THE WAY OF USE SCENARIO METHODS IN MAINTENANCE MANAGEMENT OF SELECTED NETWORK TECHNICAL SYSTEMS

LOSKA Andrzej, PASZKOWSKI Waldemar

Silesian University of Technology, Faculty of Organisational and Management,
ul. Roosevelta 26-28, 41 800 Zabrze, PL
E-mail: Andrzej.Loska@polsl.pl, Waldemar.Paszkowski@polsl.pl

Abstract: The paper presents the results of research on the possibility of use scenario methods in the planning and implementing of the maintenance work in the selected network technical system. The first part discusses the specific organizational and technical factors of maintenance work into wastewater system collection. Based on the conclusions formulated, resulting from the exploitation specificity of network systems, the proposal for use of scenario methods in modelling exploitation processes has been discussed. It is assumed that scenario models can be the basis of construction of an autonomous maintenance strategy for these network technical systems. In this regard, it has been presented the guidelines for the construction of exploitation scenarios and key aspects of their assessment in relation to specific organizational and technical conditions.

Keywords: network technical system, scenario methods, sewer system, maintenance strategy.

1 Introduction

Network technical systems (NTS) are included in the technical infrastructure, which is the basis of operation of municipal engineering sectors. Through the NTS, there are supplied various types of media complying with the required specifications to multiply groups of customers, territorially dispersed and belonging to different categories, such as households, industrial plants, utilities, service facilities and other [9]. The most common NTS include the:

- water supply system - which functions is water supply to customers in an organized and constant manner, with the required level of pressure and of appropriate quality,
- sewer system - allowing the discharge of domestic, industrial, rain and snowmelt sewage to the wastewater treatment plants, and then to the final receiver after appropriate cleaning,
- gas supply system - the main task is to meet the needs of customers in the supply of gas, which should retain sufficient amount and pressure and meet all quality requirements,
- heat supply system - main task is to transfer heat from the heat source (power plant, heating plant, boiler) to heat consumers, which are residential buildings, public buildings, industrial sites,

- electric transmission system - the main task is to ensure the supply of electricity to customers on the appropriate quality parameters (frequency, voltage).

2 Structure and characteristics of a typical sewer system

A typical example of a technical system is a sewer system, which should be understood as a set of interrelated technical elements which are used for drainage and disposal of all types of sewage from a particular area. In other words, sewer system task is to establish such a system of sewer lines and other equipment, which in a economically reasonable manner will enable the collection, sewage disposal and treatment caused by human life and activity and runoff of rainwater [18]. Sewer system has several specific features, which include first of all.

- territorial dispersion of the system components, requiring a special approach to maintenance tasks,
- large number and variety of types of objects within the system,
- powerful links and relationships between system components,
- highly dynamic of the system, which requires continuous control and monitoring of the processes performed,
- uninterrupted operation for most installations, equipment and buildings belonging to the system.

Due to the fact that the NTS belong to very expensive components of the technical infrastructure, and the period of their operation is often several years, the basic elements of such a system should perform their functions as long as possible.

Bibliography [3, 4, 11, 18, 19, 20], comprises methods for the classification of sewer systems, which arise from different needs (organizational, legal, or technical). In one aspect which is presented in this article, the most important is layout associated with the identification, physical connections between elements, and mutual location of each object constituting sewer network discussed here. The most important and most common is the external sewer system, which can take one of four forms (Fig. 1).

- combined sewer system (Fig. 1a), in the form of single lead network through which they flow together domestic, industrial and rain wastes,
- separate sewer system (Fig. 1b), in the form of two-wire network, where in one pipe domestic and industrial wastes flow, and in the second pipe runoff wastewater flow,
- semi-separate sewer system (Fig. 1c), as similar as the separate sewer, where pipes are connected for the purpose of common action system,
- mixed sewer system (Fig. 1d), as a territorially separated units of separate sewer system and combined sewer system.

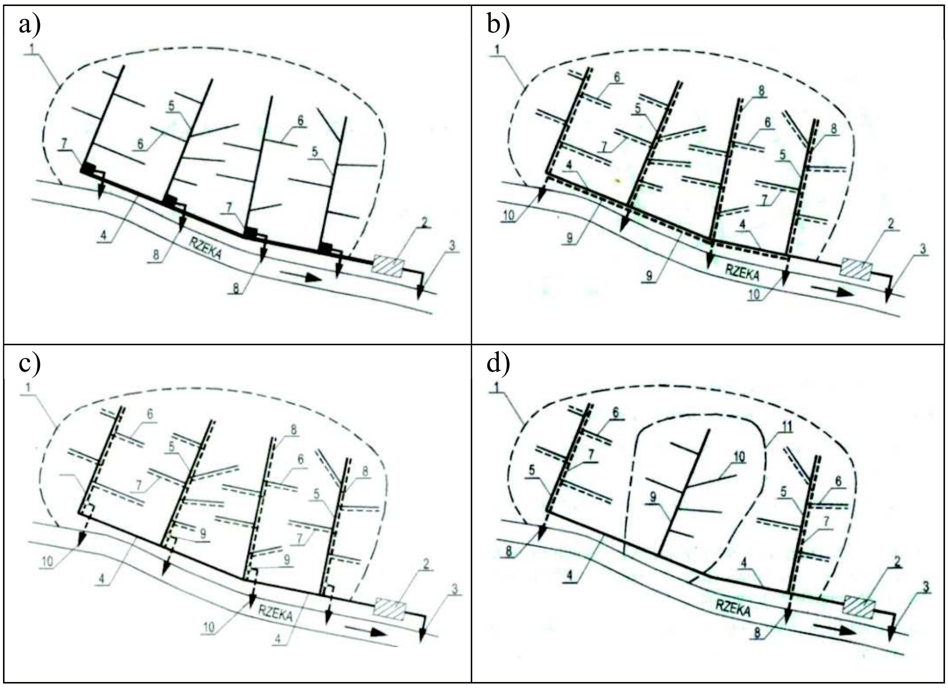

Fig. 1. Schemes of sewage systems [20]: a) combined sewage system, b) separate sewer system, c) semi-separate sewer system, d) mixed sewer system

3 Exploitation specificity of sewer system

From a technical point of view, the proper functioning of the sewer system requires to ensure continuity and quality of facilities within an extensive technical infrastructure geographically dispersed over a large area. In practice this means the need to provide an adequate level of reliability. Sewer system consists of logically interrelated subsystems, in particular:

- network subsystem,
- pumping subsystem,
- wastewater treatment subsystem,
- outlet subsystem.

Each of these subsystems has a different organizational and technical approach to the ways and ranges of maintenance work.

Supply and outlet subsystems are designed to keep the possibility of continuous transport of sewage through the pipe system and collectors to the outlet and receiver. Maintenance work, having the character of both prevention and intervention, comes down to maintain their efficiency and tightness. These works include:

1. routine network inspections including visual and instrumented checks of tightness and capacity of pipes and collectors, prevention of pollution of canals, laterals and network equipment,
2. maintain and corrective works, including cleaning and flushing of pipes and ducts, cleaning street gullies, removal of pipe system blockage,
3. repair works, including removal of damage, and replacement of worn parts of sewage system.

The nature of maintenance work of network subsystem depends largely on the availability (often limited) to specific sections.

Pumping subsystem is designed to maintain reliable and uninterrupted operation of sewerage system. To achieve such an explicit objective, maintenance works are carried out, including:

1. Supervision over pump unit, which is aimed at a constant evaluation the selected parameters.

2. Routine maintenance work, performed on the so-called "move" and including visual inspection of the pump during operation with a special focus on the vibration and the indications of measuring instruments. In addition, the exchange is made of grease or oil in the bearings and sealing glands. This type of work concerns the sewage tanks or lattices and rely on their routine cleaning.
3. Overhauls, carried on so-called downtime, include the corrective and regenerating work that depend on the pump operation time or the level of wear. For example, centrifugal pump major overhaul is carried out every 2-4 years (12000-18000 work hours) and consists of the pump disassemble and replacement of worn parts of the: rotors, steering shafts, bearings, couplings, rotor rings, exchange of measuring instruments, repair of installation of the cooling of bearings, etc.
4. Emergency repairs, involve the removal of faults of the pump units and it shall be carried out on an ongoing basis as detecting irregularities in the operation of individual technical objects. The necessity of these works is the result of such: different types of leakage, lack of water intake, reduced productivity, increased power consumption, increased vibration or heating of the bearings. A detailed overview of the most characteristic events with possible unintended symptoms, causes, and the procedures are summarized in [18].

Wastewater treatment subsystem is designed to maintain continuous operation of technical facilities belonging to other subsystems and to ensure the assumed effect of sewage. Maintenance work in this case include:

1. Boot of treatment plant, performed when you first start and after every long break in the work. Boot is a gradual and multi-stage (hydraulic start-up, technological start-up), during operational work is carried out preventive and corrective.
2. control works, including:
   - measurements of parameters of technological processes (inflow and outflow intensity, energy, air, steam, hot water and reagents), and analysis of water quality, sediments and other factors separately for each element, and also for sewage treatment as a whole,
   - assessment of the operational performance through the routine celebration and inspections of particular objects for identification of defects occurring.
3. Maintain and repair works (preventive), aimed at keeping components in the sewage treatment of full technical efficiency. This type of work are a consequence of the technical assessment as a result of routine inspection activities, as well as the effect of reliability research, reflected in the operating resources of particular objects contained in the maintenance documentation.
4. Repair work (corrective and emergency), including adjustment of mechanical equipment, power and automation, removing sediment from the channels, ducts, conduits and other places where there should not be accumulated, any failure or deficiencies removal of technical facilities.

The study of the functioning of selected Polish sewage systems and the organization of maintenance activities, allowed to distinguish several aspects pointing to the exploitation specificity of the area, which is discussed in this. In particular, these aspects include:

- structural reliable complexity of technical objects of sewer system,
- organizational and technical complexity of maintenance strategy and systems.

Reliability structure of sewage system can be represented by typical system models [11]. However, the vast majority of exploited sewage systems is based on complex models, which link serial and parallel structures [7]. In an extended sewer system, damage of a single element (such as clogging of the selected pipe) does not immediately stop the whole system, but only a particular section, the rest of the system can operate in the normal way. Sewerage system should be operational in general, regardless of events or performed maintenance work. This idea also translates into quantitative evaluation and control of exploitation efficiency, which should be referred not to the whole system but to the extracted parts or sub-systems.

4. Organizational and technical complexity of maintenance strategy and systems

In practice, construction and functionality of the sewer system determine classical forms of maintenance activities. From an organizational point of view, the activities may be enclosed in widely known and accepted forms of base maintenance strategies, especially: breakdown maintenance, preventive maintenance and predictive maintenance [10].

In order to determine the exploitation and maintenance specificity, the studies were performed, which consisted of identification and inventory of inventory events relating to selected Polish sewage systems. It was found that the items qualified for particular subsystems characterized by different organizational and technical forms for the possibility and the way of maintenance tasks performance. Based on these studies and based on the characteristics of the maintenance activities of most important elements of the sewerage system, there have been developed a hierarchy of the various strategies referenced to the particular subsystems (Tab. 1).

Table 1 Hierarchy of the various strategies referenced to the particular sewerage subsystems

Subsystem	Base maintenance strategy	Interpretation
Network and outlet subsystems	1. Breakdown maintenance strategy 2. Preventive maintenance strategy 3. Preventive maintenance strategy	On the layout of the maintenance work types influences difficulty in the direct access to selected objects and their high reliability (especially channels and pipes). Not without significance is the necessity to conduct excavation works making it difficult to carry out normal activities in the area. Therefore, in this case, highest percentage share characterizes intervention works, but preventive works are limited mainly to non-invasive activities.
Pumping subsystem	1. Preventive maintenance strategy 2. Breakdown maintenance strategy 3. Preventive maintenance strategy	Of all mentioned subsystems, pumping subsystem is characterized by the highest tool diagnosing. Pumps and their equipment are susceptible to simple and complex diagnostic procedures. With a relatively high availability of components of the subsystem, it allows you to make ongoing assessment of technical condition.
Wastewater treatment subsystem	1. Preventive maintenance strategy 2. Breakdown maintenance strategy 3. Preventive maintenance strategy	Wastewater treatment subsystem is different in the functioning and in the methodology of approach to the maintenance activities. It is assumed high direct access to technical objects and less diagnosing than pumping system. Therefore, the best in this case is a strategy based on an extended multi-level prevention from simple audit works through inspection, maintenance, repairs to complex overhauls. Other types of strategies are also important here, but they are complementary (such as diagnostics for the audit work or repair, fault, etc.).

The study and the information contained in the table (Tab. 1) shows that optimization of exploitation processes in the sewer system should be multifaceted. This results primarily from the specific structure and location of the sewerage system. On the one hand, a significant number of components of such system is located and operates under the ground, making it difficult or impossible to carry out such preventive activities, which are characteristic for typical manufacturing companies (the celebration, overviews). It is also important the dispersion of technical objects over a large area. On the other hand, here are objects such as pumping stations or sewage treatment plants, which can be seen as a typical manufacturing company (from the exploitation point of view). This allows the use of effective methods and supporting tools such as strategy TPM and CMMs/EAM system.

4. Proposal of use scenario methods to build an autonomous maintenance strategy

Presented variety and ambiguity of strategic possibilities in respect of individual components the sewerage system, cause difficulty in defining the optimal exploitation policy. However, data collected and structured allowed make assumptions for the purpose of development of autonomous computer aided exploitation strategy in the form of analytical and advisory system taking into account:

1. different nature of operational work in relation to individual subsystems of sewer system (intervention nature of the sewerage network, diagnostic character of pumping, the preventive nature of wastewater treatment plant),
2. exploitation „point" of needs of maintenance tasks realization (preventive action, removing the effects of emergencies),
3. typical aspects of the physical wear of the technical objects,
4. technical and geographic location of the technical objects,
5. information about terrain characteristics in the planning and optimization of maintenance work.

Implementation of the concept is possible on a consistent set of guidelines, which are the basis for decision-making. In this regard scenario technique can be helpful. They belong to the group of forecasting methods and they have been traditionally used in the field of economics and strategic management [1, 2, 5, 6, 12, 15, 16, 17]. In the area of technical sciences, it has still not have gained greater appreciation.

According to [8], scenario planning is based on descripting of events and indicating their logical and coherent consequences in order to determine the way of development of an object or situation. It is assumed defined reference point, which in the case of maintenance management can be, for example, past or current technical condition of the object. According to, we must clearly differentiate between the external scenario, relating to surrounding reality (eg, environmental or industrial) and internal scenario, the property of a single person.

Examples, described widely in literature are a large and diverse set of proven methods of scenarios creating, their practical use and evaluation of effectiveness. For example, according to [15], there are four basic types of scenarios: scenarios of possible events, simulation scenarios, environmental conditions scenarios, processes in the environment scenarios. These scenarios differ in the logic of their creation and the method and scope of data collection. However, according to [6], scenarios can be either inductive or deductive. The overall conclusion is that there are many forms and techniques of scenarios construction that result from the lack of explicit modelling principles developed in this task area.

Based on the results of diagnosis and identified analogy to other areas, it must be concluded that the area of exploitation of technical systems (exploitation of sewerage system) is very susceptible to the use of scenario techniques for modelling exploitation processes and building autonomous maintenance strategy.

The starting point could be the models of descriptions of activities under the exploitation processes that were proposed in [10]. It is about "passage" model of the object from the initial state (the transfer of the object to use), the final state (recall the object from the exploitation - such as scrapping), or to identify possible (typical) ways of use the “living” time of object. There are four typical ways (models) of such management, referred to the term of scenario, in particular:

1. Scenario of exploitation process of 1st type (Fig. 2), consists of use of the new object until lose the ability to perform the tasks, arising from the objective function. After the loss of suitability, the object is definitely withdrawn from exploitation. This scenario can be used to describe the exploitation processes of irreparable objects.

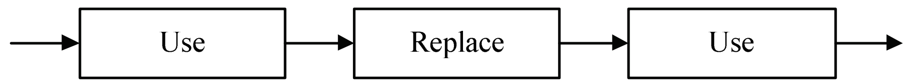

Fig. 2. Exemplary arrangement of structural links of exploitation tasks for type 1 scenario

2. Scenario of exploitation process of 2nd type (Fig. 3), consists of supplementing type 1 scenario with rehabilitation suitability activities. Therefore, this scenario can be presented in a sequence: use - loss of suitability - renovation of suitability - use...

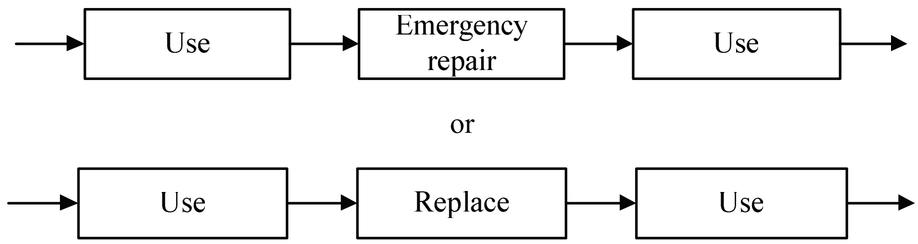

Fig. 3. Exemplary arrangement of structural links of exploitation tasks for type 2 scenario

3. Scenario of exploitation process of 3rd type (Fig. 4), consists of supplementing type 2 scenario with activities, which aiming at extending the periods of use, and thus reduce downtime periods. This can be achieved for example by introducing preventive activities.

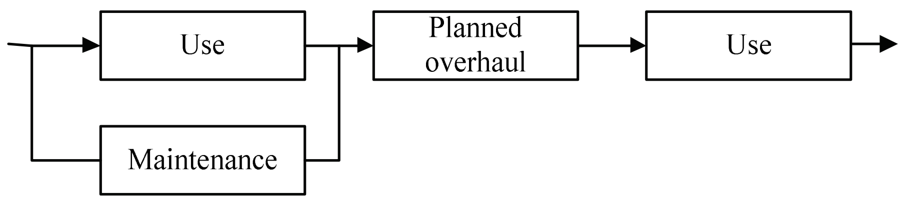

Fig. 4. Exemplary arrangement of structural links of exploitation tasks for type 3 scenario

4. Scenario of exploitation process of 4th type (Fig. 5), consists of supplementing type 2 scenario or type 3 scenario with activities, which aiming at identification of the technical condition of object (eg, inspections).

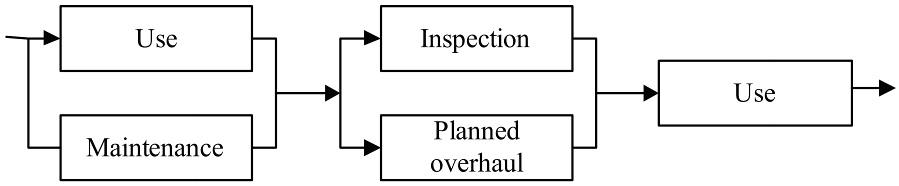

Fig. 5. Exemplary arrangement of structural links of exploitation tasks for type 4 scenario

Presented structural models are here an example. In a description real cases, the scope, as well as the layout of relationship may vary significantly and it can be more extensive.

Conclusion

Key elements of the scenario methodology and the specificity of technical systems exploitation determine a set of necessary activities (specific objectives), whose implementation will allow to develop an autonomous maintenance strategy in relation to the sewerage system [13, 14]. These activities include:

- defining the need and basis for scenario/collection of possible scenarios generation based on specific exploitation models, which may result from the reliability criteria, in this case (eg. a set of quantitative exploitation indicators),
- determining the internal and formal structure of the description of the scenario (identifying a set of parameters, the quantitative elements and features, defined as qualitative components of the situation/event),
- filling in scenarios for the object as such by mapping its environment (that is, by analogy, the author of the article proposes to describe the "scenery" in which scenario is “going on” - in addition to the same scenario),
- solution to the problem of practical use of scenarios in maintenance works, and optimization of decision-making processes relating to operating technical systems, taking into account multivariant issue of possible events and behavioral simulation of objects in shorter and longer term.

An important aspect is the use of terrain information, which in this case should be based on the study:

- possibilities and efficiency of use of information technologies (network model of open and closed channels, the atmospheric model, terrain model, NTS, soil zone model: the roughness and/or permeability of the area, density of buildings and other), to develop components of the hydrological and hydraulic water catchment model of studied area,
- opportunities for implementing and visualizing the simulation results using the developed hydrologic and hydraulic water catchment model of studied area, in the form of new thematic layers in GIS system,
- possibility of using information from the new thematic layers (spatial-statistical analysis) in the construction of model of autonomous exploitation strategies and in creating a dynamic, variant scenario of events.

The operation will be the subject of research, expressed in a further publication of the author.

PŘEKRAČUJEME HRANICE
PRZEKRACZAMY GRANICE
2014—2020

EVROPSKÁ UNIE / UNIA EUROPEJSKA
EVROPSKÝ FOND PRO REGIONÁLNÍ ROZVOJ
EUROPEJSKI FUNDUSZ ROZWOJU REGIONALNEGO

Projekt jest współfinansowany ze środków Europejskiego Funduszu Rozwoju Regionalnego
oraz z budżetu państwa RP „Przekraczamy Granice"

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SPOSÓB ZASTOSOWANIA METOD SCENARIUSZOWYCH W ZARZĄDZANIU UTRZYMANIEM RUCHU WYBRANYCH SIECIOWYCH SYSTEMÓW TECHNICZNYCH

Abstrakt (Streszczenie): W artykule przedstawiono wyniki badań nad możliwością zastosowania scenariuszy w planowaniu i wdrażaniu prac konserwatorskich w wybranym sieciowym systemie technicznym. W pierwszej części omówiono specyficzne organizacyjne i techniczne cechy prac obsługowo-naprawczych systemów kanalizacyjnych. Na podstawie sformułowanych wniosków, wynikających ze specyfiki eksploatacyjnej systemów sieciowych, omówiono propozycję stosowania metod scenariuszy w modelowaniu procesów eksploatacyjnych. Przyjęto, że modele scenariuszy mogą stanowić podstawę budowy autonomicznej strategii konserwacji sieciowych systemów technicznych. W związku z tym przedstawiono wytyczne dotyczące budowy scenariuszy eksploatacyjnych i kluczowych aspektów ich oceny w odniesieniu do specyficznych warunków organizacyjnych i technicznych.

Klíčová slova (Słowa kluczowe): sieciowy system techniczny, metody scenariuszowe, system kanalizacyjny, strategia eksploatacyjna