the loss coefficient $\alpha_{d(M)}$ and the number M of processed impulses

coefficient $\alpha_d(M)$ = 15 dB from the Fig. 4. Therefore, the limitation value of the signal-to-noise ratio of an incoherent radar is equal to $q_{lim\ inc}(M = 100)$ = 24 dB [4].

When limitation value $q_{lim\ inc}(M = 100)$ is found we can start finding a ratio for incoherent radar suppression coefficient.

From (7) in [5], by analogy, we the ratio for incoherent radar suppression coefficient

$$k_{r\ inc} = Pdn_{in}/Ps_{in} = 2M\tau_i \Delta f_{rcv\ inc}(M)/q_{lim\ inc}(M), \tag{7}$$

where $\Delta f_{rcv\ inc}(M)$ is incoherent radar pass band.

The linear receiving path has a frequency response that coincides with the spectrum of a single impulse.

Therefore, in the first approximation, it can be assumed that the bandwidth $\Delta f_{rcv\ inc}(M)$ can be found as:

$$\Delta f_{rcv\ inc}(M) = 1/\tau_i. \tag{8}$$

From (7) and (8) it follows that:

$$k_{r\ inc} = 2M/(\alpha_d(M)\ q_{lim\ inc}(M)). \tag{9}$$

In order to find $k_{r\ inc}$, it is important to substitute the value of $q_{lim}(M)$ in (9), finding it using the detection curves from Fig. 3 fin [5], as well as the value of $\alpha_d(M)$ finding it using the graphs in Fig. 4.

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Коэффициент подавления как обобщенный энергетический критерий подавления некогерентных радиолокационных систем

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Ключевые слова и фразы: импульс; коэффициент подавления; мощность; помеха; радиолокационная система; сигнал.

Аннотация. В данной работе рассматривается понятие коэффициента подавления и его дальнейшее использование в качестве обобщенного энергетического критерия, способного оценивать качество маскирующего сигнала по подавлению радиолокационных систем различного назначения. Особое внимание уделено методике определения коэффициента подавления радиолокационных систем с последетекторным накоплением в условиях действия помех. В работе приведены выражения, требующиеся для его расчета.

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Complex Quality Indicators and Ranking in Uncertainty Conditions

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Key words and phrases: quality of service; Schwartz Sequential dropping; Schulze method; ranking; stochastic dominance.

Abstract. The paper aims to develop methods of ranking complex quality indicators. The research aims to analyze the applicability of the synthesis of classical qualimetric approaches with stochastic domination methods and objects ranking methods. The result of the research is the author's way of solving the tasks of this type.

The problem of object ranking is quite a part of practical activity. If it is necessary to compare objects by one parameter, this task is trivial in most cases. However, if it is necessary to compare objects by several quality indexes, there is no single universal solution. It is impossible to reduce multidimensionality to one-dimensionality without loss of information. Simultaneously, there are private solutions to this problem in the qualimetry: the convolution of unique quality indexes into a complex with their subsequent ranking or comparison with standards.

In most cases, these problems are solved through convolution with weighted averages by Kolmogorov [1] or fuzzy logic [2; 3]. Previously, a possible solution to this problem was suggested based on the method of stochastic domination in case of nonlinear convolution of indices with the use of robust design elements for normalization of scales and the division of quality indices into dominant and compensating ones [4; 5]. The purpose of this article is to develop further the method of stochastic domination for nonlinear functions of the convolution of a sophisticated quality index using developing the method of objects ranking in conditions of uncertainty.

It is necessary to solve the optimization problem of finding such a relationship between the objects R to select k objects from the set of N, including the calculation of voting results:

$$\sum_i w_i d(R_i, R)^p \to \min,$$

where w_i is weight for R_i; d is function of the distance between individual opinions and the selected solution. In this case, such methods can be used to find the Kemeny–Young median (Kemeny–Young method, the Borda method, the pair evaluation method (Tideman method), etc.

Of all possible methods, the Schwartz Sequential dropping (Schulze method) is of the most significant practical interest, which differs from the Kemeni–Yang method, adopted in the domestic qualimetry, by a lower algorithmic complexity, and also meets the Nicolaus Tideman independence of clones criterion.

The heuristics of the Schulze method is as follows: let $d[V, W]$ be the number of votes of the candidates who prefer candidate V to candidate W. Then the sequence of candidates $C(1), \ldots, C(n)$ with properties will be named by strength p in the column from candidate X to candidate Y:

1) $C(1) = X$ & $C(n) = Y$;
2) $\forall\, i = 1, \ldots, (n-1)$: $d[C(i), C(i+1)] > \mathrm{d}[C(i+1), C(i)]$;
3) $\forall\, i = 1, \ldots, (n-1)$: $d[C(i), C(i+1)] \geq p$.

Let $p[A, B]$ be the strength of the most righteous path from candidate A to candidate B, i.e., the maximum of all possible p calculated by the above method. In case there is no path from candidate A to candidate B, $p[A, B] = 0$.

Candidate D is better than candidate E if and only if $p[D, E] > p[E, D]$. Candidate D is a possible winner over any candidate E then and only when $p[D, E] \geq p[E, D]$. It follows that if $p[X, Y] > p[Y, X]$ and $p[Y, Z] > p[Z, Y]$, then $p[X, Z] > p[Z, X]$ [6].

In practice, it is more convenient to perform calculations in specialized software packages, such as in GNU R, using the relations package [7].

The algorithm of ranking K objects can be described in the following way.

1. Robust transformation of initial quality indexes for each of the k objects [4] (solution of this problem in R language is available at https://github.com/Tushavin/RobustQ).

This transformation is based on the fact that with the removal of one of the possible axes of a single quality index from the reference to the worst, this change is not equally perceived by the consumer at different points of the scale, in this case, it is appropriate to use the function of Taguchi quality loss:

$$L = kE(Y - T)^2,$$

where L is a quality loss function; k is a quality loss factor; E is the expected value; T is the target value of Y [8]. Thus, the quality loss function looks symmetrical to the target value of the parabola. It is impossible to exceed the target (“ideal”) boundary based on the majority of single indicators of quality of services. For example, it is impossible to get an average rating of users more than 5, if a five-point scale is used, or to exceed the system availability more than 100 %. Then, by directing the scales in one direction (more – better), an inverted semi-parabola can be used as a function of quality loss, taking the value of 1 in the best point on the scale and 0 in the minimum allowed value. To find a parabola symmetric to the axis, passing through the best value, we solve the corresponding system of equations on three points [4].

2. Selection of dominating and compensating quality indicators and determination of convolution function. The dominant indicators, in this case, are understood as the main characteristics of the process, and compensating indicators – such indicators, zero evaluation of any of which does not entail a zero evaluation of the complex quality indicator, with zero or low evaluation of such an indicator can be compensated by other estimates [5]. To calculate a complex quality indicator Q, the following formulas can be used:

$$Q_d = \prod_{j=1}^{n} \left[X^{(j)}\right]^{\alpha_j},$$

$$Q_k = \sum_{i=1}^{m} \beta_i X^{(i)},$$

$$Q = \sqrt{Q_k Q_d},$$

where Q_d is the dominant quality index; Q_k is a compensating quality index; α and β are weighting factors [1].

3. Determining verbal preferences of the decision-maker in each of the groups of indicators. Limitations are presented as inequalities, and they are used to limit the generation of randomized weighting coefficients.

4. Generation of two arrays with dimension n of each randomized weights based on given preferences. When generating the values based on Dirichlet distribution with a reflection of points relative to the intersecting planes formed by inequalities is used [5].

5. For each element of the array of random weighs, we rank the values based on calculated complex quality parameters and build a matrix of *M* binary relations between objects of dimension $k \times k$. In other words, if the object is $I \geq J$, then $M_{ij} = 1$, otherwise 0. As a result, we get a set of n matrices *M*.

6. We use the relation_choice function and find the best variant (*s*), remove this element from the matrix, and repeat the procedure or rank the elements using the algorithm described above. To find the most reliable path, we can use the variant of Floyd-Warshall Algorithm to find the shortest distances between all the vertices of the weighted-oriented graph. For this purpose, it is necessary to find the matrix of $L = \sum_n M$. Then L_{ij} will be equal to the number of cases when I appear to be preferable to object *J*.

It should be noted that, firstly, the methodology described above is most applicable in cases where it is necessary to rank objects based on data from accounting systems. Secondly, the functionality of the relations package is not exhausted by this function and allows us to solve other tasks related to the relations of objects.

The use of such methods as elements of robust design, the division of indicators into dominant and compensating, stochastic domination, and ranking by the Schulze method is new. It allows the decision-maker to be more objective, reliable, and complete information than in traditional approaches. The results of this work can be useful for researchers dealing with the problems associated with business processes improvement, and have a practical focus.

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Комплексные показатели качества и ранжирование в условиях неопределенности

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Ключевые слова и фразы: качество обслуживания; метод Шварца; метод Шульце; ранжирование; стохастическое доминирование.

Аннотация. Целью данной работы является разработка методики ранжирования комплексных показателей качества. Задачей исследования является анализ применимости синтеза классических квалиметрических подходов с методами стохастического доминирования и ранжирования объектов. Результатом исследования является авторский способ решения задач такого типа.

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Methodology of Assessing and Forecasting the Development of the Investment and Construction Sector

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Key words and phrases: investment and construction sector; forecasting; development; control.

Abstract. Topical issues of development of the investment and construction sector (**ICS**) are considered. The purpose of the study is to develop a methodology for assessing and predicting the ICS development. In accordance with the purpose of the study, the following problems were identified: to formulate the stages of assessing the ICS development; to determine the stages of forecasting the ICS development; to reveal the process of applying the proposed technique. The research hypothesis is based on the assumption that the assessment and forecasting of the ICS development can be carried out on the basis of the results obtained using phase analysis. In the research, the following methods were used: an abstraction method, classification method, comparison method, analysis method, synthesis method. As a result of the study, the main provisions of the methodology for assessing and predicting the ICS development were presented.

The relevance of the development of a methodology for assessing and forecasting the development of the investment and construction complex (**ICS**) [1] is determined by the fact that its application allows to ensure the availability of information that can be used to manage the ICS development. The mentioned methodology is based on identifying the stages of the ICS life cycle [4], as well as on identifying positive changes in its functioning. Assessment of the ICS development is carried out through the implementation of the stages that are presented in Fig. 1.

At the first stage, the dynamics of the stages of the ICS life cycle is analyzed. The next step is to determine the frequency of manifestation of the ICS life cycle stages within each territory. The corresponding data are recorded in the table for the ICS of a particular territory (Table 1), in which f_1, …, f_5 are the frequencies of manifestation of the stages of the ICS life cycle.

Then, the ICS development of each territory is assessed, taking into account the stages of its life cycle, as a result of which the value of the LD_1 (level of development) indicator is determined according to formula (1):

$$LD_1 = \sum_{i=1}^{5} f_i a_i , \qquad (1)$$

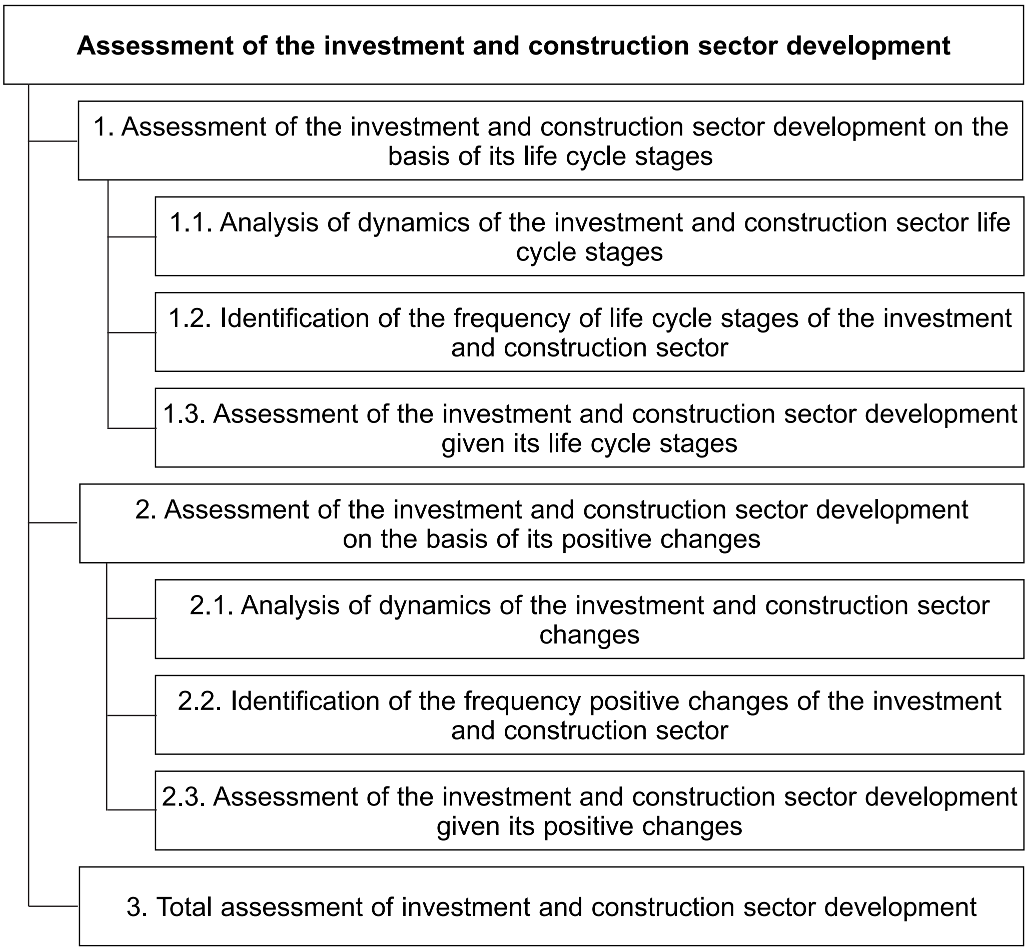

Fig. 1. Stages of assessing the development of the investment and construction sector

Table 1. The frequency of manifestation of the life cycle stages of the investment and construction sector

Stage No	Stage name	Stage frequency
1	Beginning	f_1
2	Growth	f_2
3	Prosperity	f_3
4	Slowdown	f_4
5	Decline	f_5

where LD_1 is level of development based on the ICS life cycle stages (in points); i is the number of the stage in the ICS life cycle (takes values from 1 to 5, since five stages are taken into account, 1 corresponds to Beginning, 2 – to Growth, 3 – to Prosperity, 4 – to Slowdown, 5 – to Decline); f_i is the frequency of the i-th stage of the ICS life cycle manifestation; a_i is the number of points corresponding to a single manifestation of the i-th stage of the ICS life cycle (beginning – 1 point, growth – 2 points, prosperity – 3 points, slowdown – 0 points, decline – 0 points).

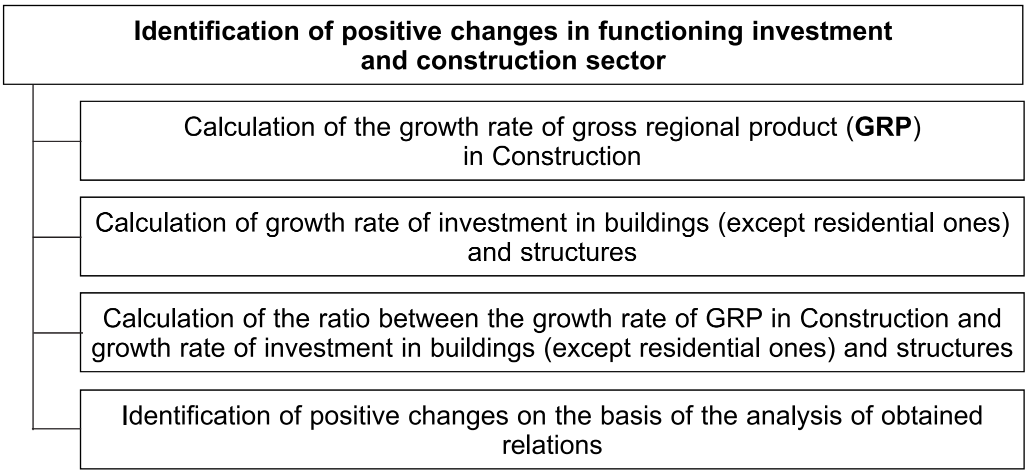

Fig. 2. Steps to identify positive changes in functioning investment and construction sector

Table 2. The frequency of manifestation of positive changes in the functioning of the investment and construction sector

Change No	Type of change	Frequency of manifestation of changes
1	Quantitative	c_1
2	Qualitative	c_2
3	Qualitative and quantitative (simultaneously)	c_3

At the next stage, the ICS development is assessed based on the identification of positive quantitative, positive qualitative changes in its activities. In order to identify the above positive changes and analyze their dynamics, it is proposed to use the ratio of the rate of growth of results to the rate of growth of resources [3; 5]. The stages of identifying positive changes in the ICS functioning are presented in Fig. 2.

After analyzing the dynamics of positive changes, it is necessary to determine the frequency of their manifestation within each territory. The corresponding data are filled in the table on the ICS of a particular territory (Table 2), in which c_1, c_2, c_3 are the frequency of manifestation of positive changes.

Further, the ICS development of each territory is assessed taking into account the frequency of manifestation of positive changes, as a result of which the value of the indicator LD_2 (level of development) is determined by formula (2):

$$LD_2 = \sum_{i=1}^{3} c_i a_i, \qquad (2)$$

where LD_2 is level of development based on positive changes in the ICS functioning of the (in points); i is positive change type number (1 corresponds to positive quantitative changes, 2 – to positive qualitative changes, 3 – to positive quantitative and positive qualitative changes occurring simultaneously); c_i is frequency of manifestation of the i-th type of positive changes; a_i is the number of points corresponding to a single manifestation of the i-th type of positive changes (quantitative – 1 point, qualitative – 2 points, qualitative and quantitative

Table 3. General assessment of the development of the investment and construction sector

Territory of the investment and construction sector	Number of points	Place in the ranking
Territory ranking first	LD_{max}	1
…	…	…
Territory ranking last	LD_{min}	*u*

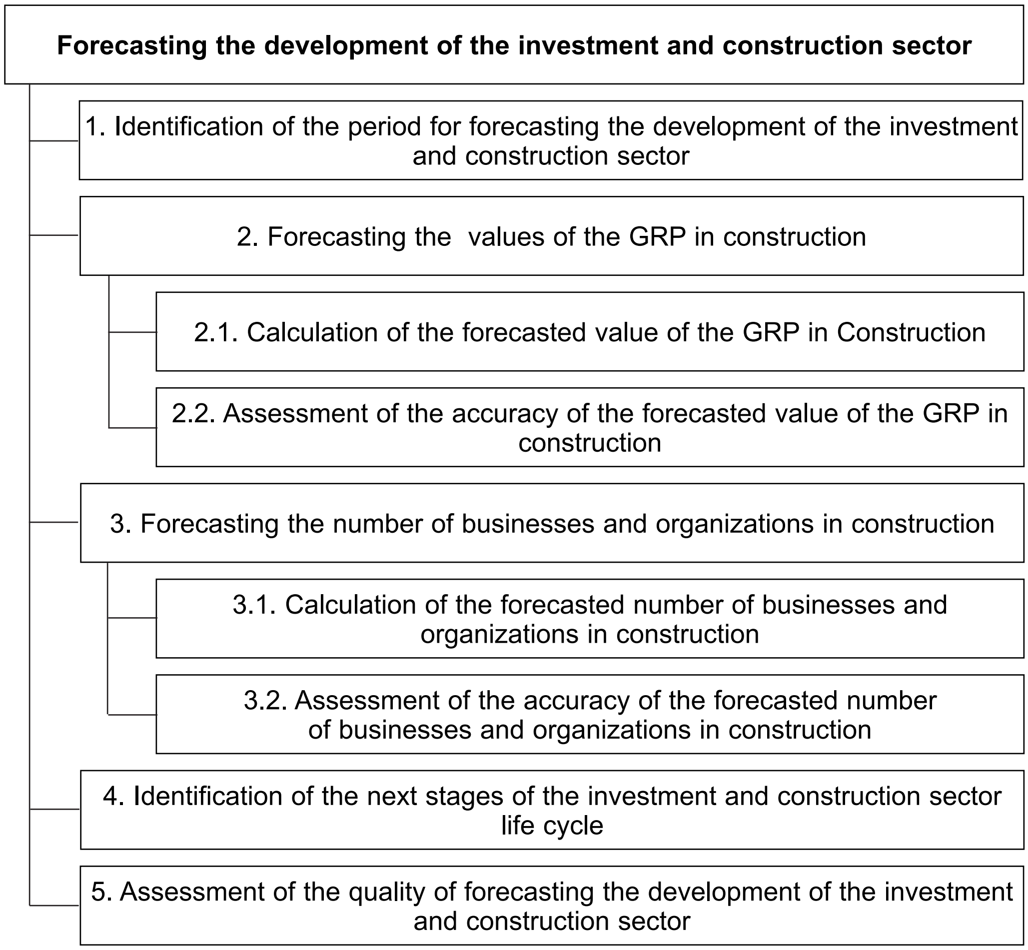

Fig. 3. Forecasting the development stages of the investment and construction sector

(simultaneously) – 3 points).

Finally, at the final stage, a general assessment of the development of the ICS is carried out, as a result of which the value of the *LD* (level of development) indicator is determined according to formula:

$$LD = LD_1 + LD_2, \tag{3}$$

where *LD* is the general level of the ICS development (in points); LD_1 is the level of development based on the stages of the ICS life cycle (in points); LD_2 is level of development based on positive changes in the ICS functioning (in points).

In addition, at this stage, in the case of researching the ICS development within several territories, a ranking can be drawn up, taking into account the results of the general assessment of the ICS development. As a result, a table is formed (Table 3), in which LD_{max} is the maximum value of the general level of development of the ICS (in points), LD_{min} is the minimum value of the general level of the ICS development (in points), u is the last place in the ranking.

To forecast the ICS development, it is necessary to select a period within which the subsequent stages of its life cycle will be considered (Fig. 3).

Then the forecasted value of the gross regional product (**GRP**) is calculated for Construction industry. It is proposed to evaluate the prediction accuracy of the values of the mentioned indicator by calculating the average absolute error in percent [2, p. 66], MAPE (mean absolute percentage error), the value of which can be determined by formula (4):

$$MAPE = \frac{1}{T}\sum_{t=N+1}^{N+T}\left|\frac{y_t - \hat{y}_t}{y_t}\right| \cdot 100\,\%, \tag{4}$$

where y_t is actual values of the time series; $\hat{y}_t$ is forecasted values of the time series; t is time; N is duration of the pre-forecast period; T is duration of the forecast period.

Further, the forecasted number of businesses and organizations in construction is determined, and the forecasting accuracy of the values of the mentioned indicator is also estimated (formula (4)). Subsequent stages of the ICS life cycle are determined on the basis of the forecasted values of indicators that were considered at the previous stages, taking into account the characteristics of these stages [4].

At the final stage, it is necessary to assess the quality of forecasting [6, p. 179] the ICS development by calculating the FQ (forecast quality) coefficient by formula (5):

$$FQ = \frac{a}{a+d}, \tag{5}$$

where a is the number of forecasts that match actual data; d is the number of forecasts that do not match actual data.

Thus, a methodology for assessing and forecasting the ICS development was developed. The basic provisions that reveal the process of its application are presented. The considered method can be used to carry out a comparative analysis of the ICS development within different territories, as well as to forecast the ICS development.

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Методика оценки и прогнозирования развития инвестиционно-строительного комплекса

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Ключевые слова и фразы: инвестиционно-строительный комплекс; прогнозирование; развитие; управление.

Аннотация. Рассматриваются актуальные вопросы развития инвестиционно-строительного комплекса (**ИСК**). Цель исследования заключается в разработке методики оценки и прогнозирования развития ИСК. В соответствии с целью исследования были определены следующие задачи: сформулировать этапы оценки развития ИСК; определить этапы прогнозирования развития ИСК; раскрыть процесс применения предлагаемой методики. Гипотеза исследования заключается в предположении о том, что оценка и прогнозирование развития ИСК могут проводиться на основе результатов, полученных с помощью фазового анализа. В процессе исследования были использованы следующие методы: метод абстрагирования, метод классификации, метод сравнения, метод анализа, метод синтеза. В результате исследования были представлены основные положения методики оценки и прогнозирования развития ИСК.

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Formation of Small Business

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Key words and phrases: small business; economic growth; acceleration of scientific and technological progress; creation of additional jobs; social and economic problems.

Abstract. Methods of economic analysis and industry analogies were used to study the impact of small business on the country's economy. The study showed that the development of small business has acquired some modern features, has an impact on economic growth, the acceleration of scientific-technical progress, on saturation of market with goods and services of required quality, the creation of additional jobs. Progress in small business solves many social and economic problems.

If we look at the experience of developed countries, small business plays a very significant role in the economy, its development affects economic growth, the acceleration of scientific and technological progress, the saturation of the market with goods and services of the necessary quality, the creation of additional jobs, all this solves many social and economic problems.

In Russia, the potential of small businesses remains unrealized to the end. There are serious economic and administrative barriers to new enterprises entering the market and developing their activities. An increasing number of small businesses are forced to "go into the shadows" due to imperfect Russian legislation. Therefore, for the development of our country, it is necessary to promote small business, so that the economic and social development of society occurs faster.

The small business sector is able to quickly develop new market sectors and types of products, and also contributes to bringing goods and services closer to the consumer. This type of business is easier to adapt to new markets and is able to develop quickly in those industries that do not attract large enterprises [6].

However, one of the most acute and important problems that small businesses face is the problem of finding and obtaining financial resources that are necessary for starting and developing this type of business. Therefore, the state is particularly important for the development of the small business sector, which can provide financial and other types of support [5].

World practice shows that even in countries with developed market economies, small business has a significant impact on the development of the national economy, solving social problems, and increasing the number of employed workers. In some countries, small businesses play a leading role in the number of products produced and sold, as well as in the number of employees.

The role of small business in the modern world is growing. The experience of developed countries shows that if previously small businesses were opened mostly because people wanted to start their own business, now the situation is different. In the modern world, the creation of small enterprises can also be initiated by large companies that assign small ones to conduct certain types of production, sell their products, and supply them with raw materials.

In the current market conditions, small business in Russia is one of the most promising forms of management. However, in our country, the share of small businesses does not occupy the same place as it does in more economically developed countries, where the share of such enterprises is more than 80 % of the total number of enterprises, this sector of the economy employs two-thirds of workers and produces more than half of GRP. In this regard, Russia is significantly behind in these indicators [3].

Small business has a huge impact in creating jobs for the population, that is, it reduces the unemployment rate, and it can also provide jobs to socially unstable segments of the population – young people, immigrants, and the disabled. And because of the small number of employees in a small enterprise, a close, trusting relationship is formed between them and this has a positive effect on the emotional state of the employee, gives him motivation to work, thereby increasing the productivity of the enterprise [1].

Small business also plays a role in social life:

– it helps to better meet the needs of citizens in products and services;
– improves the quality of services;
– participates in the formation of the middle class;
– creates people's satisfaction that they can express their creativity through their work;
– forms a large class of small owners.

In addition to the social significance of small business, there are other types of formation of positive processes in the economy and politics:

– increasing political weight in the international arena;
– filling the market with new products and services;
– promoting growth of healthy competition;
– implementing technical and technological innovations;
– promoting the activities of large enterprises;
– providing tax revenues to the budget.

From all this, we can conclude that small business is an integral part of the market economy and that its role in modern life is steadily growing [2].

All these characteristics of small business stimulate the development of the national economy and therefore the state simply needs to support it [7].

Small business in Russia cannot be formed and strengthened without full state support. As a rule, any problem related to small businesses needs government support. But the weakness, uncertainty, and timidity of such support (especially if we keep in mind not declarations, but real cases) is one of the most important factors that do not allow small businesses in Russia to find solid ground under their feet and thus create an important support for the country's exit from the protracted economic crisis. Therefore, today small business is declining, of 10.04.2018 there were about 264593 small business entities, but in 2019 this figure was already 248085 entities, and in 2020 on 10.04 there are already 222144 entities. Based on these indicators taken from the unified register of small and medium-sized businesses, it can be concluded that the state of small business in Russia has significantly deteriorated over the past few years and that the state simply needs to do everything possible to establish conditions for the development of small businesses and achieve an increase in the indicators of small businesses [8].

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Особенности формирования малого бизнеса

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Ключевые слова и фразы: малое предпринимательство; создание дополнительных рабочих мест; социальные и экономические проблемы; ускорение научно-технического прогресса; экономический рост.

Аннотация. С целью изучения влияния малого предпринимательства на экономику страны были использованы методы экономического анализа и отраслевых аналогий. Проведенное исследование показало, что развитие малого бизнеса приобретает некоторые современные особенности, оказывает влияние на экономический рост, на ускорение научно-технического прогресса, на насыщение рынка товарами и услугами необходимого качества, на создание дополнительных рабочих мест. Прогресс в области малого предпринимательства решает многие социальные и экономические проблемы.

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