REVIEW OF OPPORTUNITIES AND NEEDS OF BUILDING THE SMARTMAINTENANCE CONCEPT WITHIN TECHNICAL INFRASTRUCTURE SYSTEM OF MUNICIPAL ENGINEERING

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Abstract: Article includes an overview of the opportunities and needs of supporting decision-making process related to the operation of technical systems functioning within the municipal engineering. For this purpose, at the beginning, it was carried out a review of solutions developed within the framework of the idea of SmartCity. On this background, it has been discussed and assessed exploitation specificity of technical infrastructure systems functioning in the area of municipal engineering. In this way, it was proposed and characterized SmartMaintenance concept, as the basis of developing method and system, for supporting assessment and shape of exploitation policy and exploitation decision making process, which is realized into municipal engineering environment.

Key words: SmartMaintenance, SmartCity, maintenance management, exploitation policy, exploitation decision-making process

1. Introduction

The development of municipal centers, both small towns and large urban areas is planned and implemented more and more frequently in terms of the idea of SmartCity. This concept is based on the appropriate selection of advanced technical, organizational and information solutions, for the needs of sustainable development of local communities in the economic, environmental and social aspects [1, 26, 28, 29, 39].

Using the innovative technological developments, the aim is to build a so called. smart cities, which are characterized by a high level of safety, an efficient multi-aspects communication, failure-free transmission media etc. [27]. This concept is so "fresh", that it is currently difficult to point out a fully operative and integrated municipal environment, which functions in accordance with the SmatCity idea.

Research and practical solutions, carried out in this area, focus on:

- developing intelligent systems useful for managing staff and residents, including intelligent power systems (smart grid), intelligent measurement systems (smart metering), intelligent lighting systems (smart lighting) and others [7, 11, 18],
- developing methods of integration of developed solutions of smart subsystems, in terms of both the tool and the information [1, 16, 26],
- implementing the developed solutions in selected municipal environments, than monitoring and assessing the effects of actions taken [2, 17].

Apart from the undoubted potential benefits of the SmartCity concept, we should pay attention to problems and limitations of such apply. One of the major problems, which may be significantly interfering with effective realization of the SmartCity objectives is unreliability (level of reliability) of particular components of the implemented technical

solutions. Such unreliability is related to the physical and organizational phenomena of exploiting of technical systems [21]. In particular, the use of high-tech technologies generates additional operate and maintenance issues. This contributes to increase the degree of wear of intelligent systems components and, consequently, events occur. There are fairly problematic and difficult to control, especially in the initial period of exploitation.

Therefore, in addition to the development and implementation of innovative, intelligent and technologically advanced solutions, which significantly can improve the efficiency of technical infrastructure and quality of life of municipal residents, a key aspect of the SmartCity concept seems to be a rational exploitation policy covering both the operation and maintenance tasks.

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2. Review of sub-systems operating within the technical infrastructure of municipal engineering

The term "municipal engineering" is associated with occurrence of sectors, which are the subject of the construction and operation of technical objects for so called communal (local) technical infrastructure system [6, 23, 12]. The use of such system allows and/or facilitates the execution of key tasks of public utilities, which meet the material-living needs of population in the municipal environment [5, 24].

In this sense, municipal engineering should be considered in two aspects:

- in the tangible aspect (technical, structural) as a set of facilities/technical systems, whose operation allow implementation and support the implementation of individual actions of public utilities,
- in the intangible aspect (social, functional), as a set of exploitation activities (operate and maintenance) performed in relation to the aforementioned facilities/technical systems, whose implementation is sufficient to fulfill the tasks of public utilities.

Execution of the tasks of public utilities requires the use of technical components, which are located within the subsystems of municipal (local) technical infrastructure [5], among which the most important are:

- water supply and sewerage subsystem, including technical components whose function allows and/or supports the collective water supply to customers (residents) and discharge of domestic, economic and precipitation sewage,
- energetic subsystem, including technical components whose function allows and/or supports the supply of energy utilities (electricity, heat, gas) to customers,
- transportation and communication subsystem, including technical components whose function allows and/or supports the efficient and safe movement of people and vehicles within the city and outside,
- telecommunication subsystem, including the technical components whose function allows and/or supports the providing access residents to telecommunications services,
- waste management subsystem, including the technical components whose function allows and/or supports the collecting, sorting and storaging waste and their transportation to facilities for storage or disposal,
- cleanliness and greenery subsystem, including the technical components whose function allows and/or supports the cleaning of roads and public squares, fighting

the slipperiness of the road in the winter, as well as the constant care and maintenance of green areas.

The execution of planned tasks within these sub-systems and, consequently exploitation of the individual technical components is regulated by a number of formal requirements and guidelines including in [31 - 38], but also it should be subject to strategic planning of their sustainable development with the use of appropriate tools [30].

Objectives of the vast majority of the aforementioned subsystems is to provide of adequate resources or services to residents, It means that, in structural terms, analyzed technical systems has technical network systems specificity [4, 22]. Exploitation specificity of municipal subsystems requires to ensure co-efficient operation of all key components within an extensive technical infrastructure geographically dispersed over a large area. Therefore, such systems are characterized by a number of specific features, which include:

- high cause-effect relationship of individual subsystems in terms of operate and maintenance,
- high structural complexity, large number and variety of types of objects within the system, powerful links and relationships between system components,
- territorial dispersion of the system components,
- specific location of system components, often difficult to access - underground, at a height,
- high dynamics 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.

These features determine specific capabilities and limitations of maintenance tasks, that differ from the tasks in typical industrial enterprises focused on the production line exploitation.

3. The SmartMaintenance concept

For these reasons, there is a need for research and development of supporting maintenance management solutions of technical infrastructure functioning within the municipal engineering, driven by the idea Smart City.

The proposed concept in this regard, named by the author SmartMaintenance, includes the development of models, methods and tools adapted to requirements of exploiting of municipal engineering system and, at the same time, meets the requirements of the SmartCity. In particular, SmartMaintenance is going to shape and support the realization of technical, organizational and economic tasks, 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.

The study of such formulated objective is characterized by high complexity, both in terms of envisaged outcomes (computer support system), as well as in the form of a multiplicity of possible and/or necessary pathways achieving end results. Therefore first of all, the author carried out the study and conceptual inventory in the field:

- identifying exploitation research problems within the SmartMaintenance concept of localized municipal engineering,
- the general way of implementation of the SmartMaintenance concept,
- reviewing and assessing existing support solutions of management of technical infrastructure in the municipal engineering area,

– developing guidelines for building integrated support system under assumptions of SmartMaintenance.

4. Exploitation research problems within the SmartMaintenance concept

Exploitation practice generates a lot of new problems and recalls the existing that are and not yet resolved. It forms a range of different issues, which require work carried out both on the basis of theoretical models of technical systems, as well as experience of maintenance organization.

The research activity of development of methods and tools within the SmartMaintenance concept should be considered in multi-aspects conditions, constituting the conjunction of exploitation theory [10], exploitation engineering [9] and maintenance management [21]. Thus, the area of the intended work can be identified and visualized in the form of the three-dimensional multilayered arrangement of exploitation research problems (Fig. 1) [19].

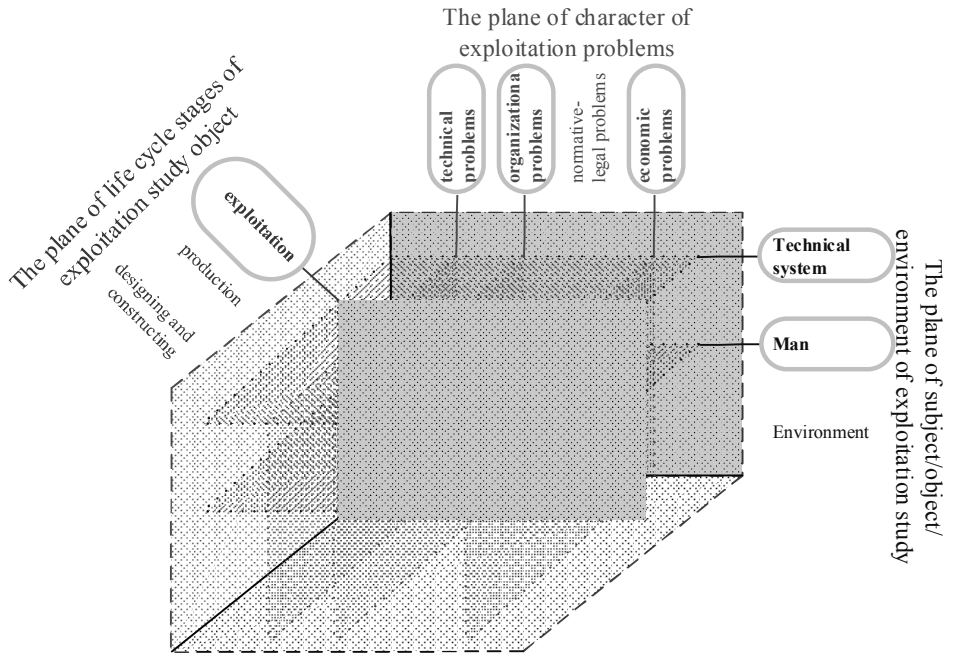


Fig. 1. Location of the SmartMaintenance concept in the three-dimensional multilayered arrangement of exploitation research problems [19]

Three-dimensional multilayered arrangement of exploitation research problems model assumes to take into account certain relationships between three planes (Fig. 1):

– the plane of character of exploitation problems, resulting from a range of operate and maintenance types of work needed to be done, in relation to individual and analyzed municipal engineering subsystems,

- the plane of life cycle stages of exploitation study object, resulting from the need to identify the characteristics of the individual components of built and exploited smart solutions,
- the plane of subject/object/environment of exploitation study, resulting from the need of technical functioning of municipal infrastructure in the external environment. involving a human operator in the analyzed processes.

Particular planes define the scope of the undertaken exploitation research. However, due to the essence of multi-ascpects conditions of the analyzed exploitation processes within the concept SmartMaintenance, interplanar relationships are also important. In particular:

- relationships between elements within a single plane determine purpose and scope of solving the already-specified exploitation research tasks in more detail and depth (e.g. analysis of the exploitation efficiency problem of technical subsystem, not only based on current and historical results of the operate process, but also including the defined and modified constructional features), the formulation of new problems becomes multithreaded, and thus complex (e.g. maintainability problem of municipal engineering subsystems should include not only the technical ability to perform appropriate service or repair tasks, but also their economic viability, taking into account the potential of organizational and legal requirements),
- interplanar links are a driving force in the area of exploitation research, becoming the main driver of innovative solutions in the context of methods, operational technical means and appropriate attitudes. (e.g. problem of the functionality of technical objects should be considered in the context of all three planes, because it is the issue of the optimization accordance with the criteria resulting from the relationship between the technical object – its features, and a operator/serviceman, in view of organizational, economic and normative-legal conditions, assuming proper exploitation culture).

It can be concluded, that the purpose of the research, necessary to develop the SmartMaintenance concept in the municipal engineering area, are technical, organizational and economic characteristics of exploited (used and supported) technical subsystems, as a result of decisions and undertakings given by the man in defined environments (closer and more distant). It influences the effect of relationship „current/passed exploitation decision – the future condition of the exploited technical system" [20].

It should be noted that each of the above and characterized subsystems can be assigned to two groups of characteristics.

1. Common features of a technical and organizational characteristics, which include [5]: technical indivisibility (utility) of the particular subsystems, relatively long periods of formation, required long periods of use, required large investments, monopolistic nature of the activities. These features underpin the need to undertake the problem of maintenance management in an integrated comprehensive approach.
2. Distinct features of exploitation characteristics, in the field of the operate and maintenance specificity of particular technical objects. These features make it necessary to customize of modeling of various exploitation processes.

5. The general way of implementation of the SmartMaintenance concept

The main objective of the proposed solution is to support exploitation decision-making process, using the information gathered during operate and service works. For the needs of the individual tasks, there were selected relevant partial solution and it was carried out their information integration. Schematic diagram of the proposed method is shown in Fig. 2.

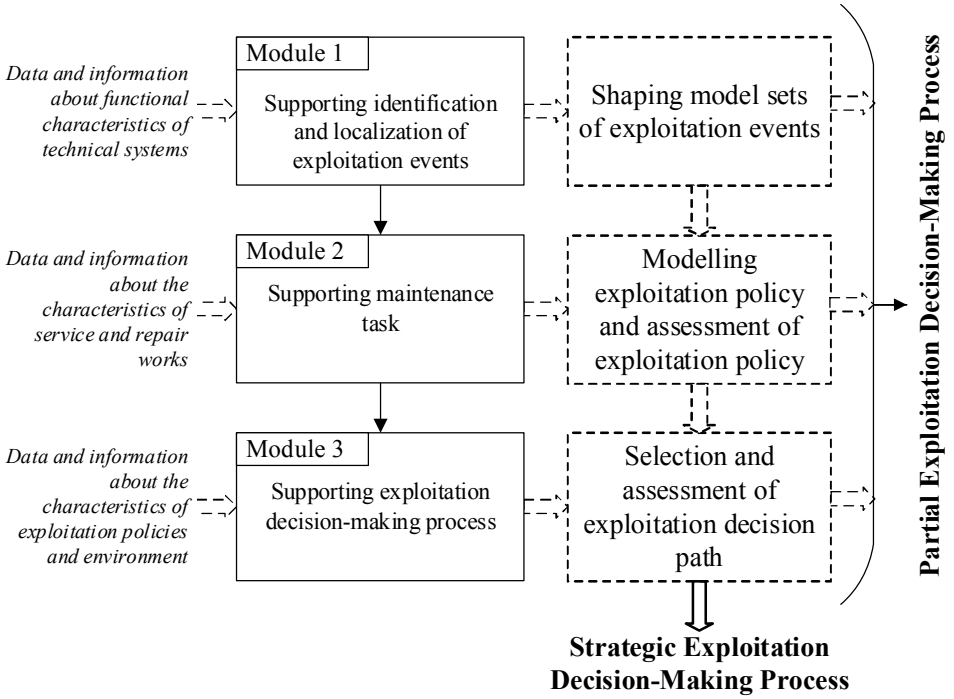


Fig. 2. Schematic diagram of SmartMaintenance concept (*own elaboration*)

The procedure for implementing the SmartMaintenance concept includes three task-tool modules, which differ in the scope of the data collected and the role of the individual components in the overall concept. It should be distinguished:

1. Module of supporting identification and localization of exploitation events, which covers the operate area. It involves the collection and processing of data and information about functional characteristics of the various parts of the technical systems, for modeling description sets of exploitation events.
2. Module of supporting maintenance organization, which covers the maintenance area. It involves collecting and processing data and information about the characteristics of service and repair works, for modeling exploitation policy and assessment of exploitation policy.
3. Module of supporting exploitation decision-making process Its function involves processing the data and information about the characteristics of exploitation policies in view of the defined environment characteristics, for the selection and assessment of exploitation decision path.

According to the proposed concept, the implementation of the decision-making process can be carried out in two directions:

A. The horizontal direction (horizontal path in the Fig. 2) - which is the subject of partial exploitation decision-making process, whose intention is to support selected aspects of the operate and maintenance processes (e.g. failure identification, workload analysis of maintenance tasks, assessment of the effects of increasing the frequency of visual inspection). In this perspective, each of these modules can be separate support solution, based on individual models and data structures, as well as ways of using them.
B. The vertical direction (vertical path in the Fig. 2) - which is the subject of strategic exploitation decision-making process (e.g. assessment of exploitation policy of water supply system, scenario shaping of exploitation decision-making process of municipal engineering system). Smart Maintenance concept requires access to consistent data and information resource. So, the effective implementation of exploitation decision-making process in respect of the integrated system of technical infrastructure of municipal engineering is the result of information synthesis of all these modules in the field of functionality of all subsystems.

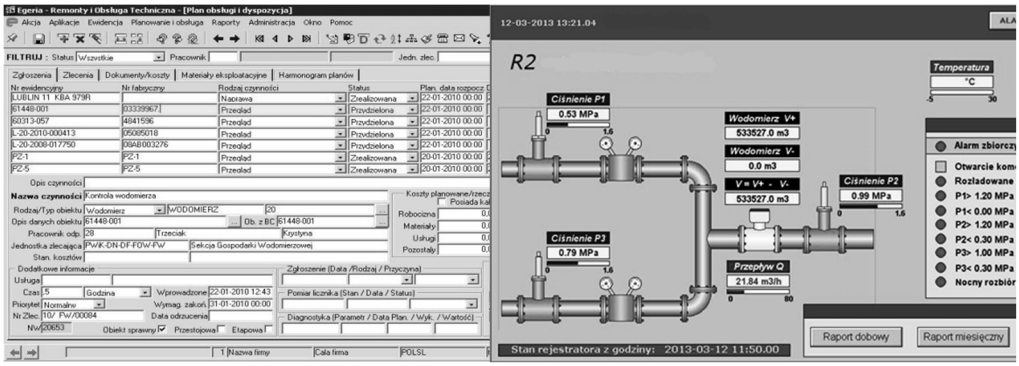
6. Overview of possible support solutions, useful within the SmartMaintenance concept

Within the application meaning, and in line with the SmartCity idea, design and development of SmartMaintenance must consider and use existing conceptual and tooling solutions, being coherent part of a larger whole.

Assuming that the vast majority of municipal engineering subsystems have network structure, there was carried out the recognition of ways and tools of supporting the realization of exploitation processes into selected technical network system. In this way, there have been identified and distinguished three groups of tools, the most common and most commonly used in the task area discussed here:

1. Computer tools supporting monitoring of operating parameters, used to acquisition, record, and consequently, processing data and information on key exploitation features, for the purpose of the diagnostic supervision of engineering equipment. Typical representatives of this group of tools are SCADA systems with artificial intelligence solutions. Practical example - system concept of detection and localization of leakages water supply network of PWiK Rybnik is described in [40, 41]. An exemplary screen of TelWin system of TEL-STER Sp. z o.o. is shown in Fig. 3a.
2. Computer tools supporting maintenance management tasks (e.g. CMMs/EAM systems) or the so-called overhaul modules of computer tools supporting enterprise management tasks (e.g. ERP systems), used for to acquisition, recording and processing of data and information about the technical, organizational and economic progress of service and repair works. Sample screen of the ROT module of EGERIA system of Comarch S.A. is shown in Fig. 3b.
3. Computer tools supporting spatial visualization and evaluation, used to inventory and location (on maps) components of technical infrastructure. A typical representative of this class of systems are GIS tools [4, 8, 14], and the practical example - Sonet system of Signity S.A. (Fig. 3c).

a. b.



c.

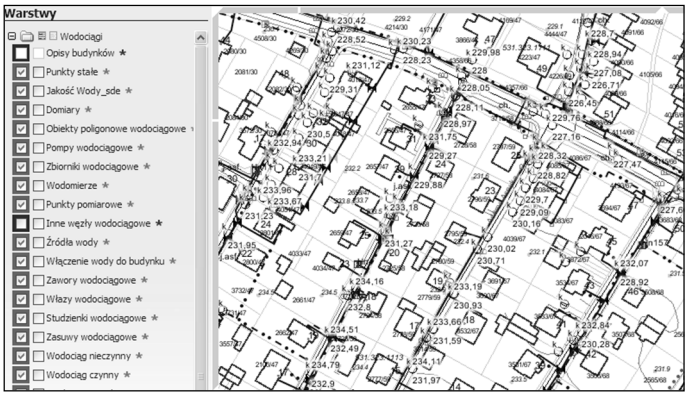


Fig. 3. Sample screens of computer tools supporting exploitation processess into technical network systems: a. screen of ROT module of EGERIA system, b. screen of TelWin system, c. screen of Sonet system (IT resources *of PWiK Sp. z o.o. in Rybnik*)

A review of methods and tools used to support the exploitation of the selected technical network systems showed [22]:

- high diversity and dispersal of information and information technology, manifested in a lack of continuity and a low compatibility tools to "produce" exploitation information, which does not constitute an analytical grounds or exploitation decision making process,
- incomplete information and utilities connections between different decision-making areas of exploitation process (e.g. separate systems supporting the identification, diagnostics, maintenance or documentation tasks),
- insufficient considering the exploitation specificities of particular technical systems,
- insufficient use of model solutions and analytical tools, especially in supporting long-term exploitation analysis and long-term exploitation decision-making process.

It should be noted, that methods and tools used in this area do not allow for full utilization of collected information about the exploited objects, exploitation events and exploitation processess, for the needs of exploitation decision-making process. In

particular, there is a clear need to supplement the information path of the exploitation processess for typical analytic and decision-making tools allowing efficient enrichment of existing management solutions. Therefore, further work will carry out both in terms of the model, as well as industrial, to develop a method and system supporting exploitation decision-making process, in accordance with the proposed SmartMaintenance concept. It includes the following task:

1. Development a method of describing the features of municipal engineering system. The aim of which is to build structural and systemic model. This will allow unequivocal localization of all features, resulting from realization of exploitation processes, as well as their use for the shaping the exploitation decision-making process.
2. Development a method of acquiring and collecting data and information from the operation of particular technical objects and perform maintenance tasks. The aim is to identify and standardization within these features and methods of measure, which have a crucial influence on exploitation decision-making process.
3. Development and testing selected methods (taxonomic, scenario) to take into account the individual characteristics in the assessment of exploitation policy and shaping exploitation decision-making process.

These activities will carry out in a manner which ensures universality of the proposed SmartMaintenance concept. This versatility lies in the possibility of support of exploitation decision-making process of municipal engineering system, which consists of any set of technical subsystems.

8. Summary

Presented in this paper, key circumstances and conditions of exploitation of selected technical systems operating within the municipal engineering, justify the need to optimize exploitation processes in the context of taking rational decisions. In order to prepare the grounds for such decisions, it seems necessary to build a coherent system of acquiring, collecting and processing data and information about the objects and exploitation tasks. A review of existing tool solutions shows high diversity in terms of functions and spectrum of their use. Also, the insufficient information integration is important at the decision-making level, which:

- makes difficulty and/or impossibility to maximize the effectiveness of the current exploitation oversight,
- makes difficulty and/or impossibility to take optimal strategic decisions in relation to the exploited systems of municipal engineering.

The solution proposed by the author, methodologically housed within the SmartCity concept, would enable development of system, supporting rational exploitation decision, and thereby it would improve the efficiency of the technical systems operated within the municipal engineering.

Works, which have been initiated and carried out at the Institute of Production Engineering of Silesian University of Technology, focus on the identification of exploitation information flow within the municipal engineering subsystems, as well as creating models of the proposed integrated support system, separately for all three modules.

These studies are supported by the participation of the Institute of Production Engineering in the framework of the Cluster of Services Development Support in the Field of Media Metering – Smart Metering. The purpose of the cluster is implementing the

SmartCity concept, through cooperation between research teams, manufacturers and suppliers of smart technology and potential customers and recipients of prepared solutions in the field of municipal engineering. Participation in the cluster will allow us to simplify paths and procedures for obtaining valuable exploitation information and opportunities for practical verification of research results.

Bibliography

1. Angelidou M.: Smart city policies: A spatial approach. Volume 41, Supplement 1, July 2014, Pages S3–S11.
2. Bakici T., Almirall E., Wareham J.: A Smart City initiative: The case of Barcelona. Journal of Knowledge Economy, 4 (2) (2013), pp. 135–148.
3. Billewicz K.: Smart metering. Inteligentny system pomiarowy. Wydawnictwo Naukowe PWN, Warszawa 2012.
4. Dąbrowski M.: Innowacyjny sposób wykorzystania modeli GIS dla potrzeb zarządzania eksploatacją systemu zaopatrzenia w wodę, Mechanik, 7/2014, pp. 363 - 372).
5. Denczew S., Podstawy gospodarki komunalnej. Współczesne zagadnienia sektorów inżynieryjnych, Wydawnictwo Politechniki Białostockiej, Białystok 2004.
6. Denczew S.: Organizacja i zarządzanie infrastrukturą komunalną w ujęciu systemowym. Szkoła Główna Służby Pożarniczej, Warszawa 2006.
7. Galán-García H.L., Aguilera-Venegas G., Rodríguez-Cielos P.: An accelerated-time simulation for traffic flow in a smart city. Journal of Computational and Applied Mathematics, Volume 270, November 2014, Pages 557–563.
8. Kaźmierczak J., Loska A., Dąbrowski M.: Use of geospatial information for supporting maintenance management in a technical network system. 21th European Congress on Maintenance and Asset Management Euromaintenance 2012, Belgrad (Serbia) 14-16 May 2012, pp. 287-297.
9. Kaźmierczak J.: Eksploatacja systemów technicznych. Politechnika Śląska, Gliwice 2000.
10. Konieczny J.: Podstawy eksploatacji urządzeń. Wydawnictwo Ministerstwa Obrony Narodowej, Warszawa 1975.
11. Koral W.: Systemy zdalnego opomiarowania w budynkach. Proceedings of the Conference „Smart Metering – wstęp do pilotażowych wdrożeń zarządzania", Gliwice 2014.
12. Krassowski K., Banach-Paszkiewicz H.: Eksploatacja lokalnej infrastruktury technicznej. PWN, Warszawa 1986.
13. Kwietniewski M., GIS w wodociągach i kanalizacji, Wydawnictwo Naukowe PWN, Warszawa 2008.
14. Kwietniewski M., GIS w wodociągach i kanalizacji, Wydawnictwo Naukowe PWN, Warszawa 2008.
15. Kwietniewski M., Rak J.: Niezawodność infrastruktury wodociągowej i kanalizacyjnej w Polsce. Polska Akademia Nauk, Komitet Inżynierii Lądowej i Wodnej, Instytut Podstawowych Problemów Techniki, Warszawa 2010.
16. Lazaroiu G.C., Roscia M.: Definition methodology for the smart cities model. Energy, Volume 47, Issue 1, November 2012, Pages 326–332.

17. Lee J.H., Hancock M.G., Hu M.Ch.: Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco. Technological Forecasting and Social Change, In Press, Corrected Proof, Available online 3 October 2013.
18. Lis A. Otwarty inteligentny system sterowania oświetleniem ulicznym. Proceedings of the Conference „Smart Metering – wstęp do pilotażowych wdrożeń zarządzania", Gliwice 2014.
19. Loska A. Modelowy przegląd badań dla potrzeb skuteczności funkcjonowania służb utrzymania ruchu przedsiębiorstwa przemysłowego. in: R. Knosala: Innowacje w Zarządzaniu i Inżynierii Produkcji, Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2013, Conference Innowacje w Zarządzaniu i Inżynierii Produkcji, Zakopane 2013, pp. 978-990.
20. Loska A. Remarks about modelling of maintenance processes with the use of scenario techniques. Eksploatacja i Niezawodnosc – Maintenance and Reliability 2012; 14 (2): 5–11.
21. Loska A. Wybrane aspekty komputerowego wspomagania zarządzania eksploatacją i utrzymaniem ruchu. Monografia. Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2012.
22. Loska A.: Modeling of decision making process using scenario methods in maintenance management of selected technical systems. Proceedings of the International Conference Maintenance Performance Measurement and Management 2013 - MPMM 2013, Lappeenranta (Finland) September 2013, pp. 219-233.
23. Makieła Z., Szromnik A. (red.): Miasto innowacyjne: wiedza, przedsiębiorczość, marketing. Studia Polskiej Akademii Nauk, Komitet Przestrzennego Zagospodarowania Kraju, t. 141, Warszawa 2012.
24. Myna A.: Modele rozwoju lokalnej infrastruktury technicznej. Wydawnictwo Uniwersytetu Marii Curie-Skłodowskiej, Lublin 2012.
25. Nantka M.B.: Ogrzewnictwo i ciepłownictwo. Wydawnictwo Politechniki Śląskiej, Gliwice 2013.
26. 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.
27. Nitkiewicz G.: Smart Metering jako narzędzie skutecznego budowania i zarządzania Smart City. Proceedings of the Conference „Smart Metering – wstęp do pilotażowych wdrożeń zarządzania", Gliwice 2014.
28. Nowicka K.: Smart City – miasto przyszłości. Gospodarka Materiałowa i Logistyka, 2014, nr 5, pp. 2-6.
29. Szulc T., Gumienny J.: Nowe Gliwice – studium przypadku rewitalizacji terenów pokopalnianych. Problemy Rozwoju Miast - Kwartalnik Naukowy, nr 3/2013, str.
30. Szulc T.: Rozwój lokalny a innowacyjne metody planowania strategicznego, w: Jasieński M. (red.): Innowatyka – nowy horyzont. Innowacyjność naukowców, przedsiębiorców, menedżerów i urzędników. Centrum Innowatyki WSB-NLU, Nowy Sącz 2014.
31. Ustawa z dnia 10 kwietnia 1997 roku - Prawo energetyczne – Dz. U. 1997 nr 54 poz. 348.
32. Ustawa z dnia 14 grudnia 2012 roku o odpadach – Dz. U. 2013 nr 0 poz. 21.
33. Ustawa z dnia 16 lipca 2004 roku - Prawo telekomunikacyjne – Dz. U. 2004 nr 171 poz. 1800.

34. Ustawa z dnia 20 grudnia 1996 roku o gospodarce komunalnej – Dz. U. 1997 nr 9 poz. 43.
35. Ustawa z dnia 21 marca 1985 roku o drogach publicznych – Dz. U. 1985 nr 14 poz. 60.
36. Ustawa z dnia 27 kwietnia 2001 roku – Prawo ochrony środowiska – Dz. U. 2001 nr 62 poz. 627.
37. Ustawa z dnia 6 września 2001 roku o transporcie drogowym – Dz. U. 2001 nr 125 poz. 1371.
38. Ustawa z dnia 7 czerwca 2001 roku o zbiorowym zaopatrzeniu w wodę i zbiorowym odprowadzaniu ścieków – Dz. U. 2001 nr 72 poz. 747.
39. Wdowiarz-Bilska M.: Od miasta naukowego do Smart City. Czasopismo Techniczne. Architektura, 2012, R.109, z. 1-A/2, pp. 305-314.
40. Wyczółkowski R., Matysiak G. Rozwój inteligentnego systemu monitorowania rozdzielczej sieci wodociągowej. Eksploatacja i Niezawodnosc – Maintenance and Reliability 2009; 2 (42): 71-75.
41. Wyczółkowski R.: Inteligent monitoring of local water supply system. Eksploatacja i Niezawodnosc - Maintenance and Reliability 2008; 1(37): 33-36.

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