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CONTROL OF GAS DISTRIBUTION NETWORK RELIABILITY

Background. Despite the fact that technical state of gas distribution networks is on relatively high level, the problem of ensuring of their reliability and efficiency is one of the priority problems, becoming more and more urgent year after year, which is due to ongoing ageing of gas distribution networks and increase in accident rate. The possible way out is the reconstruction and technical extension of gas pipelines and gas distribution points.

Results and conclusions. The groups of reliability indicators of gas distribution network elements are described. The reliability criterion of a gas distribution network is proposed. The forecast of the number of emergency repair demands and emergency service operation is performed. The geoinformational system is used to control the reliability of the gas distribution network.

Keywords: reliability criterion of gas distribution networks, indicators of reliability, reliability management, geoinformational system (GIS).

Introduction

Gas supply, which is the set of processes of transportation, distribution and consumption of natural gas, forms the energy basis of economics. In the future, the importance of gas supply will increase, which is due to the increasing importance of the role of energy in industry development and intensification of gas supply interaction with social environment.

Despite the fact that technical state of gas distribution networks (GDN) is on relatively high level, the problem of ensuring of their reliability and efficiency is one of the priority problems, becoming more and more urgent year after year, which is due to ongoing ageing of GDN and increase in accident rate. The possible way out is the reconstruction and technical extension of gas pipelines and gas distribution points (GDP).

It should be noted, however, that reconstruction requires considerable financial and material resources. In such conditions, the use of technologies of GDN reliability management can lead to the increase in operation reliability of GDN without considerable investments. In addition, even the problems of drawing up the plans of reconstruction and technical extension of GDN can be solved optimally just with the use of reliability management technologies.

Considering the problems of GDN reliability assessment, it should be noted that effective means providing the solution of the problem of reliability increase and efficient operation is the passing from traditional operation system to the operation which takes into account the reliability indicators. A new approach involves optimization of repair and technical maintenance of GDN and their reliability management on the basis of data on real technical state and characteristics of each group of reliability indicators of GDN elements and their change in time.

Passing to the reliability management is impossible without developing appropriate techniques. At the same time the problems of technical provision require further improvement in validity of reliability assessment and development of new algorithms and programs. Further theoretical and applied researches on innovative potential of gas distribution systems are needed to increase quality and reliability of gas supply. Complex interdisciplinary studies on GDN reliability management are therewith of great importance.

We performed the analysis of the structure and age composition of the elements of GDN of Voronezh. Underground gas pipeline length is 76 %, above-ground gas pipeline length is 24 %.

The ratio of the length of gas pipelines of different pressure stages is as follows:

- high pressure — 10 %,
- middle pressure — 10 %,
- low pressure — 80 %.

Voronezh began to be supplied with gas in 1956, accordingly, the age of gas pipelines varies in the range from 0 to 53 years. Age composition of gas pipeline network is shown in Fig. 1. A roughly equal number of GDP serves dead-and and annular networks. Age composition of GDP is shown on Fig. 2.

In the initial stage of assessment of gas distribution system (GDS) reliability it is necessary to determine homogeneous groups of elements of the system. The analysis of GDS condition allowed us to differentiate following groups: pressure; diameter; mode of laying; age composition with 5-year interval; corrosivity of soil, and laying depth.

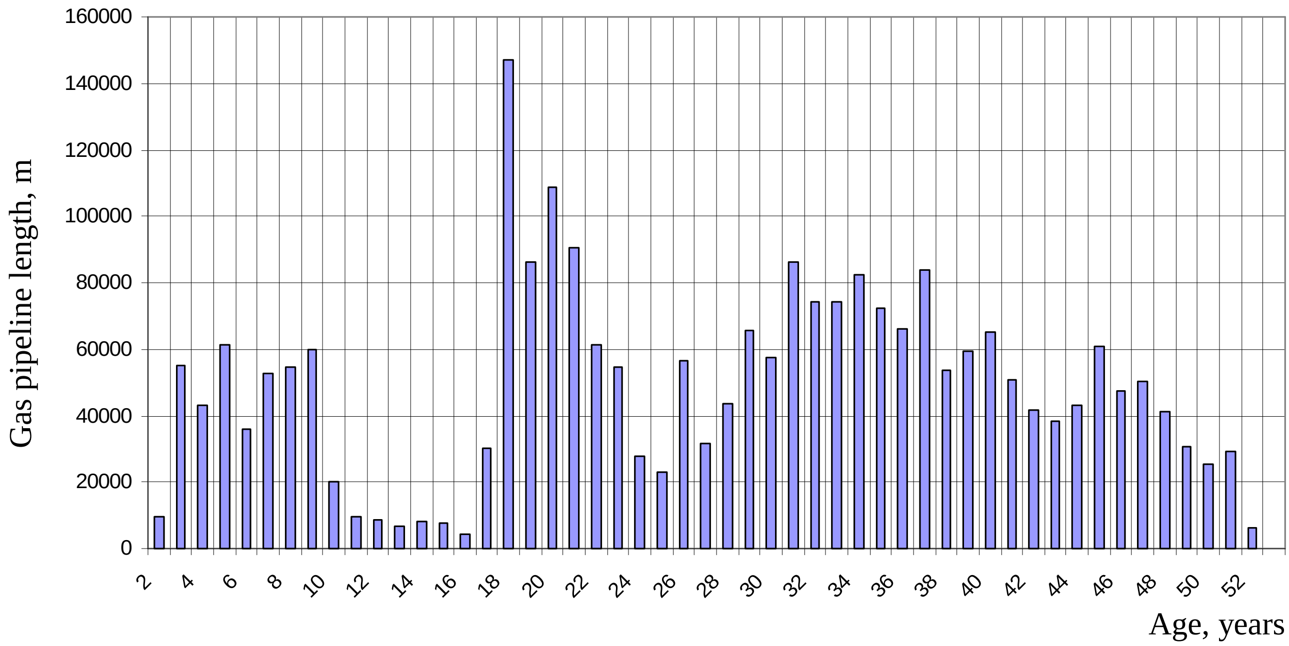

Fig. 1. Age composition of GDN of Voronezh

a)

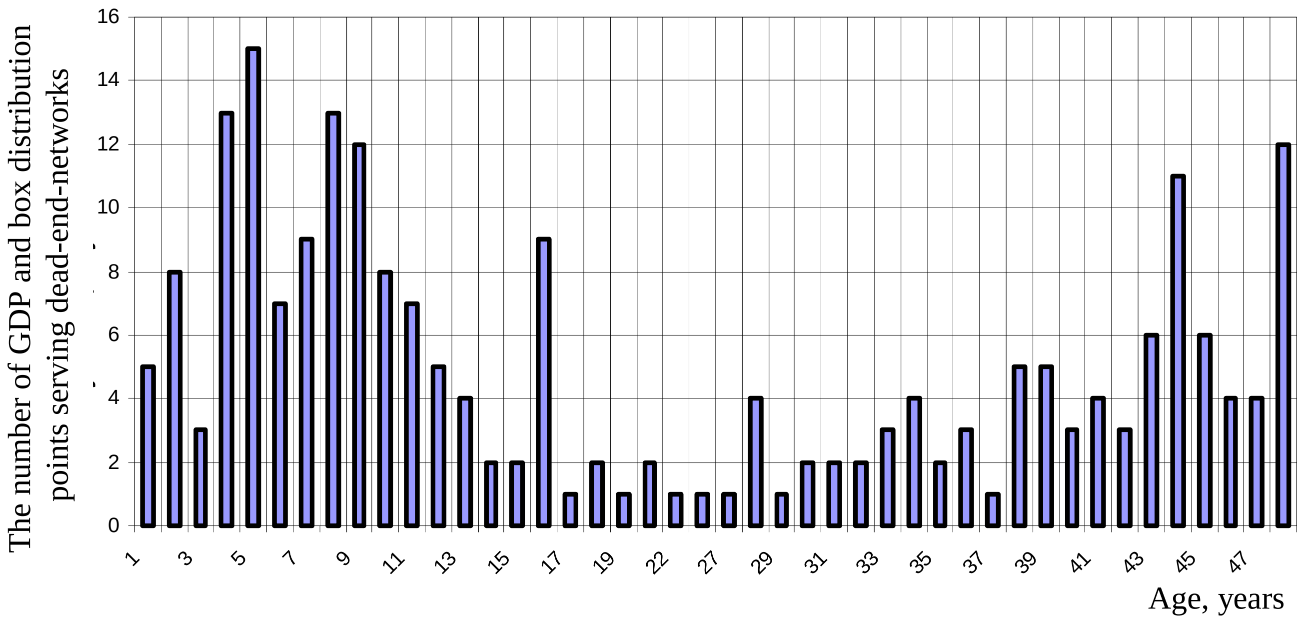

Fig. 2a. Age composition of GDP serving dead-end networks

b)

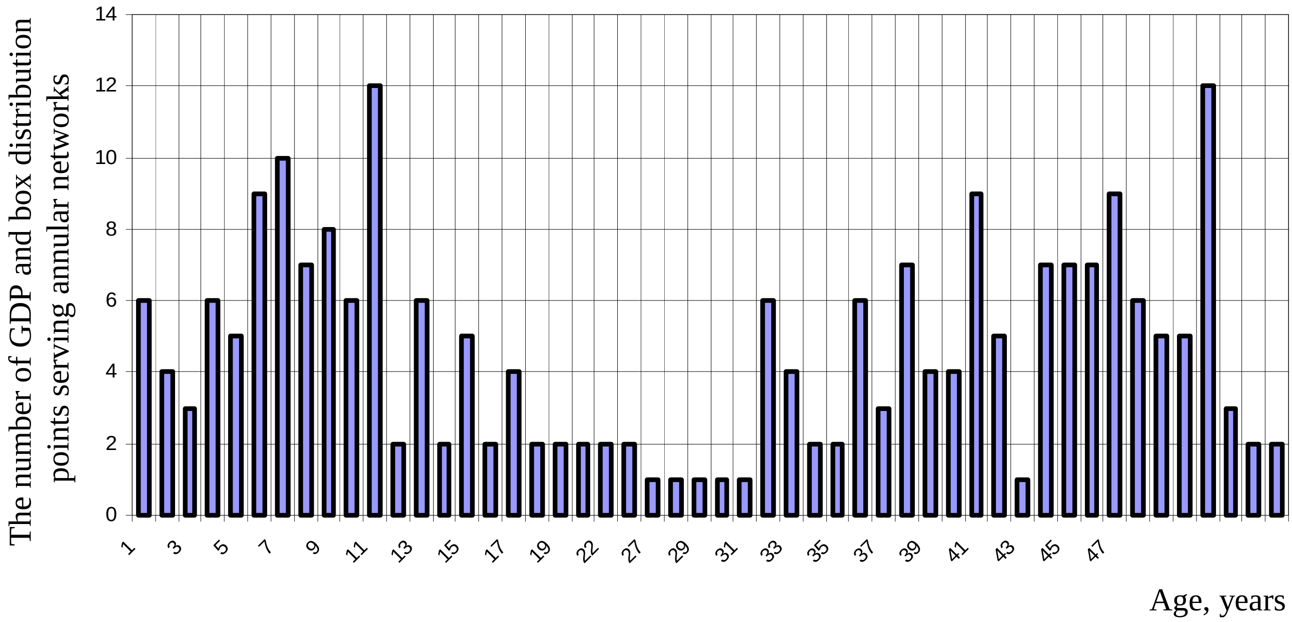

Fig. 2b. Age composition of GDP serving annular networks

The reliability of GDN can be estimated using different methods [1, 2], but all of them do not take into account the gas supply contracts with consumers. To assess the reliability of GDN of high, middle and low pressure, it is suggested to use the criterion of GDN reliability.

The criterion is the ratio of the volume of actually supplied gas to the volume of gas which should be supplied to consumers under the contracts.

The criterion is integral, it includes the reliability of work of pipelines, gas equipment, and gas services:

$$R^j(t) = \frac{\Phi^j(t)}{\Phi^j_\partial(t)}, \tag{1}$$

where $\Phi^j(t)$ is the volume of the gas actually supplied by the network of j stage of pressure, m^3/h; $\Phi^j_\partial(t)$ is the volume of gas which should be supplied by the network of j stage of pressure to consumers under the contracts, m^3/h.

The volume of supplies under the contracts performed by GDN of j stage of pressure:

$$\Phi^j_\partial(t) = \sum_{i=1}^{N_j} \Phi^j_{\partial i}(t), \tag{2}$$

where $\Phi^{j}_{\partial i}(t)$ is the volume of supplies by under the contracts with the network of *j* stage of pressure for *I* consumer, m^3/h; N_j is the number of consumers of network of *j* stage of pressure.

The volume of actually supplied gas of network of *j* stage of pressure:

$$\Phi^{j}(t)=\sum_{i=1}^{Nj}\Phi_i^j(t), \tag{3}$$

where $\Phi_i^j(t)$ is the volume of actual gas supplies by the network of *j* stage of pressure to *i* consumer, m^3/h.

The parameter of the flow of system failures of *k* group of system elements is determined by the formula

$$\omega_k(t)=\frac{\Delta m_k(t)}{\Delta t\cdot N_k(t)}, \tag{4}$$

where $\Delta m_k(t)$ is the number of failures in *k* group of elements; N_k is the number of observed elements in *k* group; Δt is the interval of observation, year.

The assessment of failure flow of *k* group of elements:

$$\hat{\omega}_k=\frac{1}{N_k}\ln\frac{N_k}{N_k-\Delta m_k(t)}. \tag{5}$$

The receipt of emergency repair demands on gas distribution network of Voronezh is shown in Fig. 3.

To predict the receipt of emergency repair demands, neural networks were used [3], approximating the initial time series. Neural network is the potent method of modelling which makes it possible to reproduce and predict complex dependencies. Multilayer perceptron MLP was used as a network. This perceptron is of frequent use in prediction. For multilayer perceptron learning, the method of back-propagation was used, with the rate of learning and inertial coefficient varying with time.

The forecast was obtained after the passing cumulative observations through the neural network. Thereupon, time series projection for 30 observations and schematic diagrams of prolongation of the initial time series were constructed (Fig. 4).

To assess the work of repair services, the mathematical model of service of demands for gas distribution element repair was developed on the basis of queueing theory. This model combines analytical calculations and program for simulation modeling in MatLab 6.1-Simulink. The main program units are presented in Fig. 5.

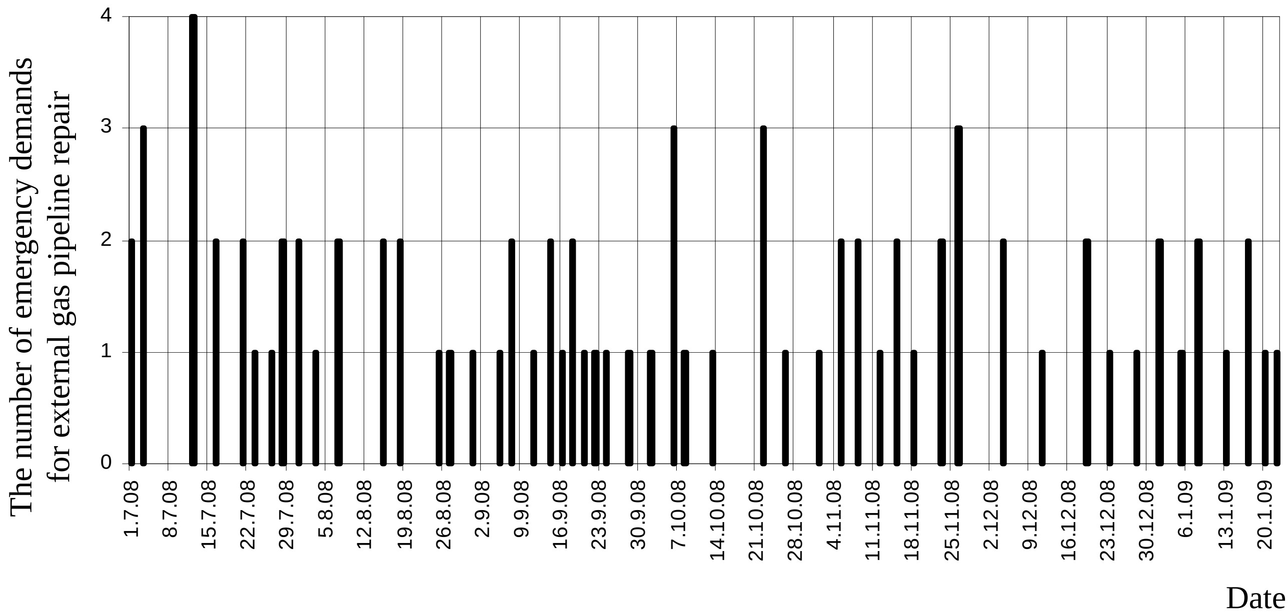

Fig. 3. Receipt of emergency demands for external gas pipeline repair

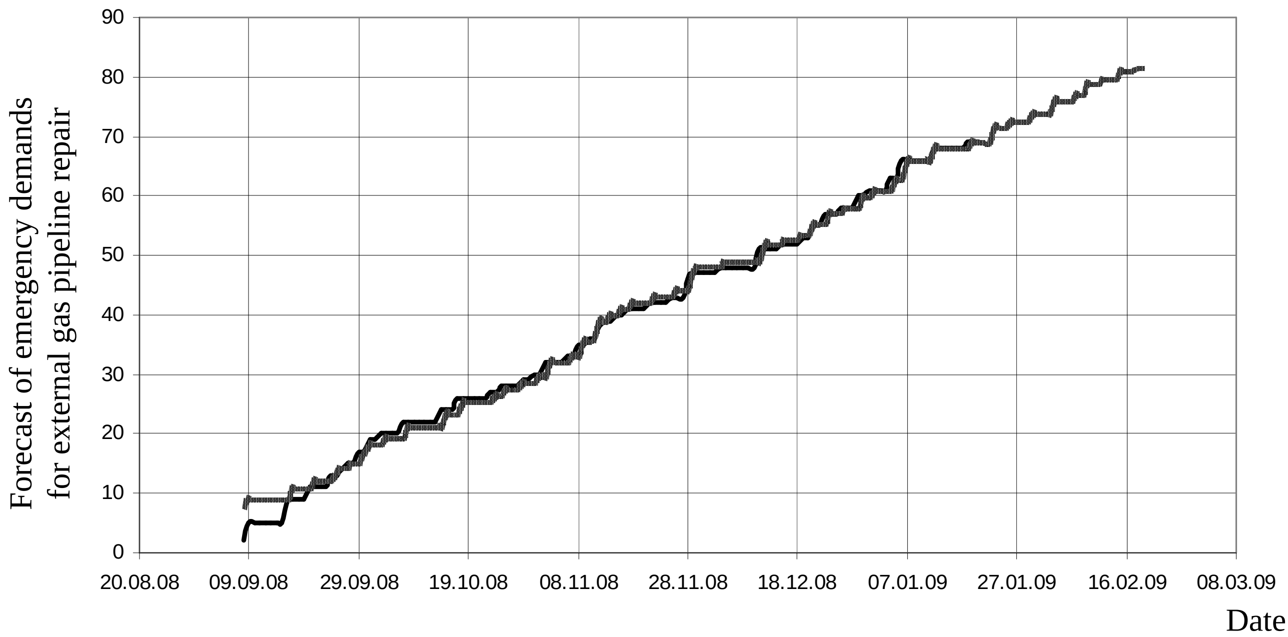

Fig. 4. Forecast of the number of cumulative emergency demands for external gas pipeline repair, network MLP 1-6-1:
— actual; — predicted, coefficient of correlation 0.97356

Time of receipt of demand or repair is taken on the basis of forecast of the number of emergency demands. Modelling resulted in obtaining the following basic characteristics of the service system: emergency service capacity, average number of demands in the queue**,** and average demand service time.

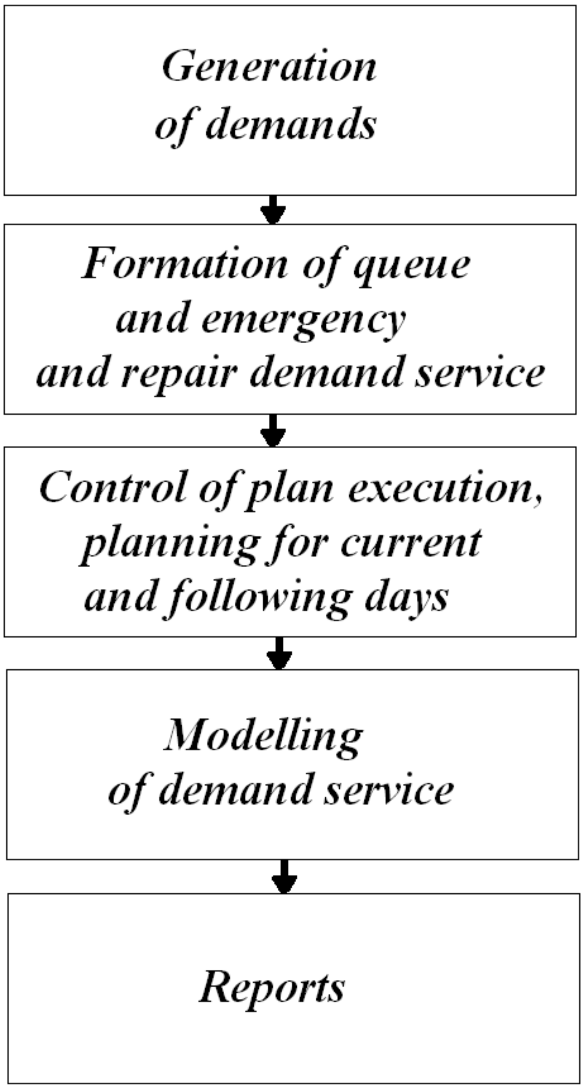

Fig. 5. Basic units of the service model for GDN repair

Not only general assessment of influence of different factors on gas supply systems, but also their differentiation with respect to topographic location is of great importance for reliability management. The problem of gas distribution network reliability management can be solved only on the basis of the complex use of modern technologies of forecast, simulation modeling, methods and instruments of geoinformation technologies.

Geoinformation system (GIS) was used as the basis for development of the system of gas network reliability management [4]. The system makes it possible to analyze combinations of the factors influencing the reliability of gas distribution networks for the purpose of developing certain measures on its increase. Fig. 6 outlines the layers of GIS, topographic and technological information.

Fig. 6. Layers of GIS with topographic and technological information

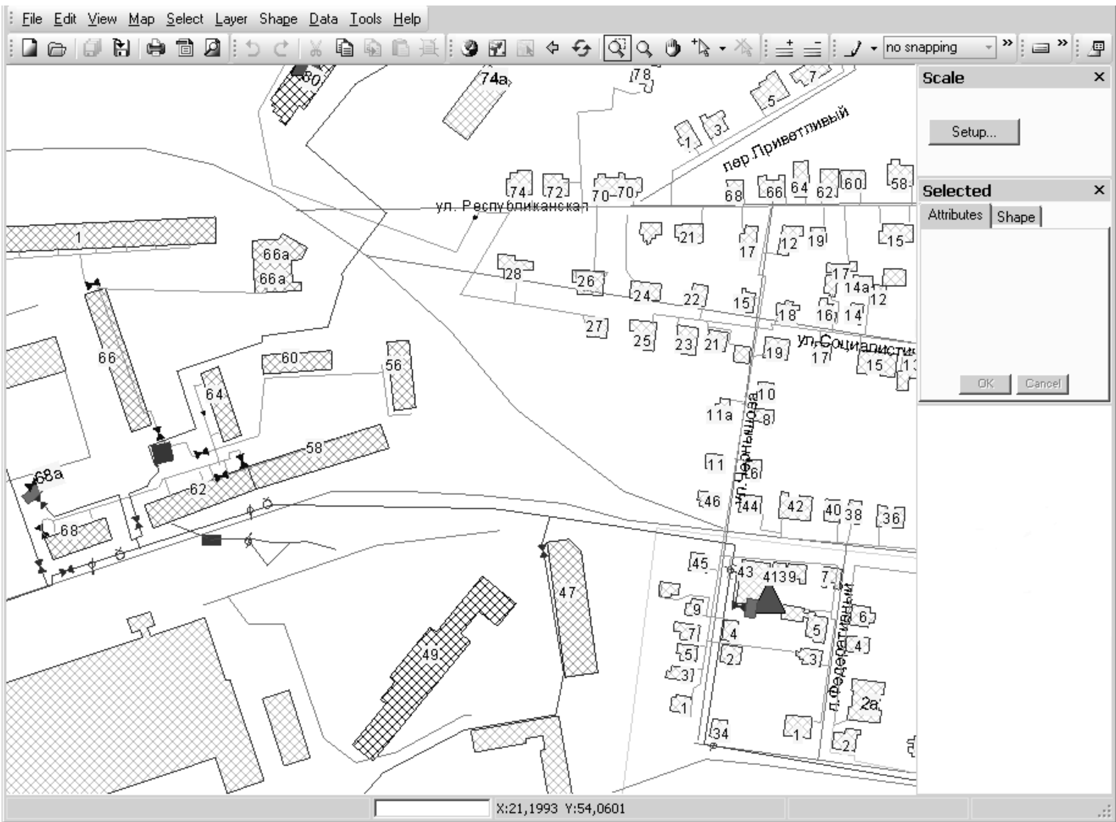

Fig. 7. Main window displaying cartographic and technological information

Modules of GDN reliability management were developed in the medium of GIS in programming language C++. The main window of GIS displaying cartographic and technological information is shown in Fig. 7.

Modules allow one:

- to assess the reliability of the elements of gas distribution networks;
- to evaluate criteria of GDN reliability;
- to predict the receipt of emergency demands;
- to predict the emergency demands service.

Summary

The criterion of gas distribution networks reliability which makes it possible to consider the reliability of gas pipeline work, gas equipment, and gas services.

Groups of indicators of reliability of gas distribution networks elements are described.

The technique of predicting the number of gas distribution network failures and emergency demands is developed.

The mathematical model of the service of demands for repair of the elements of gas distribution networks is developed on the basis of queuing theory.

Modules of management of gas distribution network reliability are formed on the basis of geoinformation technologies.

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