ECONTECHMOD. AN INTERNATIONAL QUARTERLY JOURNAL – 2012, Vol. 01, No. 2, 63–67

Use of GIS systems in the construction of hydraulic model of networks

K. Wróbel, S. Styła, A. Sumorek

Department of Computer and Electrical Engineering, Lublin University of Technology,
20-618 Lublin, ul. Nadbystrzycka 38a; e-mail: k.wrobel@wis.pol.lublin.pl, s.styla@pollub.pl

Received March 15.2012: accepted April 25.2012

Abstract. This article presents the use of GIS system for the construction of a hydraulic model in the network enterprise. The model has been built on the basis of data associated with the objects existing in the network and with their spatial relations. The data describing the network objects are usually transferred from existing technical documentation. The local stocktaking of networks is carried out in case of any doubts regarding data update status. The preparation of properly processed data, as well as verification of their correctness while entering them into a database is the most difficult and labour consuming phase of network modelling. A properly configured network model should incorporate at least the following features: the possibility to perform comprehensive analyses of the existing system functioning as well as analyses of the system modernization and extension variants in order to optimize technical solutions.

Key words: GIS, hydraulic model, bit map, vector map.

INTRODUCTION

Since the launch of the first GIS systems (Geographic Information Systems) in early 1960s in Canada up to the present time, the number of their users increased dramatically. Their popularization was possible mainly as a result of the development in the scope of information technology and public Internet access. The methods have been created together with technical progress in order to enable the access to bit maps by means of websites, data transfer in network and finally the creation of and the access to vector maps.

GIS system is defined as an organized set consisting of hardware, software, spatially referred data and its users. The tasks of the system are as follows: acquisition, retrieval, processing, analysis and visualization of all geographical data.

The multilayer structure of graphical data is the basic feature of GIS technology. The data collected in GIS system can be illustrated in the form of editable thematic layers (Fig. 1). This solution makes it possible to assign a set of attributes to determined layer and to display only those selected by the user.

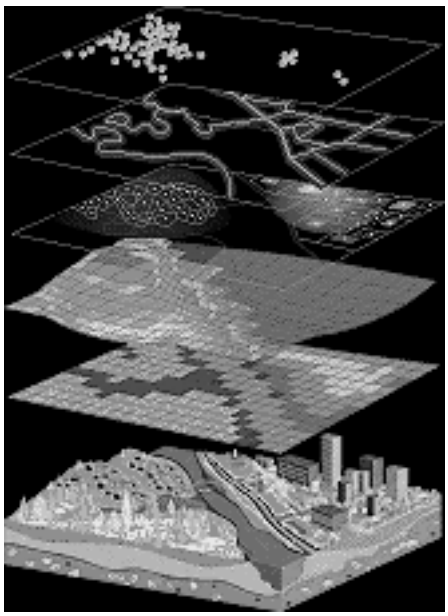

Fig. 1. Diagram illustrating an area subdivision by means of editable layers [19]

The specialized Geographic Information Systems (GIS) find a wide range of applications facilitating the decision making processes, reducing the period of time required to perform a task, performance of routine tasks associated with network inventory in network enterprises without necessity to spend several hours in the company archive of technical documentation [8, 12, 14]. The research in the scope of time saving indicated the savings in individual fields of the enterprise activity achieved as a result of the use of GIS systems, as illustrated in Table 1.

Tab. 1. Work time required for the conducting of activity in individual areas in Yokosuka City Waterworks Bureau enterprise [13]

The scope of enterprises activity	*Annual number of hours before GIS introduction*	*Annual number of hours after GIS introduction*	*Time saving [hours] [(%)]*
Water recipients service as a result of complaints	2200	600	1600 (73%)
Designing of networks	2500	700	1800 (72%)
Works associated with water supply shortage	2500	700	1800 (72%)
Granting of permits for the use of water supply systems	1800	550	1250 (69%)

A continuous improvement of the Geographic Information Systems is associated with the use of advanced mathematical possibilities supported by specialized databases. One of the most important tasks to be performed by network enterprises is to ensure the management of the whole network operation in a rational manner. However this task is not easy due to the size and extensiveness of the network as well as the spectrum of materials used for its construction and diversification of working parameters of individual fragments of this network.

ACQUISITION AND PROCESSING OF DATA REQUIRED FOR MODELLING

The network enterprises perform many tasks, among others associated with the operation, overhauling and extension of the network as well as with its inventory. GIS systems are an excellent tool designed for execution of various analyses represented in the form demanded by the user and for the disclosure of potential problems before they progress to serious symptoms disturbing correct operation of the network. In course of the creation of GIS database, only the latest information describing the factual state of the network is entered. The local stocktaking of networks is carried out in case of any doubts. The age of the documentation collected in the enterprise archive is diversified and its technical condition is sometimes unsatisfactory. It happens that the technical condition of the network illustrated in the technical documentation significantly deviates from its factual condition. The network inventory systems are provided in order to make it possible to quickly process and analyze the recorded data spatially associated with map as well as to make the decision in a manner adequate to existing situation [3, 9, 10].

The software available on the domestic and global market is sufficient to support the operation processes, to enable the measuring data support and the integration with AM/FM (Automated Mapping/Facilities Management) and SCADA (Supervisory Control And Data Acquisition) systems. Therefore it is possible to use the digital or vector maps only with background bitmap for the visualization of the network layout as well as the integration of 3D data and descriptive network objects, network operation status and the works in progress [15, 18].

The majority of GIS systems is equipped with the functions enabling the execution of economic – spatial analyses in order to compare the costs of various variants of network extension and to evaluate the impact of intended construction of the network on hydraulic and reliability characteristics of the whole system. The purpose of the creation and implementation of the system is [5, 9]:

- to collect the data in single point in order to expedite decision making process;
- to increase the efficiency of business processes, exploitation works as well as to identify the locations of failures and their elimination;
- to increase the efficiency of engineering department and emergency service operation;
- to improve the supervision over the time of works carried out in the field;
- to furnish a complete and updated database for network operations parameters in order to create the modelling system based on that database.

The construction of a complete GIS system needed for mathematical model can be subdivided into several phases [1, 9]:

- preparation and elaboration of updated documentation required for the creation of database;
- digitalization of principal maps with S and U patch in the network presence location;
- data entry, verification and updating by the personnel employed in an enterprise, most frequently by employees of engineering departments (local stocktaking of networks is carried out in case of any doubts);
- ordering, analysis and elaboration on the basis of entered data and information from technical documentation, preparation of data for modelling by means of properly simplified methods used to describe individual objects.

As early as 15 year ago, the designers commenced the creation of electronic engineering drawings by means of computer software e.g. AutoCad or similar type. The preparation of the technical documentation in hardcopy format and in electronic version is mandatory in major part of enterprises. The laws of Poland contain the technical (geodetic) manuals determining how to create the maps and information recorded therein. The principles in this scope have been established in order to eliminate the problems associated with maps preparation at an

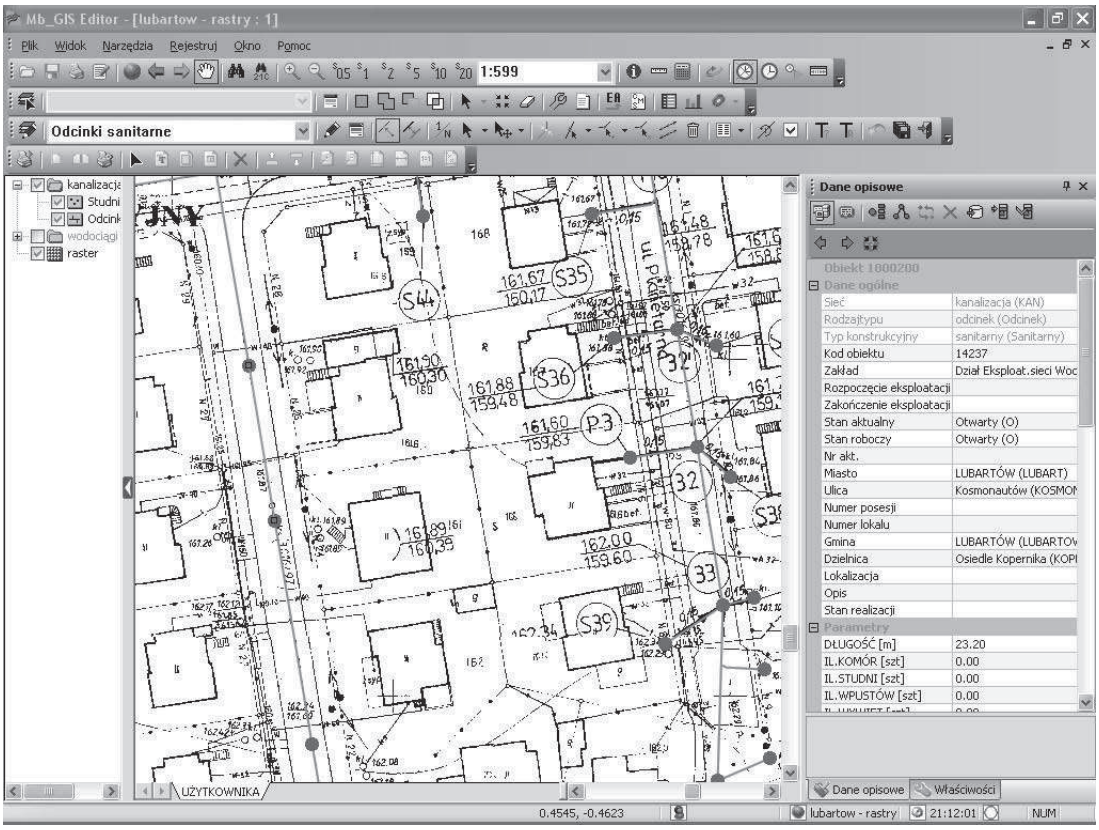

Fig. 2. The layout of network in the connection of oriented graph of the network (3D data) with descriptive data in Mb_GIS Edytor program using a bit map [16]

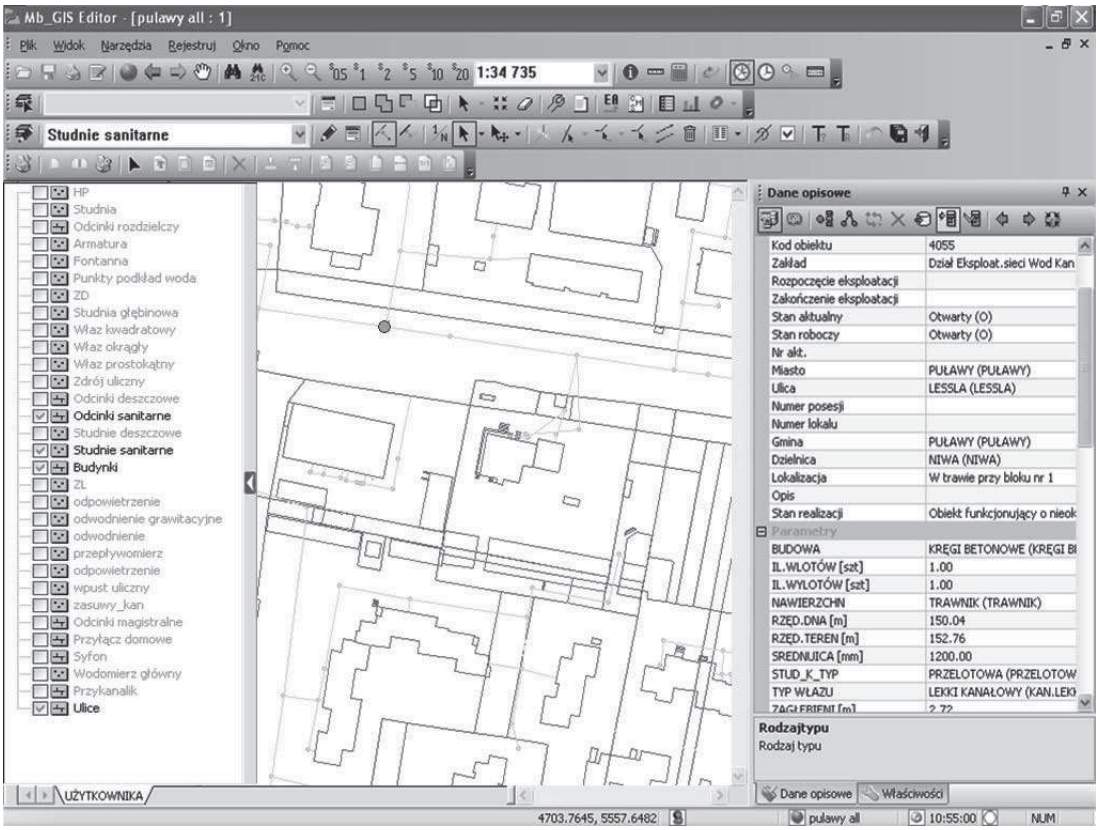

Fig. 3. The layout of network in the connection of oriented graph of the network (3D data) with descriptive data in Mb_GIS Edytor program using a vector map [2]

individual discretion or with the use of symbols conforming with regional habits. However, despite the use of GIS system in various disciplines, there are still no uniform standards and guidelines describing an unified approach to the creation of electronic versions of technical documentation [6, 17]. Most commonly encountered problems associated with the creation of electronic versions of technical documentation are:
– creation of the whole drawing in one layer only (usually "0") and diversification of individual elements by means of various thickness of line;
– lack of colour concept for drawings presented in geodetic manuals for the creation of principal maps;
– individual drawings are drawn in various scales, instead of 1:1;
– use of various styles and sizes of fonts;
– use of diversified nomenclature and symbols;
– drawing of networks in a manner not always conforming with media flow direction.

NETWORK MODEL BASED ON GIS SYSTEM

A system enabling the use of digital maps in connection with database by several users simultaneously is essential for a network enterprise. The use of vector maps and the display of network geometry shall be possible in an automatic mode, with possibility of the selection of a background bitmap (Fig. 2), a vector map (Fig. 3) or an orthophotomap [4] by the user in accordance with actual needs.

The network objects database contains detailed information about descriptive data, for individual network objects and their spatial relations. The Geographic Information System created in an appropriate manner makes it possible to collect the information about the networks at the same place and its proper presentation. Thanks to the introduction of insignificant corrections and simplifications in the description of some network objects, GIS system can be used as data source for the execution of computer simulations of the network operation.

The computer analyses in case of sewage network can be carried out [7, 11]:
– to determine the correctness of network structure described in the system,
– to simulate the runoffs,
– to determine the throughput of severs,
– to determine the level of severs filling.

The scope of analyses in case of water supply networks is similar to the scope of analyses in case of sewage networks (with consideration of changed medium transported by the network):
– to determine the correctness of network structure described in the system;
– to determine the sections of the network with insufficient values of flow rate;
– to determine the areas to be modernized in order to eliminate water stagnation;
– to determine the areas to be provided with closures in order to achieve an insignificant change of flow direction.

CONCLUSIONS

The creation of an oriented graph using the network objects parameters described with appropriate accuracy is the most labour consuming and the most difficult phase of the mapping of a real network system. Any erroneously entered data from GIS database make any accurate representation of the network operation impossible and contribute to the falsification of parameters.

The simulations of the network operation by means of properly created mathematical models are carried out to support the problems solution and to facilitate the efficient functioning of network enterprises. The basic condition to be met by the mathematical models used for this purpose is to represent really existing network features validated through the previous verification of GIS system data and their confrontation with reality.

Considering the measuring system and monitoring (existing in an enterprise) in the computer analyses of network operation, the tasks of individual units in this enterprise can be performed in a more efficient manner in the following scope:
– modernization and extension of networks – assessment of the impact of intended structures and their diameters (in design phase) on operation of the whole network;
– network operation – checking for possibility of additional loading of the network without necessity of its extension; the assessment of failure consequences associated with a sever out of service, the assessment of network utilization degree – on the basis of a network (e.g. sewage network);
– recording – control of the correctness of network data entries.

REFERENCES

1. **Adamowski W. 2008.** *Doświadczenia związane z wykorzystaniem GIS do budowy modelu sieci wodociągowej i kanalizacyjnej w MPWiK w m. st. Warszawie S.A.*. „Instal", pp. 279. Warszawa.
2. **Bondyra M. and Jałocha R. 2006.** *Zastosowanie Gis do inwentaryzacji systemu dystrybucji wody w Puławach na przykładzie Osiedla Górna Niwa*. Praca dyplomowa wykonana pod kierunkiem M. Kwietniewskiego. Politechnika Lubelska, Wydział Inżynierii Środowiska.
3. **Fedorowicz R., Kołodziński E. and Komarec R. 2002.** *Komputerowe wspomaganie zarządzania siecią w przedsiębiorstwie wodociągów i kanalizacji na przykładzie systemu WodKan, cz.1 - Zakres i możliwości komputerowego wspomagania zarządzania siecią w przedsiębiorstwie wodociągów i kanalizacji*. „Nowoczesne Techniki i Technologie Bezwykopowe", pp. 03/2002. Kraków.
4. **Fedorowicz R., Kołodziński E. and Komarec R. 2002.** *Komputerowe wspomaganie zarządzania siecią wodocią-*

gową i kanalizacyjną na przykładzie systemu WodKan cz.2 - Praktyczne zastosowania pakietu programowego symulacji statycznej dla sieci wodociągowej i kanalizacyjnej. „Gaz Woda i Technika Sanitarna" 4/2002.

5. **Grzenda M. 2008.** *Systemy informatyczne we wspomaganiu eksploatacji sieci*. „Instal", nr. 279. Warszawa.
6. **Kasprzyk Z. and Pawłowski B. 2006.** *Standaryzacja dokumentacji w budownictwie*. „Inżynieria Budowlana", nr 12.
7. **Komarec R., Fedorowicz R. and Kołodziński E. 2001.** *Symulacja komputerowa w sieciach kanalizacyjnych*. Materiały VIII Warsztatów Naukowych PTSK „Symulacja w badaniach i rozwoju". Gdańsk - Sobieszewo 2001.
8. **Kwietniewski M. 2008.** *GIS w wodociągach i kanalizacji*. Wydawnictwo Naukowe PWN. Warszawa.
9. **Kwietniewski M. 2008.** *GIS w przedsiębiorstwie wodociągów i kanalizacji – możliwości i ograniczenia*. „Instal", pp. 279, Warszawa.
10. **Kwietniewski M., Miszta-Kruk K. and Wróbel K. 2007.** *Możliwości zastosowania GIS w wodociągach na przykładzie wybranego systemu dystrybucji wody*. „Ochrona Środowiska Selected full texts rok: 2007", R. 29, nr 3, 73–76.
11. **Longley P. A., Goodchild M. F., Maguire D. J. and Rhind D. W. 2008.** *GIS. Teoria i praktyka*. Wydawnictwo Naukowe PWN. Warszawa.
12. **Myrda G. 1997.** *GIS - czyli mapa w komputerze*. Helion. Gliwice.
13. **Takahashi Y. 1992.** *Mapping System Introduced in Yokosuka City Waterworks Bureau*. IWSA Specialised Conference on Geographic Information Systems "Mapping the Future", Water Supply, vol. 10, Lyon, pp. 93-104.
14. **Tomlinson R. 2005.** *Thinking About GIS*. Revised and Updated Edition, ESRI Press.
15. **Wróbel K., Żurawski A., Kowalska B., Sobczuk H. and Łagód G. 2009.** *Przygotowanie danych oraz elementów składowych modelu sieci kanalizacyjnej z zastosowaniem GIS*. Polska Inżynieria Środowiska pięć lat po wstąpieniu do Unii Europejskiej, tom 3, pod redakcją: Marzenny Dudzińskiej, Lucjana Pawłowskiego. Monografie Komitetu Inżynierii Środowiska PAN, vol. 60, pp. 279-286, Lublin.
16. **Wróbel K. 2006.** *Zastosowanie GIS do ewidencji sieci kanalizacyjnej na przykładzie osiedla Kopernika w Lubartowie*. Praca dyplomowa wykonana pod kierunkiem M. Kwietniewskiego. Politechnika Lubelska, Wydział Inżynierii Środowiska.
17. **Zawilski M. and Wierzbicki P. 2007.** *Rola GIS w modelowaniu i monitoringu systemów kanalizacyjnych*. materiały konferencyjne: GIS Modelowanie i Monitoring w Zarządzaniu Systemami Wodociągowymi i Kanalizacyjnymi, Warszawa.
18. www.megabit.com.pl
19. www.esri.com