MODELLING OF TECHNICAL STRUCTURE OF MUNICIPAL ENGINEERING SYSTEMS DRIVEN BY THE SMARTMAINTENANCE IDEA: MULTI – MODEL CONCEPT

Andrzej LOSKA

Abstract: The article is a continuation of the author's research on ways to support the maintenance management of technical infrastructure objects, which function within municipal engineering. A key aspect of SmartMaintenance concept, developed by the author, is unambiguous identification and location of components of exploited technical systems, taking into account requirements of the exploitation decision-making process. For this purpose, the paper presents the concept of exploitation multi-model, binding features and possibilities of three patterns of modelling of technical objects. The proposed solution was later interpreted in relation to the features of selected technical network systems.

Key words: municipal engineering systems, SmartMaintenance, SmartCity, maintenance management, exploitation decision-making process

1. Introduction

One of the most developed concepts within the municipal engineering while also widely discussed is the idea of SmartCity. This concept relies on selection of advanced technical, organizational, and informational solutions, for the sustainable development of local communities in economic, environmental and social aspects [1, 2, 20, 21, 28, 29].

Use of advanced technical solutions within the municipal engineering, generates problems resulting from aging and wear processes of particular components of considered technical systems. The consequences of these situations are unintended exploitation events. Thus, in the context of developed and implemented innovative and technologically advanced solutions, it should take into account aspects directly related to the maintenance management, performed both in the operate phase, as into the service and repair works.

For this purpose, author proposed the concept of SmartMaintenance, whose basic assumptions are presented in [14]. SmartMaintenance is intentional complementary of assumptions and components of SmartCity on the models, methods and tools supporting shaping exploitation decision-making process. Purpose of the proposed complex solutions is to ensure rationality of maintenance policy for system and all subsystems of municipal engineering, and thereby it achieves the desired functionality of smart technical solutions at the assumed level.

One of most important thing in optimal exploitation decision-making process and rational exploitation policy is to have reliable results of exploitation analyzes, performed on the basis of information resources about the objects and exploitation processes [13, 14, 27]. In this regard, a key aspect seems to be the construction of such models of technical systems functioning within the municipal engineering, which will allow to take into account multi-dimensionality of information in exploitation decision-making process and, consequently, in maintenance management process.

Therefore, later in the article, the author proposed a comprehensive way of modelling technical systems functioning within municipal engineering, as the next step in the development of the SmartMaintenance concept.

The article includes a part of the statutory research no. 223/ROZ3/2015, carried out at the Institute of Production Engineering of the Silesian University of Technology.

2. Review and assessment of ways used in modelling of technical objects in maintenance management

Models of facilities can be developed for the unambiguous identification of components of exploited technical systems and their relationships [9, 22], This allows to carry out maintenance analysis [13, 17, 19, 27], and consequently - support for exploitation decision-making process [18]. Such models are expected to allow for the identification and location of key technical, organizational and economic exploitation characteristics, for aggregation of their values. In the maintenance management practice, exploitation models are most often hierarchical (vertical) and they are the basis for the implementation and operation of CMMs/EAM systems [15, 22]. In this regard, it is possible:

- assignment of information on realized works directly to maintained technical object (or to component of technical system),
- transfer of information up and / or down the hierarchy in accordance with a defined arrangement of links with the simultaneous aggregation (fusion) of selected features.

The hierarchical method of modelling of technical objects is typical and sufficient for the production technical systems, due to such their features as: compact structure, accessibility for maintenance works, "depth" disassembly logic. This allows for the implementation of the decision-making process based on feedback information, aggregated at the next hierarchical levels of the exploited technical system. Examples of descriptions of productive technical systems using hierarchical model, were described in earlier author's publications, including [15, 16].

However, the hierarchical way of describing objects characterizes limited possibility of (horizontal) functional relationships, that do not occur in a typical hierarchical arrangement. For this reason, a specificity of technical network systems (difficult to access or maintenance tasks, systemic logic of connections and a large dispersion of components) makes hierarchical models insufficient for realization and support of exploitation decision-making process. In particular, the main reasons for this insufficiency:

- inability (or at least very large obstacle) to model systemic (horizontal) specificity of technical network systems,
- inability to acquire functional characteristics (typical for horizontal connections between components of the technical system),
- inability to perform the analyzes resulting from operation or failure of distinguished section of the system.

It should also be emphasized insufficiency of this modelling method, rather than the inadequacy (uselessness).

3. The concept of exploitation multi-model for the needs of describing the technical structure of municipal engineering systems

The response to the above conditions and also a way to solve restrictions of modelling structures in exploitation of technical network system can be identification of mutual relations between components of the technical system in a multidimensional approach – in the form of exploitation multi-model. It need taking into account the following assumptions.

- technical system consists of the technical objects, describable with a set of exploitation characteristics,
- exploitation features of technical objects are defined in three contexts: operate, maintenance and topological,
- each of the contexts appoints relationships between the features creating multi-model.

Exploitation of multi-model of technical network system is a submission of disjoint sets of exploitation features (technical, economic, organizational) organized in under these contexts, including:

1. Systemic model considered in the operate context. It reflects the temporal and spatial conditions (or the lack of them) of realization of the objective function, that is, the ability to achieve its final parameters (output) at known and set input values. In the systemic sense, technical network system is arrangement of components (technical objects), at which their subsequent operation enables the realization of main function, that is efficient transporting media from source to user.
2. Hierarchical model considered in the maintenance context. It reflects the relationships parent - child, within a specific section of the system or a particular class of similar objects - groups of objects [8, 15]. In the hierarchical sense, technical network system is arrangement of components (technical objects) due to fulfilled functions and/or the nature of their activities.
3. Topological model considered in the location context. It reflects the interaction between technical objects and the environment [3, 5, 12]. In the topological sense, technical network system is arrangement of components (technical objects) in an integrated manner with their physical locations of occurrence in the area.

The synthetic specification of functions of models that make up the multi-model of technical network system are shown in Tab. 1.

Tab. 1. The compact list of functions of component models of exploitation multi-model

Models	Functions
Systemic model	• defines the technical approach to the identification of operating functions and tasks carried out with the participation of technical network system • integrates all technical objects into one coherent arrangement
Hierarchical model	• defines the technical approach to the identification of maintenance functions and tasks in relation to technical network system • integrates and organizes all components of individual technical objects within a established classes or groups
Topological model	• defines and integrates the technical objects with their physical locations of occurrence • describes mutual exploitation relations of technical network system with its environment

The models consisting of exploitation multi-model take into account division of technical network system into two categories of objects:

- linear objects with network equipment, whose function is to transfer media and connect other components within a coherent system,
- engineering objects, whose task is to support the basic functions of the technical network system, in achieving and maintaining the assumed parameters, both the network components and the media flow.

Examples of objects belonging to the above categories, for the selected technical network systems, are summarized in Tab. 2.

Tab. 2. Classification of sample objects for the selected technical network systems (own elaboration based on the [4, 6, 11, 32])

System category	**Linear objects/network equipment**		**Engineering objects**
Water supply system	transit pipes, main pipes, distribution pipes	water flow control devices, draw devices, safety devices, measuring devices	water intakes, reservoirs, pumping stations
Sawage system	main channels, lateral channels and sewage collectors, open channels, collectors	storm overflows, laterals, sewer manholes, rain inlets, discharges to receiver	sawage pumping stations, sewage treatment plants
Heating system	main pipes, distribution pipes, return pipes	shut-off valve and regulatory, control and measurement instruments, safety, feedback and feed-through valves, gravel cleaners, vents, heating chambers and wells	heating plants (sources of heat), thermal centers

Linear objects and network equipment are characterized by a highly territorial dispersion and irregularity density, because decomposition of the subcomponents is a horizontal whereby it is more prone to arrangement using the systemic model. Engineering objects have the specificity similar to the production facilities, where dominates the vertical decomposition, which is based on a hierarchical arrangement of components. Regardless of the above classification, individual objects have uniform susceptibility to their spatial identification and location. In this perspective, a form of arrangement depends on the features of environment and neighbouring objects located in the area. These features determine the a multi-dimensional (multilayer) connection system. The share of components of technical network system in such a connection system, includes only the definition of the parameters locating in so built virtual space.

4. Characteristics of exploitation multi-model components of technical network systems

The concept of exploitation multi-model, presented in the previous section, will be illustrated according to conventional technical network systems, functioning within the technical infrastructure of municipal engineering, in particular: water supply system, wastewater system and heating system.

4.1. Exploitation systemic models of technical network systems

In the systemic sense, technical network system consists of a collection of components, which can be assigned to one of three serially connected generalized subsystems (Fig. 1).

- acquiring and collecting subsystem, whose task is acquiring and accumulating media in the required quantities and in a manner allowing the continued use,
- processing subsystem, whose task is to change selected features of the media, in a way that adapts to the requirements and expectations of the recipients,
- distributing subsystem, whose task is to transport and delivery (in the sewer system - discharge) media to end users for utilizing.

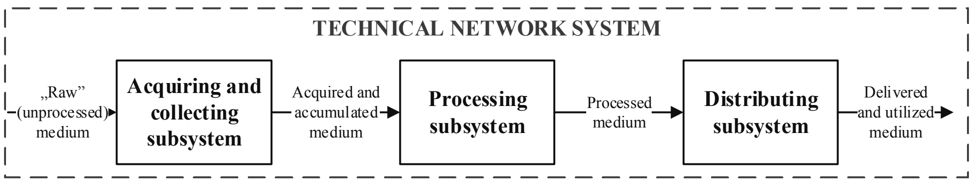

Fig. 1. A generalized scheme of systemic model of a technical network system (own elaboration)

Operation of technical network system in the systemic sense relies on realization of functions specified for engineering objects (located symbolically in blocks), with using medium, which is transported through linear objects (located symbolically in the form of connections between blocks). Graphical example of systemic model of discussed technical network system - water supply system, on the background of symbolic patterns of connections between components (subsystems), is shown on Fig. 2. And list of operate tasks assigned to selected subsystems are summarized in Tab. 3.

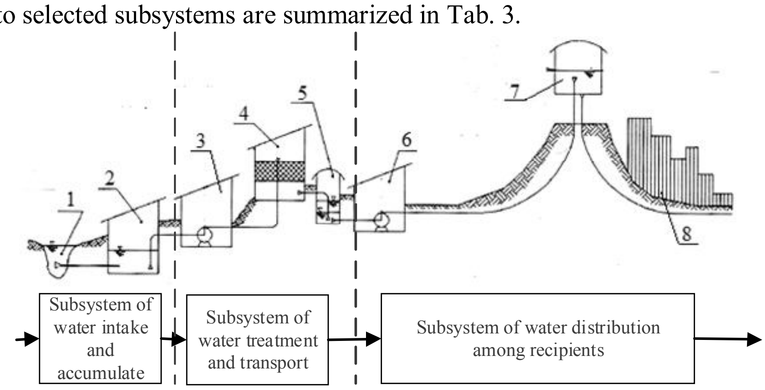

Fig. 2. Example of systemic model of water supply system on the background of its illustrative scheme: 1 – water intake, 2 – collective well, 3 – pumping station of 1-st degree, 4 – water treatment station, 5 –clean water tank, 6 – pumping station of 2-nd degree, 7 – expansion tank, 8 – supply area (own elaboration based on the [4, 11])

Tab. 3. The compact list of functions of component models of exploitation multi-model of technical network system (own elaboration based on the [4, 6, 11, 32])

	Acquiring and collecting subsystem	**Processing subsystem**	**Distributing sybsystem**
Water supply system	Subsystem of water intake and accumulate	Subsystem of water treatment and transport	Subsystem of water distribution among recipients
	• acquiring water from a source • transport and accumulation of water in the well or reservoir of raw water	• transporting accumulated water to treatment plant • performing the required physicochemical and biological processes	• transporting water to the supply area • distributing water within the supply area
Wastewater system	Subsystem of wastewater receive and accumulate (catchment system)	Subsystem of wastewater treatment and transportation	Subsystem of wastewater discharge from sewage system
	• receiving wastewater from recipients • accumulating wastewater from different sources in the collectors	• gravity or pressure transporting wastewater to the sewer system • neutralization and removing colloids and suspensions (treatment of wastewater)	• removing treated wastewater from the sewage system (eg. to a river, lake, sea or ground)
Heating system	Subsystem of heat generation	Subsystem of heat transport and transfer	Subsystem of heat distrinution among recipients
	• heating water or steam	• supplying heat to substations • exchanging heat in nodes of substation between external and internal networks • transporting cooled water to the heat source	• transporting heat to the supply • distributing heat within the supply area • discharging cooled water to the main network

In exploitation practice, systemic models supporting functioning of the technical network systems and assessment of their use, can be the basis the development of methods and tools for process monitoring realized with participation of objects discussed here. Typical representatives of such tools are Supervisory Control And Data Acquisition system (SCADA) [7, 26], Sample screen of SCADA system for monitoring the sewage network is shown in Fig. 3.

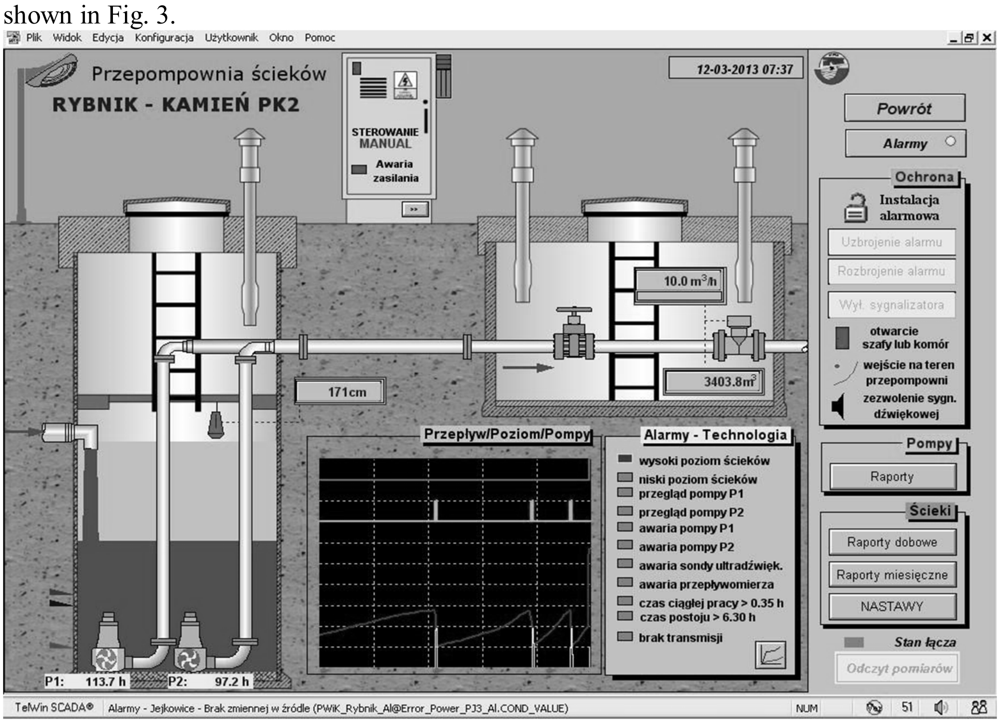

Fig. 3. Sample screen of SCADA system called TelWin

In this particular case (Fig. 3), SCADA system named TelWin of TEL-STER is used to support the monitoring of selected operating parameters of the sewage network and to carry out diagnostic monitoring the functioning particular network components.

4.2 Exploitation hierarchical models of technical network systems

Exploitation hierarchical models of technical network systems, enable the identification of the components on an aggregated level (for particular sub-structures, and the structure as a whole), for the needs of realization of maintenance works and exploitation analysis. They may at once be based on two complementary schemas [8, 15, 16]:

1. Hierarchical group models, describing technical network system, in terms of features belonging to the specified class (group) of objects.
2. Hierarchical individual models, built on the basis of group models, reflecting the features of structures associated with a specific location of operation. These relationships can be represented by division and decomposition of fragment of network into units, subassemblies and parts.

Scheme of technical network system is shown in Fig. 4.

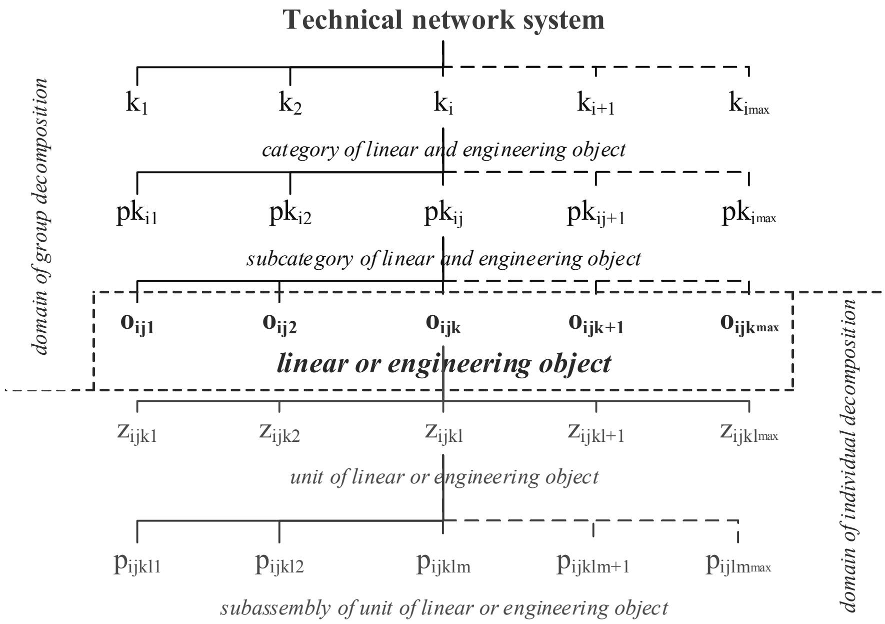

Fig. 4. Hierarchical model of technical network system

The hierarchical model (shown in Fig. 4) of technical network system, assumes complete decomposition of a technical object, with regard:

- domain of group decomposition, as a range of arrangement of separate technical objects and their locating within the technical system, and/or to the closer environment of the system,

– domain of individual decomposition, as a range of arrangement of subassemblies and parts, which are components of objects, distinguished within the area of group decomposition.

Into exploitation practice, hierarchical models supporting maintenance supervision are the basis of computer tools supporting maintenance management tasks (CMMs/EAM systems or overhaul modules of ERP systems) [10, 15, 22]. Hierarchical arrangement of components allows the transfer of feature values (e.g. cost, failure causes, indicators) „up" of structures, with a simultaneous their accumulated into within the relevant of the parent components. An example of a hierarchical model of the wastewater system, defined within the MAXIMO system, is shown in Fig. 5.

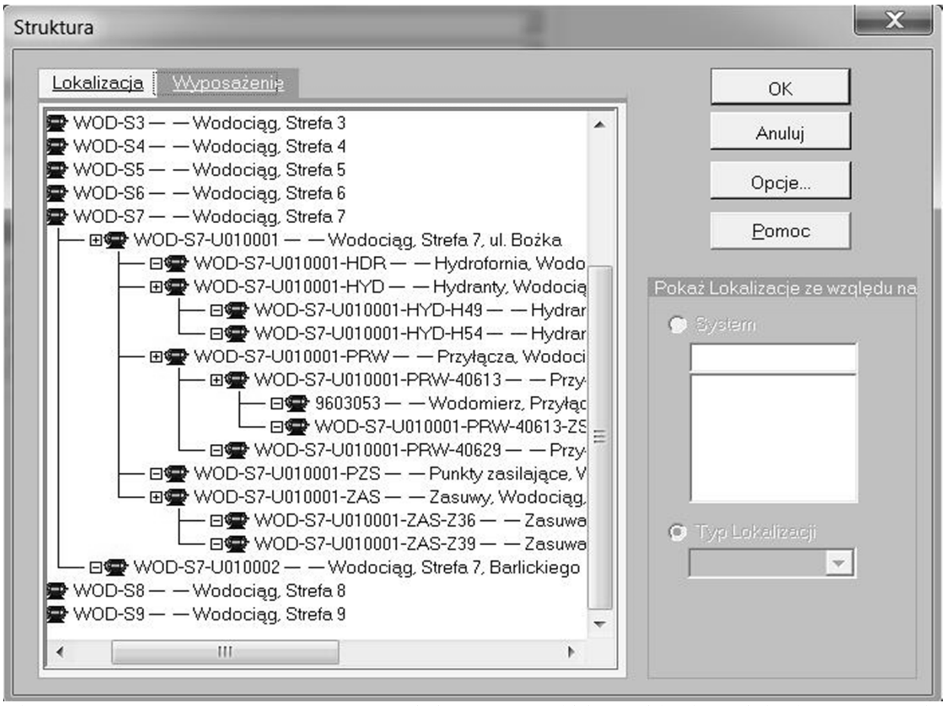

Fig. 5. MAXIMO system screen containing a part of hierarchical model of water supply system including flange valve DN 250

4.3. Exploitation topological models of technical network systems

The form of exploitation topological model for considered class of objects – technical network systems, can be based on the general conditions described, among others, in [5, 12]. Developed concept aims to locate technical objects:

– directly, in reference to other technical objects, which are components of considered technical network system, with preserving and taking into account types of relationships discussed earlier (systemic model and hierarchical model),
– indirectly, in reference to technical objects, that are not components of considered technical network system, but which are valuable reference to the points and fields in defined area.

Realization of the assumptions is based primarily on identifying topological definition of the components of technical network system, with regard form of an unambiguous representation of the objects. Next, there is identified topological definition of reference area having regard to the coordinate system, which is adequate for analyzed technical network system. As a consequence, it should lead to valuating topological features, describing relationships between components of technical network system, and the reference area.

Considering the terrain specificity of exploitation of technical network systems, it can be assumed, that the technical objects belonging to the technical network system should be represented by vector notation, where:

- linear objects are a set of segments (vectors) and they are identified by the beginning and ending coordinates (1-D),
- engineering objects are a set of points, which describes locations of objects in the assumed coordinate system (0-D).

In this case, the reference area should be raster map of the terrain, where the technical network system operates. Tt is worth to take attention to the fact, that the use of topology information for exploitation decision-making process results not so much from collecting and using location data of objects, but it involves opportunities of decomposition of defined thematic classes specified by the layers. This allows you to build a model of connections of technical network system in a different context than the systemic and structural, with regard to the objects which do not belong directly to the system, but which affect its functioning. In this way, we can distinguish two variants of topological arrangement of technical objects with simultaneous aggregation of classes, particularly (Fig. 6):

1. Variant no. 1, in which a layer includes an ordered set of technical objects having common or similar features of classification, directly involved in performing specific function of the technical system (e.g. layer 1: a set of objects performing an electrical function – electric subsystem, layer 2: - a set of objects performing a transportation function – transport subsystem). The structure of such a model includes static arrangement of separate thematic layers, allowing the aggregation of the features of objects in the sense of performed functions (Fig. 6a).
2. Variant no. 2, in which there are:
   - the layer (the layers) identifying components of the technical network system arranged using the systemic model,
   - the layers identifying components of environment not belonging directly to considered technical network system, and which are potential physical positions of technical objects.

   In this way it is possible to aggregate exploitation information on components of the technical network system in terms of various forms of the environment (neighbourhood), e.g. in relation to the supply zones, districts or streets (Fig. 6b).

Application of topological models within the exploitation multi-models allows to increase significantly current classical opportunities of aggregation of the features for the purpose of exploitation analysis, and hence to exploitation decision-making process. Within exploiting technical network systems, variant no. 1 is dedicated mainly large and geographically undispersed subsystem, having a specificity similar to the production systems (pump station, sewage treatment plant, heating plant), because it increases opportunities of selecting and grouping technical objects for exploitation analysis, regardless of the space (location) of their operation. On the other hand, the second variant is typical for applications in the field of territorially dispersed subsystems, with using the features of the space (terrain) of the exploited technical system and objects functioning in it, which do not belong directly to the analyzed technical system. This allows for research exploiting objects in the urban environment. Proposals and examples of similar works in the field of exploitation analysis in urban environment presented, among others, in [23, 24, 30, 31].

a. b.

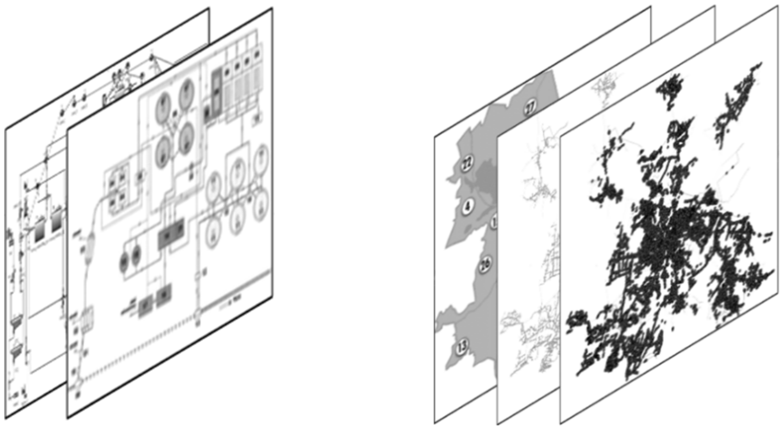

Fig. 6. Examples of variants of topological arrangement of technical objects: a. variant 1 - a set of two layers of subsystems of wastewater system (sewage treatment plant), b. variant 2 - a set of three layers of geographical dispersion of technical objects of water supply system

In exploitation practice, topological models may complement management tasks relative to technical network infrastructure, in the field of identifying, selecting and locating individual components, both for current activity (dispatching), as well as developing analytical and decision summaries (planning). An exemplary of this class of system is EC.GIS of Globema company (Fig. 7).

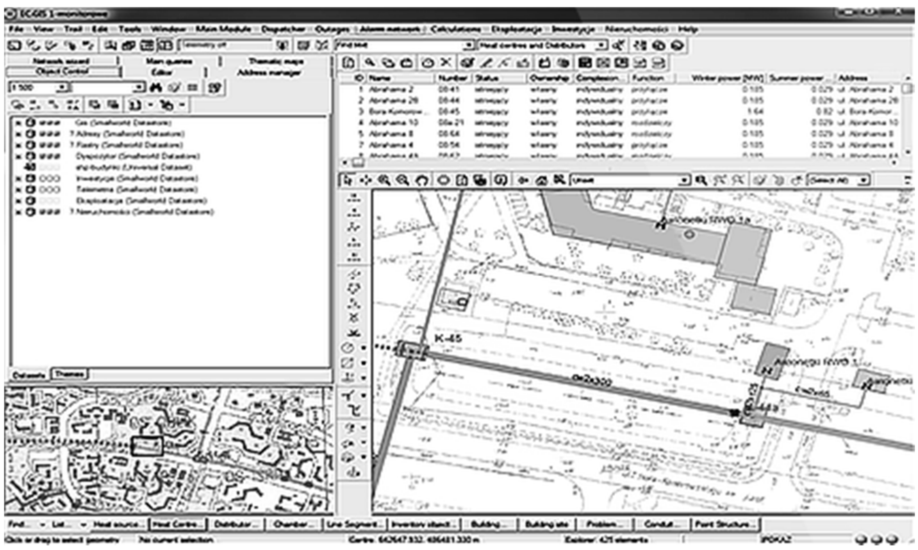

Fig. 7. EC.GIS system screen of Globema containing spatial visualization of sample part of heat distribution network [25]

The screen of EC.GIS (Fig. 7) shows the module, which allows to estimate the financial outlay for the expansion, maintenance or renovation of the heating network with using topological models and GIS technology.

4. Summary

Described in this paper a comprehensive way to describe technical systems operating within the municipal engineering extends the capabilities of hierarchical way of modelling previously used in maintenance management. This allows for solving analytical problems, the effects of which are reflected within the exploitation decision-making process.

Typical applications area of proposed way of modelling is the municipal engineering, which results from the specificity of functioning in the area of the objects and technical systems, mostly - technical network systems. This does not exclude the possibility of using exploitation multi-model for production systems as well.

It should be noted, that practical application of exploitation multi-model concept lies in its implementation within the available maintenance management supporting tools. This requires an unambiguous mathematical definition of the multi-model. The specificity of technical systems of municipal engineering, in particular network nature of subsystems, justifies the choice of graph description and matrix model associated with it.

Attempt to solve this particular problem has already been taken. The results of this research, carried out within municipal engineering, will be the subject of the next author's publication.

Bibliography

1. Angelidou M.: Smart city policies: A spatial approach. Volume 41, Supplement 1, July 2014, Pages S3–S11.
2. Bartnicka J., Mleczko K.: Doskonalenie e-usług publicznych z uwzględnieniem potrzeb osób o różnych typach niepełnosprawności, Roczniki Kolegium Analiz Ekonomicznych, 2014, z. 33, s. 599-617.
3. Dąbrowski M.: The supporting of exploitation and maintenance management within networked technical systems. Management Systems in Production Engineering 2015; No 2(18), pp 81-87.
4. Denczew S., Królikowski A.: Podstawy nowoczesnej eksploatacji układów wodociągowych. Wydawnictwo Arkady, Warszawa 2002.
5. Eckes K.: Modele i analizy w systemach informacji przestrzennej. Uczelniane Wydawnictwa Naukowo-Dydaktyczne Akademii Górniczo-Hutniczej, Kraków 2006.
6. Górecki J., Sieci cieplne. Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław 1997.
7. Ip W.H., Lee K.C., Yung K.L., Yam R.: SCADA in an integrated maintenance management system. Journal of Quality in Maintenance Engineering, 2000, Vol. 6 Iss: 1, pp. 6 - 19.
8. Kaźmierczak J.: Eksploatacja systemów technicznych. Politechnika Śląska, Gliwice 2000.
9. Kelly A.: Strategic Maintenance Planning. Butterworth-Heinemann, 2006.
10. Kłos S., Patals-Maliszewska J.: The impact of ERP on maintenance management. Management and Production Engineering Review, 2013, Vol. 4, No. 3, pp. 15-25.
11. Knapik K., Bajer J.: Wodociągi. Wyd. Politechniki Krakowskiej, Kraków 2011.

12. Lewandowicz E.: Modele topologiczne danych przestrzennych. Roczniki Geomatyki, 2007, t.5, z.5, str. 43-53.
13. Loska A. Modelling of decision-making process using scenario methods in maintenance management of selected technical systems. International Journal of Strategic Engineering Asset Management, 2015 Vol.2, No.2, pp.190 - 207.
14. Loska A. Review of opportunities and needs of building the SmartMaintenance concept within technical infrastructure system of municipal engineering. w: monografii pod red. R. Knosali: Innowacje w Zarządzaniu i Inżynierii Produkcji, Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2015, Konferencja Innowacje w Zarządzaniu i Inżynierii Produkcji, Zakopane 2015, tom 2, str. 544-555.
15. Loska A. Wybrane aspekty komputerowego wspomagania zarządzania eksploatacją i utrzymaniem ruchu. Monografia. Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2012.
16. Loska A., Senczyna S., Kaźmierczak J.: Modelowanie struktury technicznej przedsiębiorstwa dla potrzeb komputerowego wspomagania zarządzania eksploatacją. Ekonomika i Organizacja Przedsiębiorstwa, Instytut Organizacji i Zarządzania w Przemyśle „ORGMASZ", nr 6, sierpień 2007, str. 81-82.
17. Loska A.: Methodology of variant assessment of exploitation policy using numerical taxonomy tools. Management Systems in Production Engineering 2015; No 2(18), pp 98-104.
18. Loska A.: Scenariuszowy moduł obsługi polityki eksploatacyjnej - SMOPE. Czasopismo Mechanik 7/2015, str. 469-478, XVIII Międzynarodowa Szkoła Komputerowego Wspomagania Projektowania, Wytwarzania i Eksploatacji, Jurata 2015.
19. Loska A.: Variant assessment of exploitation policy of selected companies managing technical network systems. Management Systems in Production Engineering 2015; No 3(19), pp 179-188.
20. Neirotti P., De Marco A., Corinna Cagliano A., Mangano G., Scorrano F.: Current trends in Smart City initiatives: Some stylised facts. Cities, Volume 38, June 2014, Pages 25–36.
21. Nowicka K.: Smart City – miasto przyszłości. Gospodarka Materiałowa i Logistyka, 2014, nr 5, pp. 2-6.
22. Orłowski C., Lipski J., Loska A. Informatyka i komputerowe wspomaganie prac inżynierskich. Polskie Wydawnictwo Ekonomiczne, Warszawa 2012.
23. Paszkowski W.: Identyfikacja cech diagnostycznych w ocenie środowiska zurbanizowanego zagrożonego hałasem. Czasopismo Mechanik 7/2015, str. 637-644.
24. Paszkowski W.: Innowacyjna metoda oceny hałasu drogowego w środowisku miejskim. w: monografii pod red. R. Knosali: Innowacje w Zarządzaniu i Inżynierii Produkcji, Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2015, Konferencja Innowacje w Zarządzaniu i Inżynierii Produkcji, Zakopane 2015, tom 2, str. 810-818.
25. Strona internetowa http://www.globema.com - strona domowa oprogramowania EC.GIS.
26. Studziński J.: Kompleksowe zarządzanie miejską siecią wodociągową w oparciu o systemy GIS, SCADA i modele matematyczne. „Wodociągi i Kanalizacja" 12/2011.
27. Szulc T.: Analiza możliwości wdrożenia koncepcji Total Productive Maintenance (TPM) w organizacjach użyteczności publicznej. Czasopismo Mechanik 7/2015, str. 821-830. XVIII Międzynarodowa Szkoła Komputerowego Wspomagania Projektowania, Wytwarzania i Eksploatacji, Jurata 2015.

28. Wolniak R. Skotnicka-Zasadzień B.: Perceptions of people with disabilities of architectural barrier on the example of the Municipal Office in Katowice. International Multidyscyplinary Scientific Conference on Social Sciences and Art. SGEM 2014, Bułgaria, pp. 1025-1032.
29. Wolniak R.: Factors related to architectural barriers quality of customer with disability service in Siemianowice city offices, The Annals of the University of Bucharest, Economic and Administrative Series, Vol. 8, 2014, pp. 35-46.
30. Wyczółkowski R.: Inteligentny system monitorowania sieci wodociągowych. Eksploatacja i Niezawodnosc – Maintenance and Reliability 2008; 1 (37): 33-36.
31. Wyczółkowski R.: Metodyka detekcji i lokalizacji uszkodzeń sieci wodociągowych z wykorzystaniem modeli przybliżonych. Wydawnictwo Politechniki Śląskiej, Gliwice 2013.
32. Żuchowicki A.W.: Odprowadzanie ścieków. Wydawnictwo Uczelniane Politechniki Koszalińskiej, Koszalin 2002.

Dr inż. Andrzej LOSKA
Politechnika Śląska
Instytut Inżynierii Produkcji
Wydział Organizacji i Zarządzania
41-800 Zabrze, ul. Roosevelta 26-28
tel.: (0-32) 277 73 63, fax: (0-32) 277 73 62
e-mail: Andrzej.Loska@polsl.pl