Organizational and technological approaches to the reconstruction of municipal infrastructure facilities

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Abstract. Housing and public utility services constitute one of the most important sectors of the national economy. Reforming and renewal of the housing and public utility services sector is unthinkable without technological modernization of the utility pipeline networks. At the same time, public utility infrastructure facilities in many cities and towns of Russia can be characterized by significant deterioration. Frequent accidents negatively affect the life support of populated areas, which urges the development of organizational and technological approaches to the reconstruction of municipal infrastructure facilities.

1 Introduction

Housing and public utility services (HUS) is one of the largest sectors of the Russian economy [1]. The HUS sector accounts for about a quarter of the country's fixed assets; municipal services consume more than 20% of electricity and about 45% of thermal energy [2, 3]. The most important components of HUS include the maintenance and operation of the housing fund, water supply and sanitation, heat and electricity supply, sanitary cleaning of cities, development and maintenance of populated areas [4-6].

The reform of the HUS industry, which has been going on for two decades, has made it possible to resolve many issues, such as organizing and carrying out major repairs of apartment buildings and the liquidation of uninhabitable housing fund [7, 8]. At the same time, the issue of significant deterioration and technological inferiority of utility systems and infrastructure remains unresolved to the fullest extent.

2 Research materials and methods

In the absence of effective measures to replace worn-out utility pipeline networks, their condition is constantly deteriorating. The consequence of the deterioration of utility infrastructure is the inferior quality of provision of utility services, which does not meet the needs of consumers [9]. Currently, the obsolescence of municipal infrastructure in Russia exceeds 60%; a significant portion of fixed assets has completely exhausted its service life.

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More than 40% of linear objects in the HUS sector need to be replaced. Physical deterioration of water supply networks is 43.4%, water disposal networks - 46%, heating networks - 30% [10]. The increase in accidents at facilities represented by utility pipeline networks is due to their extreme deterioration.

There are losses in heating networks, leaks and unaccounted water consumption during transportation in water supply systems due to the deterioration of municipal infrastructure, as well as environmental pollution due to insufficient sewage treatment [11, 12]. The disrepair of heating and electrical networks causes shutdowns of heat supply to houses during winter season.

Currently, scheduled preventive maintenance of networks and equipment of pipeline systems has almost completely given way to emergency repair work, the costs of which significantly exceed the cost of building new ones [13]. Thus, the primary task is to quickly assess the condition of individual facilities, the ability to quickly make decisions based on the inspection, which allows not only to eliminate accidents in the shortest possible time, but also to prevent them, and precisely at the location of the possible failure. This, in turn, makes it possible to avoid costly liquidation of the consequences of accidents in all respects (both time and money).

Any equipment, system, material has a certain life cycle: manufacturing (purchase), installation, operation, depreciation, maintenance and repairs, modernization, dismantling (decommissioning) [14]. Over time, utility infrastructure facilities produce effects in the form of work performed in a given volume, and require costs to maintain their operational state [15]. As time passes, these cost and profit functions decrease and increase accordingly, depending on external factors, the maintenance and repair system, and depreciation of facilities. There is an optimal replacement period for facilities in terms of the current cost-profit ratio, and in terms of the cost of ownership of the facility over its entire life cycle (Fig. 1).

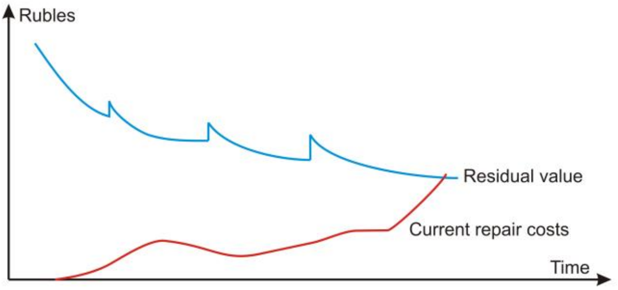

Fig. 1. Typical graph of the relationship between the residual value of fixed assets and time.

Periodically, the cost increases by the amount of repairs performed. Over time, repair costs increase as the resource of the facility is being exhausted (Fig. 2).

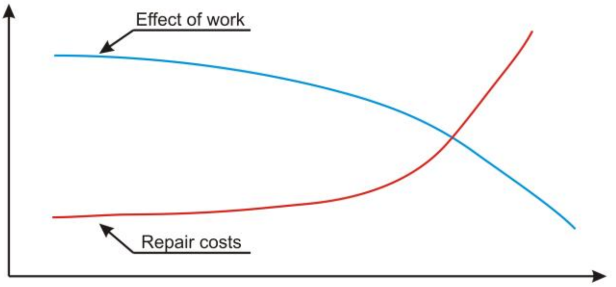

Fig. 2. Typical graph of the relationship between work efficiency and repair costs taking into account time.

Over time, the share of repair time and the number of failures increase, and the reliability of the facility decreases [16]. The task of managing the operation of a facility comes down to periodical determination of the optimal mode of use, type and timing of repairs, and possible replacement of equipment with new ones in order to ensure a high level of quality of operation and reliability.

The reserve for increasing reliability is the transition from planned preventive maintenance and repair to maintenance and repair based on actual technical condition. The implementation of such maintenance strategy requires the widespread use of automated monitoring and technical diagnostic tools and methods [17].

Continuous or periodic monitoring of condition parameters is carried out using technical diagnostic tools. Forecasting is performed with continuous monitoring to determine the time during which the operational state will be sustained, and with periodic monitoring to determine the time of the next control.

The results of diagnostics and monitoring provide the basis for making decisions about the need for maintenance, its time and scope, as well as the time for the next technical condition monitoring.

The implementation of maintenance is associated with the costs of diagnosing and forecasting, so it is advisable to use such type of maintenance when economic costs are not decisive or when this method is more economically profitable [18]. One of the conditions for utilizing the method is also the predominance of gradual and preventable failures over sudden and non-preventable failures.

Forecasting of the technical condition is the most effective method of increasing the operational reliability of utility pipeline networks through timely implementation of maintenance and repair activities (Fig. 3).

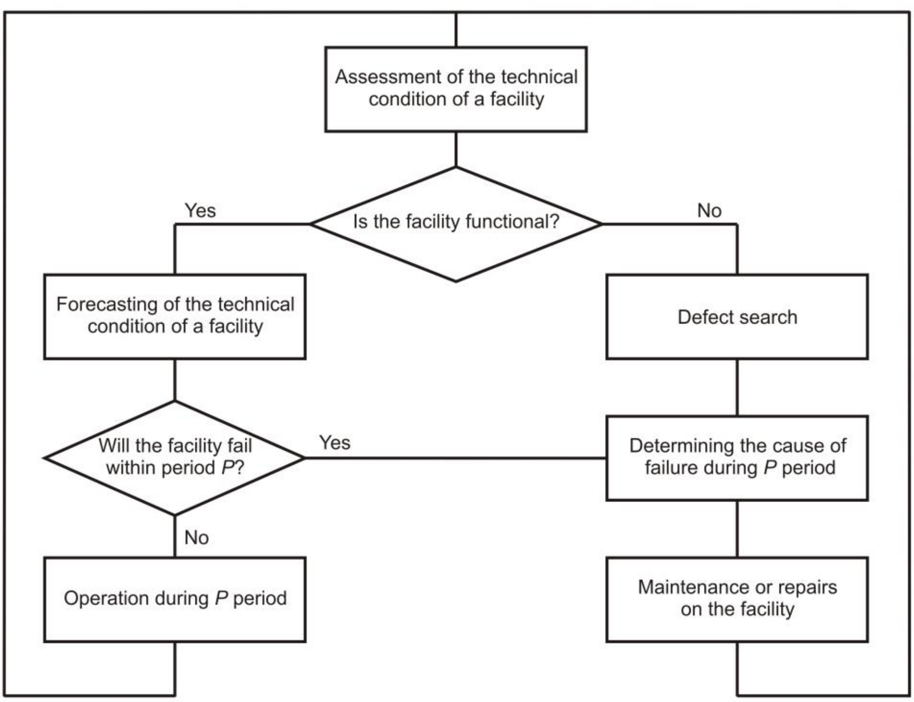

Fig. 3. Functional algorithm for assessing the technical condition of municipal infrastructure facilities.

Forecasting allows to prevent both gradual and sudden failures. Typically, two forecasts are performed simultaneously (for a short period of time for operational purposes of planning intended use, up to several days; as well as for an interval from a week to several months for the purpose of planning maintenance and repair) in practical applications of forecasting the technical condition of a certain facility.

3 Results and Discussion

A characteristic feature of cities in Russia is the presence of fairly extensive and branched sewerage and water supply networks, represented by pipelines made of various materials and various diameters [19]. At the same time, the level of their physical wear increases over time, which leads to the risk of defects and failures.

The reason for this is not only time, but also the extremely low level of maintenance. Wear and obsolescence of engineering communications with various purposes leads to the following consequences:

- deterioration of throughput and pressure losses due to encrustation of pipes;
- decrease in the physical and chemical parameters of drinking water transported through networks due to corrosion;
- likelihood of re-contamination of water (due to cracks, failure of butt joints, etc.);
- pollution of both surface and underground waters, atmosphere and soils.

Reducing the degree of physical wear of underground communications, increasing the reliability of their operation and eliminating the consequences of accidents on networks are of particular relevance, because the technical condition of underground utility networks has reached a critical level in the utility sector [20]. In this regard, there is a need to develop effective technologies for laying utility networks.

Traditional underground construction methods that exist today and are used in this industry, such as shield penetration, driving of steel cases with manual excavation of the soil in the bottom and piercing of pipes, do not meet all the requirements arising from the analysis of cramped urban conditions when carrying out repair and construction work. In addition, all these methods of laying and replacing utility lines in one way or another carry the threat of subsidence of the soil surface.

In the context of new urban development and during the reconstruction of existing ones, in areas where underground communications (water supply, sewerage, drains, cable and heating networks) are most dense, laying new utility pipeline networks or replacing old ones using the traditional open method can be quite challenging [21]. In addition, the use of the open method is practically impossible in the case of placing utility lines under tram and railway tracks, city streets with heavy traffic flow. Thus, the use of a closed method for laying utility pipeline networks is the most promising solution for modern cities.

The development of trenchless technologies is directly related to the development of the infrastructure of cities and settlements, as well as the possibility of reconstruction of utility pipeline networks without compromising the comfort of people's lives. Thus, trenchless technologies for repair and construction work are an alternative to the traditional open method.

Laying pipelines using trenchless technologies involves the use of specialized tools and equipment, represented by pneumatic punches, microshields and horizontal directional drilling (HDD) installations. Each type of equipment has its own specific application, and the efficiency of its use depends on such parameters as the depth of installation, the diameter of the pipeline, the required level of accuracy of drilling a well, the drilling distance, the engineering and geological conditions of the area, the type of communications, as well as the direct organizational and technological conditions of the work on reconstruction, etc. [22, 23].

The use of trenchless technologies in urban areas makes possible reduction of the time required for repair and restoration work of municipal pipeline networks, rational use of material resources, reduction of the load on ecological environment, and also does not require the introduction of traffic restrictions.

In addition, the development of trenchless technologies has a positive socio-economic effect, because allows for reduction of environmental risks during repair and restoration work and preservation of the natural landscape, minimizes damage to green spaces and amenities, and also helps reduce the negative impact on the living conditions of the population.

Active and massive introduction of trenchless repair technologies for utilities into the HUS sector will make it possible to carry out work on the reconstruction of utility pipeline networks with the least interference in the organization of life in populated areas, including in the cramped conditions of modern cities.

4 Conclusion

Experience in the practical application of various diagnostic methods to carry out work on the reconstruction of utility pipeline networks has shown that presently there is no reason to rely only on one method. To obtain practical information about the state of the material at any point in the pipeline, one or another method should be used, depending on the type of pipeline installation. It is most advisable to carry out diagnostics using two or three methods, supplementing them with visual measurement control to increase the reliability of the results obtained. It is necessary to conduct selective surveys in those sections of utility pipeline networks where reconstruction is planned in the near future, in order to collect statistical data and assess the reliability of diagnostic methods. It is necessary to look for new methods of reconstruction, study and systematize the results of surveys in order to restore the normal level of technical condition of engineering communications.

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