

Development of strategic management tools for heat supply enterprises in the Donetsk region

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Abstract

Raising the effectiveness of strategic management in conditions of high complexity and dynamic change of modern management systems requires the development of an appropriate mathematical toolkit. The task of raising effectiveness of strategic management is especially topical for heat supply enterprises of the Donetsk region, where operations have been complicated by a number of general system problems, and by the presence of substantial external challenges. At the same time, the question of using mathematical apparatus to raise the effectiveness of strategic management of enterprises in the sphere of residential-communal services appears not to have been widely studied. In this regard, the objective of this study is raising the effectiveness of strategic management of heat supply enterprises of the Donetsk region by developing a respective toolkit of mathematical modeling. To achieve the goal we have set, in this work we carried out an analysis of the viability of the system using the methodology proposed by S. Beer; we made an analysis of the elements of the market of heat supply, and also developed system dynamic models based on the approach of J.W. Forrester.

As a result of our research, we discovered the basic problems influencing the viability of the system at the strategic level. It was established that the problems revealed are the consequence of the imperfections of the methodological base, including absence of timely information on the dynamics of the external environment, forecasting of the key parameters, a toolkit for making decisions, etc. For the purpose of finding a toolkit to improve the methodological base, we performed an analysis and forecast of the heat supply market in the Donetsk region as part of the external environment which exerts a very significant influence on the activity of the heat supply enterprises of the Donetsk region.

In the course of this market analysis, we established that the offer of heat supply services is not constant and depends on the tariff setting costs. Due to this, we proposed an approach to forecasting tariff setting costs based on the methodology of A.G. Ivakhnenko but distinguished from that by the

presence of a training sample and two test samples. In addition, in the course of analyzing the market we discovered new forms of demand for heat supply services – lost demand and unpaid demand. On the basis of the dependencies established, we built a model for forecasting the behavior of consumers of a heat supply company oriented to the level of marketing. With the help of this model, by means of supplements to it and modifications, we built a complex model of strategic management of heat supply enterprises of the Donetsk region allowing us to analyze the effectiveness of using one or another lever of strategic management on the basis of scenario analysis.

Key words: strategic management; system dynamic modeling; sustainability; tariff setting costs; heat supply enterprise.

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Introduction

The complexity of contemporary economic systems resulting from the high agility of the processes occurring in them, by the presence of external challenges, by the large quantity and non-linearity of links of elements in such systems, leads to reduced effectiveness of traditional methods of management and makes it very topical to use a complex approach based on the toolkit of mathematical modeling.

The desirability of raising the effectiveness of strategic management by developing a complex toolkit acquires special relevance for heat supply enterprises of the Donetsk region, due to several factors: the primary importance of heat supply services to protect the lives of the population and ensure the functioning of the region's companies, as well as the scale of the regional market of residential communal services (including heat supply services). Thus, the residential communal entities of the region cover the needs of around 2.5 million people, as well as more than 180 major enterprises. More than 8% of the working population is engaged in this sphere.

Furthermore, the problems with which heat supply enterprises of the Donetsk region

encounter bear a deep and general systemic character. These include a high degree of deterioration of the basic assets, insufficient volumes of financing, low solvency of the consumers, large amounts of receivables, etc.

Solutions to the enumerated problems require high effectiveness of strategic management, which is difficult to achieve when the respective toolkit is missing.

A whole series of both foreign and domestic works has been devoted to the issues of finding more effective approaches to management (including strategic management) of heat supply enterprises, among them by E.Yu. Adzhagulov [1], D.L. Bakieva [2], E.V. Balandina [3], E.E. Vorobieva [4], A.V. Darbasov [5], T.A. Makarenya [6]. Such scholars as A.V. Allakhverdyan [7], L.N. Brazhnikova [8, 9], S.G. Kulikov [10], R.N. Lepa [11], Ya.A. Lyashok [12], E.A. Perkova [13], V.P. Poluyanov [14], and I.A. Yurchenko [15] are among those who have dedicated their works to the specifics of heat supply companies of the Donetsk region.

At the same time, despite the attention researchers have given to questions of the effectiveness of management of companies in the residential communal sphere the problem

of developing an effective toolkit of strategic management of heat supply enterprises remains unresolved. Thus, works devoted to application of the apparatus of economic-mathematical modeling and modern tools for raising effectiveness of strategic management in the sphere of residential communal services have focused on solving the problems at the regional and municipal levels. Meanwhile, the questions of developing a toolkit for mathematical modeling to raise the effectiveness of strategic decisions at the level of management of individual heat supply enterprises remain among the least developed, all of which predetermine the timeliness of the line of research we have chosen.

In connection with the foregoing, the objective of this research is to raise the effectiveness of strategic management of heat supply enterprises of the Donetsk region by developing a respective toolkit of mathematical modeling.

In accordance with the goal of the research, we formulated a methodological base which is comprised of the works of a number of authors devoted to the questions of raising effectiveness of management of business systems by using mathematical apparatus [16–27].

1. Analysis of the viability of a heat supply enterprise of the Donetsk region

Raising the effectiveness of strategic management of a heat supply enterprise of the Donetsk region requires that we carry out a retrospective analysis of the functioning of the system, as well as that we reveal and systematize the basic problems of enterprises in the given sphere.

For this, in the framework of a heat supply system, we can distinguish six subsystems relating to various levels of management - strategic, tactical and operative. In particular, at the strategic level we find the subsystem for decision making and the subsystem providing information. At the tactical level, we find the subsystem for distribution of resources in short supply, the subsystem

of internal audit and the subsystem for resolving current problems. At the operative level, there is the “operational element” subsystem.

Let us examine the characteristics of the enumerated subsystems and the causes of problems arising inherent in the current state of the heat supply system.

The subsystem for decision making is characterized by the fact that the basic functions of decision making relating to the entire heat supply system are accorded to the bodies of departmental control. The reasons why problems arise are the economic and social groundlessness of the tariffs, as well as the imperfections of the methodological base which enables one to react to deviations which arise.

The subsystem of information management is supposed to send to the decision-making subsystem information on the state of the external world and basic trends of its change, as well as information about the necessary action in response to these changes. At the same time, the de facto fulfillment by the information management subsystem of its functions is limited exclusively to stating the actual values over the preceding periods. The sources of the problems – the lack of up-to-date information about the functioning of the real sector of the economy, significant time lags, and also the lack of formalization of threshold values of deviations below which it is necessary to take control.

The function of the subsystem for distributing resources in short supply in the system of heat supply is carried out by various institutions: distribution of subsidies is provided from local budgets, other subsidies come from the budget of the republic, investments from all subjects of the market. Moreover, the distribution of investment flows at the micro level is performed by the operational elements independently. The sources of the problems – ineffectiveness of the distribution of resources in short supply, and also growth of expenses for the bureaucratization of processes of issu-

ing subsidies, financing and regulating the system.

To provide for the functions of internal audit, there are specialized commercial organizations whose services are paid by the enterprise. However, the selection of these organizations is done, as a rule, by local self-government authorities. The causes of the problems existing in this area arise beyond the boundaries of the given research.

The subsystem for resolving current problems is represented by laws and sublegal documents regulating the activity of enterprises from the sectoral ministry and local authorities of self-administration. Here among the sources of the problems we can mention the legally nonregulated nature of the monopoly status of the enterprises, the forms and methods of republic tariff policy, as well as the forms and methods for recovering accounts receivable.

Finally, the “operative element” subsystem is represented in the form of enterprises of various kinds of ownership and functional affiliation. Here the causes of the problems which arise are the deteriorated state of the basic assets, the use of outdated technologies, high expenses and low efficiency, an ineffective innovation and investment policy, the unsatisfactory financial condition of the enterprise, an ineffective policy on price formation, an ineffective system of managing expenses, an imperfect system of managing the receivables and credit policy, the low quality of services provided, and low attractiveness for investment.

Due to the specific external conditions of the functioning of heat supply enterprises of the Donetsk region (as with many other systems in depressed territories) one of the most important tasks of their operations is to achieve a system of viability, which is taken to mean “the ability of the system to independently support its autonomous existence for as long as possible” [16]. This characteristic of the system has been given the name “viability” and was described in the works of S. Beer [16], as well

as by a broad circle of scholars in the context of systemic and cyber approaches.

In connection with the foregoing, it is interesting to analyze the problems of the functioning of heat supply enterprises of the Donetsk region at various levels of a viable system. The basic problems of strategic management of a viable system of heat supply are related to shortcomings of the subsystems of information management and management decision making.

These problems are the consequence of shortcomings of the methodological base, including lack of up-to-date information about the dynamics of the external environment, an ineffective approach to forecasting key parameters, as well as lack of a toolkit to support the adoption of strategic decisions.

Due to the fact that one of the key problems of managing heat supply enterprises of the Donetsk region is lack of up-to-date information on the dynamics of the external environment, and also proceeding from the goals of raising the effectiveness of strategic management of heat supply enterprises of the Donetsk region, it is worthwhile to do an analysis of and forecast of the external environment. Moreover, in the context of a cyber approach it is customary to separate out the parts of the external environment which exert the most significant impact on the subject of the research (external supplement [16]). For the enterprises we analyzed, the market of heat supply in the Donetsk region can be seen as the external supplement.

2. Analysis of the market elements of heat supply: demand, supply, price level, market conditions

We take the heat supply market to mean the exchanges which develop between its participants based on the sale-purchase of specific benefits (hot water supply and provision of heating) which can be measured quantita-

tively and described in the form of characteristic behavior of market participants.

Analysis of the specialized literature made it possible to reveal the basic common elements of the market for residential communal services. They comprise: offer of services by the residential-communal companies, demand for residential-communal services, tariffs for residential-communal services and the market conditions.

Given the limitation and complexity of influence on the market conditions, what is of practical interest for the purposes of management is to review the categories of demand and supply on the market of residential-communal services, as well as the processes of price formation.

Development of the model basis for evaluating the behavior of producers of heat supply services (i.e. evaluation of the offer) has been described in the work [28]. In particular, it was established that offer by heat supply enterprises in the Donetsk region is not a fixed amount, i.e., it changes under the influence of several factors. At the same time it was shown that the use of price (tariffs) as the main factor of the offer with respect to heat supply services is wrong, insofar as the tariff is a conditional value. In this connection, we proposed to use as the basic factor tariff setting costs. The dependency shown raises the relevance of applying up-to-date methods of forecasting tariff setting expenses of heat supply enterprises of the Donetsk region. For determination of the character and closeness of the bond, we analyzed the existing methods of selecting parameters and established that their application is difficult under conditions of the economic shocks which the economy of the Donetsk region has been experiencing ever since 2014. In this respect, in [28] we see further development of the inductive method of organizing models of complex systems proposed by A.G. Ivakhnenko [18]. The approach to constructing a model for forecast-

ing expenses underlying the tariffs of heat supply enterprises is distinguished by the existence of training and two test samples, all of which allows us to analyze the suitability of the basic model under conditions of the economic shocks of 2014–2015, and also the suitability of the refined model for forecasting the following trend of the readings.

Analysis of the system of tariff formation and its interdependence with consumer behavior (demand) in heat supply enterprises of the Donetsk region allowed us to establish that low solvency of the population causes a high level of accounts receivable and serves as an impediment to establishment of economically justified tariffs. In this connection, in [29] a method is proposed for calculating the critical maximum tariffs for services of residential-communal service enterprises.

Study of the behavior of consumers (demand) is described in the works [30, 31], where it is proposed to examine lost demand, which is expressed as refusal to buy services of centralized heat supply and as unpaid demand, which takes the form of consumer debt (accounts receivable).

Revealing the factors influencing the dynamics of market elements of heat supply and behavior of its subjects lay at the basis of our building system dynamic modeling of strategic management.

3. Constructing system dynamic models of strategic management of a heat supply enterprise of the Donetsk region

An original toolkit for system dynamic modeling of strategic management of a heat supply enterprise consists of two basic models: an simulation model of forecasting the behavior of the enterprise's consumers [32] and a complex model of strategic management of a heat supply enterprise.

It should be noted that the simulation model of forecasting the behavior of a heat supply

enterprise's consumers is oriented at the level of marketing and therefore has a number of limitations and simplifications. The complex model of strategic management of a heat supply enterprise is based on a model of forecasting the behavior of consumers but is geared to the level of top leadership of the enterprise, and therefore presupposes a larger number of management levers, as well as a smaller number of limitations and simplifications.

3.1. The simulation model of forecasting the behavior of a heat supply enterprise's consumers

Changes in the behavior of consumers exert an influence on the financial results of the activities of heat supply enterprises. Moreover, it should be noted that rejection of the services of heat supply enterprises exerts an influence on the functioning of the enterprise both in the short term and as regards long term prospects.

Under conditions in which the heat supply enterprises of the Donetsk region operate, consumer arrears (accounts receivable) have a short term influence on the financial performance of the enterprise, and also have a persistent tendency to turn into hopeless, frozen assets for the long term, changing the nature of this influence from short term to long term. Thus, one may conclude that an increase in lost demand, as well as the growth in unpaid demand exert an influence both on short term and on long term financial results from operations in heat supply enterprise. It follows from this that research into the behavior of consumers has high theoretical and practical significance for developing a toolkit to raise the effectiveness of strategic management.

On the basis of the analysis carried out, the equation of dependency of indicators of the increased level of accounts receivable from the population on the correlation of the level of tariffs and the level of salaries can be presented in the following manner:

$$\Delta D_{z1} = a_{01} + a_{11} \frac{T_n^t}{M^t}, \quad (1)$$

where a_{01} , a_{11} – regression coefficients of the model;

T_n^t – the level of tariffs for the population of heat supply services on the heat supply market at moment in time t ;

M^t – the average level of salaries in the region at moment in time t .

At the same time, the interest of enterprises, unlike the population, is formed under the influence of two factors – the quality of the services offered and the system of material incentives. There is practically no system of material incentives in the heat supply market of the Donetsk region. Due to this, it is worthwhile reviewing the dependence of increased level of consumer arrears (accounts receivable) on the quality of services provided.

Tariffs exert an influence on the possibility and ability to pay for heat supply services. Thus, growth in accounts receivable of heat supply companies may be presented in the following way:

$$\Delta D_{zk} = a_{0k} + a_{1k} T_p^t + a_{2k} W^t, \quad (2)$$

where ΔD_{zk} – growth in the level of accounts receivable of the k category of consumers for the period $[t_0; t]$;

k – categories of consumers, $k \in [1; 4]$;

W^t – the quality of heat supply services at moment in time t ;

a_{0k} , a_{1k} , a_{2k} – regression coefficients of the model.

Lost demand is also an indicator which to a certain extent depends on the level of tariffs and quality of services. Quality of heat supply services is an aggregate indicator which is calculated from information about the quality of boilers, networks and communications, as well as the quality of the accompanying service.

Evaluation of the quality of the service for heat supply services is made using a calculation of an integral reading which changes within a given range [0; 10] and is calculated using the sum of partial coefficients determined by expert evaluations.

The model obtained for forecasting the behavior of consumers of a heat supply enterprise in its most simplified form can be presented in the form of a diagram of cause and effect links (Figure 1).

3.2. The complex model of strategic management of a heat supply enterprise

On the basis of our analysis of the model of forecasting the behavior of heat supply enter-

prise consumers, one can conclude that the problems of managing the behavior of the enterprise's consumers are in direct dependency relations with effectiveness of the policy of tariff formation, as well as policy in the sphere of quality of services provided.

At the same time, based on the orientation of the model towards the level of the marketing department, it presupposes the following assumptions and simplifications:

- ◆ a change in the level of tariffs, as well as in the level of quality over time, and not under the influence of management decisions;
- ◆ it does not presuppose analysis of the cost and effectiveness of such management decisions;

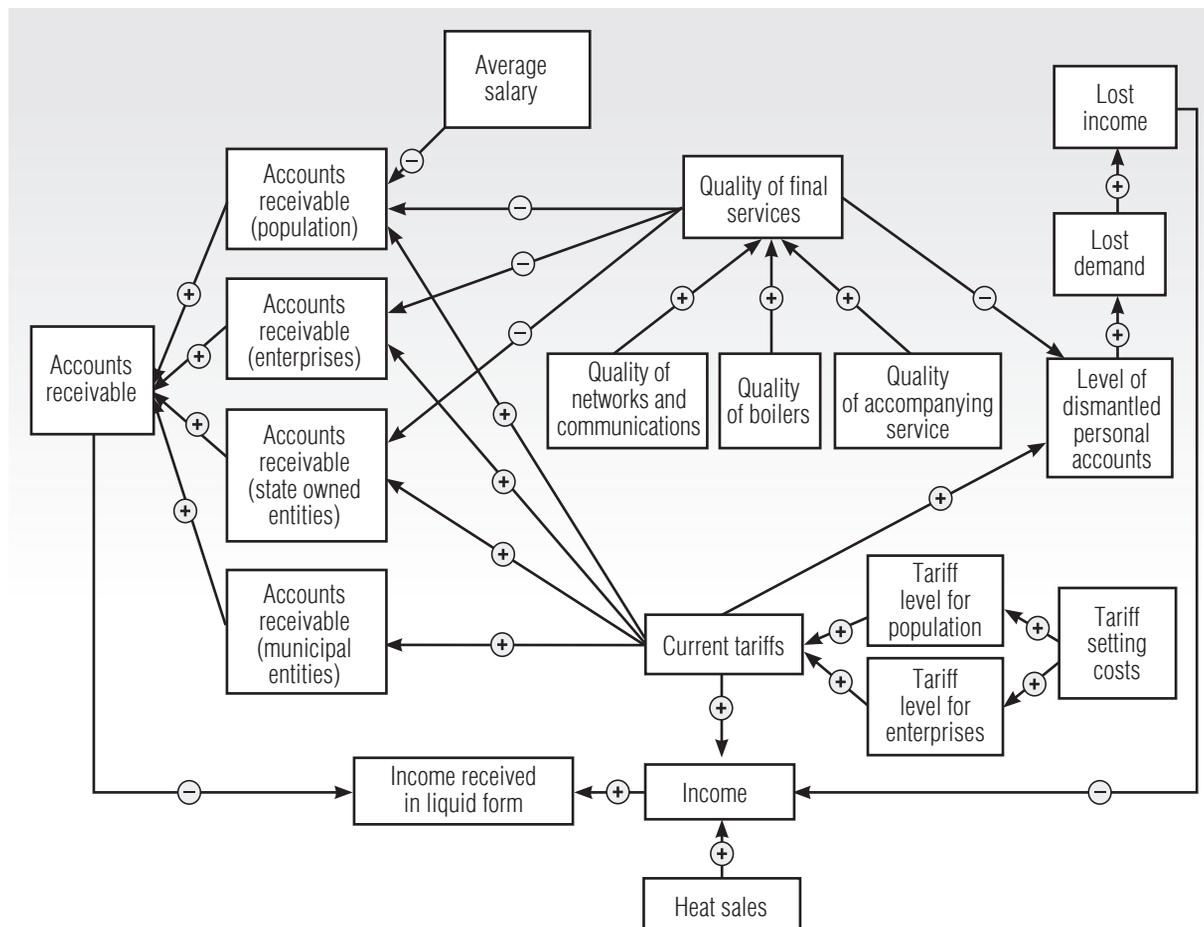


Fig. 1. Model of forecasting the behavior of heat supply enterprises' consumers in the form of causal links

- ◆ it does not consider the investment policy;
- ◆ the model does not allow us to trace the influence of the indicators being analyzed on the financial results of the enterprise's activities.

In this connection, and also to improve the methodology of managing a heat supply enterprise as a whole, it is interesting to see modification of the previously developed model of forecasting the behavior of the enterprise's consumers by changing it and supplementing it to reach a complex model of strategic management of a heat supply enterprise.

Based on the assumptions and simplifications described above, it is proposed to make the following changes in the complex model of strategic management:

- ◆ to establish the mutual dependency between the level of tariffs and the quality of services, as well as with the management decisions adopted;
- ◆ analysis of the elasticity of the level of quality and service in relation to the expenses needed to raise it;
- ◆ analysis of the effectiveness of management decisions and, in particular, decisions on the investment policy;
- ◆ inclusion in the model of the indicator of financial results from the enterprise's activities as a resulting element.

In this regard, in the complex model the quality of boilers, equipment, networks and communications depends on the total investments of the enterprise, with a delay in two periods (quarters), and the level of service depends on the total investments or the enterprise in the current period.

The effectiveness of the management decisions adopted is determined according to the formula:

$$E_m^t = \frac{R_m^t - R_0^t}{Z_m^t - Z_0^t}, \quad (3)$$

where E_m^t – the effectiveness of the m -th management decision at moment in time t ;

R_m^t – the financial result (profit/loss) at moment in time t under conditions of the implementation of the m -th management decision;

R_0^t – the financial result (profit/loss) at moment in time t under conditions of the implementation of the basic scenario (keeping the current dynamics of the indicators);

Z_m^t – total expenses of the heat supply enterprise at moment in time t under conditions of the implementation of the m -th management decision;

Z_0^t – total expenses of the heat supply enterprise at the moment in time t under conditions of implementation of the basic scenario (keeping the current dynamics of the indicators).

It should be mentioned that the calculation of the financial result at moment in time t presupposes inclusion of the accounts receivable. At the same time, the accounts receivable of heat supply enterprises of the Donetsk region have very low liquidity. Due to this, we introduced the term “absolutely liquid financial result,” meaning the financial result of a heat supply enterprise without considering accounts receivable. Thus, there is enhanced interest in the calculation of the indicator of effectiveness of management decisions expressed in the increment of absolutely liquid financial results:

$$EL_m^t = \frac{RL_m^t - RL_0^t}{Z_m^t - Z_0^t}, \quad (4)$$

where EL_m^t – the effectiveness of the m -th management decision expressed as the increase of absolutely liquid financial results at moment in time t (liquid effectiveness);

RL_m^t – absolutely liquid financial results (profit/loss) at moment in time t under conditions of the implementation of the m -th management decision;

RL_0^t – absolutely liquid financial results (profit/loss) at moment in time t under conditions of the implementation of the basic sce-

nario (maintaining the current dynamic of the indicators).

Thus, liquid effectiveness is the liquid effect correlated with costs for achieving it.

On the basis of the foregoing, and also on the basis of the previously described model of forecasting the behavior of consumers of a heat supply enterprise we developed a complex model of strategic management of a heat supply enterprise of the Donetsk region. The main elements and interconnections of the model in the form of a diagram of cause and effect are set out in *Figure 2*.

By share of dismantled personal accounts we mean the correlation of the number of dismantled personal accounts (i.e., by those who have rejected using the services of centralized heating) and the overall share of personal accounts served by the heat supply enterprise.

By element of the model of ‘aggregated quality’ we mean the indicator reflecting the overall level of quality of heat supply services, including the quality of the boilers and networks, as well as the quality of the accompanying service. The numerical values of the indicator are obtained by polling the users of the services.

The model we developed allows us to analyze the effectiveness of one or another lever for purposes of obtaining economic results expressed as the change of the financial result or of the absolutely liquid financial result of the activities of heat supply enterprises of the Donetsk region.

The following are used as management levers (managing the parameters) in the model:

- ◆ the level of tariffs for enterprises;
- ◆ the level of tariffs for the population;
- ◆ the volume of investments in modernization of the networks;
- ◆ the volume of investments in modernization of the boilers;
- ◆ the volume of investments in improving the service;

- ◆ the volume of other costs.

Thus, the model allows us to raise the effectiveness of the investment policy, the tariff policy and the policy in the sphere of managing costs.

The block of evaluation of the effectiveness incorporated in the model is intended for calculating the effectiveness of management decisions expressed as the incremental growth of both the financial result and the absolutely liquid financial result.

As a constant we used the discount rate and the volume of state investments. All other indicators of the model are calculated and obtained by applying a modification of the inductive method of self-organization of the models of complex systems, the method of lowest quadrates, spline-interpolation, etc.

3.3. Results of simulation modeling

On the basis of the complex model of strategic management of heat supply enterprises described above, using scenario analysis, we carried out a series of experiments allowing us to determine the most effective management levers. The results of the numerical experiments are shown in *Figure 3*.

For evaluation of the effectiveness of applying various management levers we carried out the following experiments:

Scenario 1: Increasing the level of tariffs for enterprises by 10%;

Scenario 2: Increasing the level of tariffs for the population by 10%;

Scenario 3: Increasing the volume of investments for modernization of the networks by 10%;

Scenario 4: Increasing the volume of investments for modernization of the boilers by 10%;

Scenario 5: Increasing the volume of investments for improving the service by 10%.

The results of the numerical experiments are

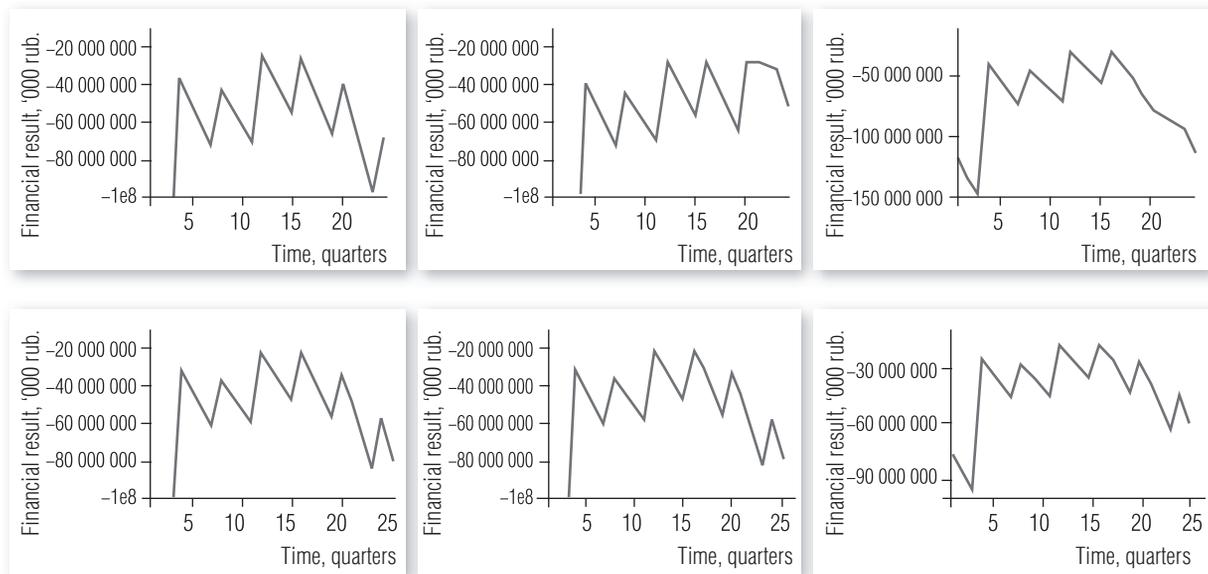


Fig. 3. The results of numerical experiments with the complex model of strategic management of heat supply enterprises using PowerSim software

compared with the forecast values of the operations of the system (Scenario 0).

Due to the fact that reducing other costs in the long-term perspective is a precondition for lowering the quality of services, the given management lever cannot be viewed as an effective instrument of strategic management.

The economic effect expressed in the change of financial result obtained taking into account implementation of various scenarios is shown in *Table 1*. We note that the first step of modeling corresponds to the first quarter. Insofar as the model reflects both retrospective data which cannot be changed by implementation of the scenarios (modeling steps 1–19) and the forecast values of indicators assuming the implementation of one of the scenarios (steps 20–30), the evaluation of the economic effect is seen as worthwhile beginning only from the 20-th period of modeling.

The graphic illustration of calculated values of the economic effect obtained expressed in the change of financial result following the implementation of the indicated scenarios is shown in *Figure 4*.

As we see in *Figure 4*, implementation of scenario 5 is the most justified, i.e., increasing the volume of investments in improving the service.

Conclusion

Thus, we propose an approach to increasing the effectiveness of strategic management of heat supply enterprises of the Donetsk region based on the development of a respective toolkit of mathematical modeling. Use of the proposed approach assumes step-by-step solution of a number of tasks, namely:

- ◆ analysis of the viability of the object of strategic management with a view to revealing the most significant problems which bear on the ability of the system independently to maintain its autonomous existence;
- ◆ analysis of the market elements as the most significant part of the external environment where the enterprise operates;
- ◆ development of approaches to raising the effectiveness of forecasting the behavior of subjects of the market as the methodological basis of the system of information management serving the strategic management of the enterprise;

Table 1.

Calculation of the economic effect expressed in change of the financial result obtained as a result of implementing the scenarios, ‘000 rub.

Step of modeling, quarter	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
20	15,022,278.2	-37,039,787.0	66,88,398.2	6,773,671.3	17,071,830.7
21	31,365,227.5	-24,636,261.0	6,992,516.1	7,121,654.8	17,390,125.1
22	49,158,587.6	-11,162,374.0	7,389,110.1	7,498,771.3	17,941,160.3
23	68,523,705.6	3,457,305.0	7,888,227.4	7,913,766.8	19,433,125.6
24	-30,659,758.0	-46,881,056.0	8,304,901.1	8,383,596.3	21,051,172.1
25	-14,493,133.0	-33,234,769.0	8,882,913.3	8,879,167.0	20,523,925.8
26	3,032,885.7	-18,447,471.0	9,323,873.7	9,432,300.9	21,828,511.6
27	22,052,699.9	-2,420,088.9	9,928,832.2	10,024,012.6	23,745,262.4
28	-40,777,450.0	-61,262,349.0	10,609,403.7	10,687,335.9	26,426,168.4
29	-22,017,860.0	-45,712,459.0	11,245,107.8	11,397,205.4	28,554,870.3
30	-1,696,379.3	-28,885,661.0	12,114,398.9	12,162,980.9	30,962,618.7

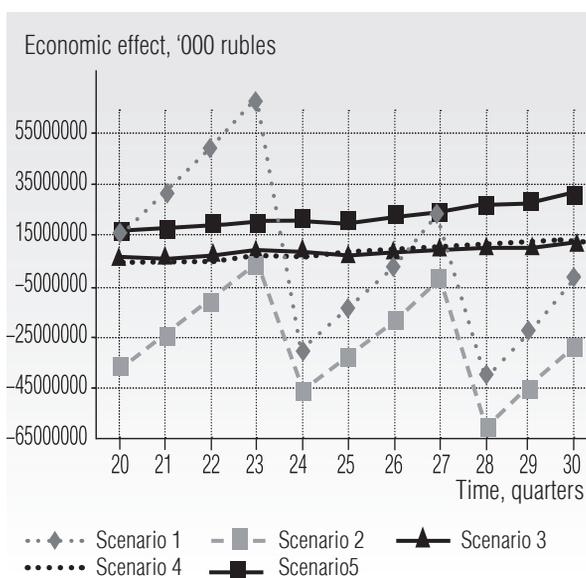


Fig. 4. The economic effect expressed in the change of financial result obtained as a result of implementing the scenarios of the complex model of strategic management of heat supply enterprises, ‘000 rubles

◆ building a model basis to support decision making, taking into account the main correlations we discovered and allowing us to perform a scenario analysis of the effectiveness of management levers;

◆ carrying out numerical experiments with the model, as a result of which we established that the most effective management lever is raising the volume of investments directed into improvements to the accompanying service. Use of the given lever allows us to receive an economic effect of 17,071,830.7 rubles in the first quarter. Moreover, we forecast a growth of the economic effect given systematic application of this management lever.

As regards the direction of further research, we can mention adaptation of the results obtained to a wide range of objects, as well as the programmatic realization of a system for supporting the decisions taken. ■

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