



POLISH ACADEMY OF SCIENCES

Systems Research Institute

**DEVELOPMENT OF METHODS
AND TECHNOLOGIES
OF INFORMATICS
FOR PROCESS MODELING
AND MANAGEMENT**

Editors:

**Jan Studzinski
Olgierd Hryniewicz**



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This book consists of papers describing applications of informatics in process modeling and management and in environmental engineering. Problems presented in the papers concern development of methods supporting process management, development of calculation methods for process modeling and development of technologies of informatics for solving some problems of environmental engineering. In several papers results of the research projects supported by the Polish Ministry of Science and Higher Education are presented.

Paper Reviewers:

Prof. Olgierd Hryniewicz

Dr. Jan Studzinski

Text Editor: Anna Gostynska

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Systems Research Institute of Polish Academy of Science
Newelska 6, PL 01-447 Warsaw

Section of Scientific Information and Publications
e-mail: biblioteka@ibspan.waw.pl

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CHAPTER 3

Tools of informatics in environmental engineering



DEVELOPMENT OF COMPUTER SYSTEM TO SUPPORT MANAGEMENT OF COMMUNAL WATER SUPPLY AND WASTEWATER NETWORKS

Jan STUDZINSKI

Systems Research Institute, Polish Academy of Sciences

<studzins@ibspan.waw.pl>

Abstract: *In the paper a project of a complex computer system supporting management of communal water supply and wastewater networks including planning and realization of their repairs and modernization is presented. Problem of communal waterworks, especially those several tens years old is their failure frequency caused by the fact, that individual parts of the nets are made of varied materials and, very often, by their incorrect work conditions. Frequent failures, for large networks, cause enormous losses of water, large costs of repairs and displeasure of inhabitants of the cities because of the waits in water supply. Nowadays in domestic communal waterworks computer aided systems supporting decision processes that counteract failures and minimize costs caused by them are not applied though now we have got adequate IT tools and equipment to develop and apply such systems*

Keywords: water and wastewater networks, computer aided decision making systems

1. Introduction

The computer system, proposed in the paper, is designed to solve the problems connected with planning repairs and modernization works of water and wastewater pipes in communal waterworks. It consists of several subsystems that realize different tasks connected with monitoring of the work of the networks (monitoring subsystem), modeling and optimization of the nets (hydraulic calculations subsystem), statistical analysis of localization and reasons of the failures (analysis subsystem), preparation of revitalization plans of the water-supply and wastewater networks (planning subsystem) and formulation of running plans of the networks in case of repairs and modernization works (control subsystem). Individual subsystems are integrated and share information. At the same time all subsystems realize their tasks using data collected in one central branch data base.

Research works will be executed by the Systems Research Institute of the Polish Academy of Sciences in Warsaw that owns a large experience in developing computer aided decision making systems won in the last ten years as a result of cooperation with the waterworks in Rzeszow, a medium size city in the East-

South part in Poland. The objects of the research will be two municipal water and wastewater enterprises in Lublin and Rzeszow that administer two water-supply and wastewater networks. These enterprises will also supply measurement data that will be used for testing the computer system and as the end users will make possible to check running correctness of the particular subsystems virtually.

As a result of the project IT tool will be developed that improves planning and execution of the modernization and repairs works in communal water and wastewater networks. Application of this tool will widely reduce failure frequency, losses of water, environmental pollution, exploitation costs of water and wastewater networks and better life conditions of the inhabitants of the cities participating in the project. It will be also possible to use new developed computer system, after its adaptation, in other municipal water enterprises.

2. The reasons for developing the computer system

Characteristic of large communal water-supply and wastewater networks, that have been built several tens years ago, with their particular parts made of varied materials and in different age, is their big failure frequency reaching several hundreds failure cases a year. Each failure causes large losses of water up to several tens percent of the whole production. Capacity of water network is dozens of thousands cubic meters a day so this brings enormous financial losses to an enterprise and widely increase exploitation costs. Failure frequency is also conditioned by the correctness of the work of the water and wastewater networks and grows rapidly when the network load is non-uniform or an unexpected pressure jump occurs in the net. To minimize failure frequency and connected with it financial and water losses particular parts of the nets must be replaced and optimization of the nets' parameters and often also of their structure must be done. For large water networks (several hundreds kilometers length and with structure that consists mostly of the rings) this is a difficult optimization task that requires the usage of advanced computer methods and sophisticated algorithms.

At present repairs and modernization plans of the water-supply and wastewater networks are prepared manually resting upon the knowledge and experience of the networks operators what means intuitively and arbitrary. When a problem to be solved is very complicated it leads mostly to not optimal solutions. Nowadays the development of modern information technologies has created the situation that formulation of computer systems supporting decision making can help to optimize these solutions. Development and implementation of such systems is connected with large financial and organizational difficulties what denotes serious barriers in their realization. Development of a computer system that supports revitalization works of the water and wastewater networks requires the involvement of a large and interdisciplinary research team including specialists in automatics, information scientists, branch engineers and software developers, and to coordinate the work of such team

is not an easy task. Large costs of the research-development works follow from the necessity of making experiments in the investigated objects, i.e. to make research measurements and to test the developed computer software. Especially good co-operation between scientists from research institutions that realize the project and employees of the investigated enterprises, which are the end users of the project, is not easy to accomplish.

The computer system that will be formulated in the frame of the research project will be built of subsystems realizing individual tasks, which are: monitoring system, hydraulic model, statistical analysis algorithm, optimization, planning and control systems. The item that will interface all modules will be branch data base of the water and wastewater networks that is usually a kern element of a GIS system installed in the waterworks for digital visualisation in form of a numerical card of the networks investigated (Figure 1).

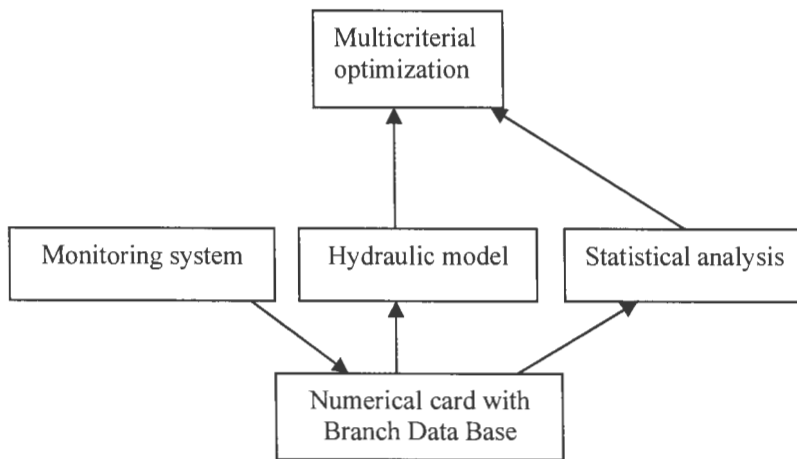


Figure 1. Main modules of the computer system proposed.

The expected profits of introducing the planned computer system into the waterworks under consideration will be as follows:

- better management of water resources, reduction of environment pollution, amelioration of the life conditions in the city. The current losses of water in the investigated waterworks are at the average level of 2 mill m³/year and there is expected to reduce them after the implementation of the system to the level of 1 mill m³/year.
- reduction of number of failures of the networks, reduction of losses of water, lower networks running costs. At the present the water supply network failure frequency equals to ca. 300/year, the wastewater network failure frequency is

about 300/year and the losses of water in the water network oscillate by 20 %. After implementing the system there is expected to reduce these numbers to 100/year in the case of the water and wastewater network failure frequencies and to 10 % by the water losses in the water net.

- possibility of using computer hydraulic models of the water supply and wastewater networks to simulate the run of the both nets. Now there is lack of such possibility in almost all Polish waterworks and with these models the current information of water flows and pressures in all network pipes as well as optimization of networks planning will be attained.
- possibility of using optimization and control algorithms for water supply and wastewater networks. Now the planning of the water and wastewater networks as well as their control are made in the manual way and as a result of the project these activities will be supported by some computer algorithms.
- automatic generation of the revitalization plans of the water supply and wastewater networks. At the present the plan for revitalization of water and wastewater nets are made manually and after the Project will be finished they will be made by a computer.

3. The tasks realized by the development of the computer system

The development of the computer system planned needs the preparation of a detailed timescale that shall be then carefully realized and kept, especially because of the cooperation with the running enterprises. The tasks which will be then made are following:

1. Development of the monitoring systems for the water-supply and wastewater networks in the waterworks investigated. This task consists of the following problems:
 - choice of the measurement points for the water and wastewater networks under consideration
 - development of the data transfer systems, data collecting systems and visualization systems for the data measured
2. Formulation of the hydraulic models for the water-supply and wastewater networks in the waterworks. The problems to be solved in the frame of this task are:
 - formulation of the hydraulic calculations programs for the water and wastewater networks under consideration
 - formulation of the graphs of the investigated networks making the hydraulic calculations possible

3. Calibration of the hydraulic models using measurement data collected by the monitoring systems. The problems connected with this task are:
 - preparation and realization of the measurement experiments for the investigated water and wastewater networks
 - adjusting of the developed models to the investigated networks using some optimization algorithms
4. Optimization of the water and wastewater networks in the waterworks with the help of hydraulic models developed
5. Statistical analysis of the failures of the water and wastewater networks using the data concerning the past and current failure cases
6. Generating of the revitalization plans of the water and wastewater networks in the waterworks investigated
7. Choice of the technologies of the network pipe lines exchange according to the revitalization plans generated
8. Verification of the work quality of the network revitalized with the help of hydraulic calculation
9. Formulation of the control plans of the watery and wastewater networks revitalized taking into consideration the parts of the networks which will be excluded from the exploitation for the time of revitalization
10. Development of the computer aided decision making system producing the revitalization plans for water and wastewater networks
11. Testing the decision making system in the waterworks investigated.

Realization of the project requires the purchase of the adequate research-measurement tools and equipments and the usage of modern, advanced calculation methods in the area of mathematical modeling, optimization, control and statistical research. These tools mean firstly the powerful and fast computers which are needed for making the large calculations for water and wastewater networks consisted of many thousands of pipe lines and nodes. These tools mean secondly measurement devices needed to monitoring the water and wastewater networks and especially the pressure and flow measuring instruments. These instruments will be also used in the first phase of the project realization to calibrate the hydraulic models of the water and wastewater networks.

The calculation methods that will be included into the computer system supporting the generation of network revitalization plans will be used for solving large systems of non-linear algebraic equations, for optimizing the water and wastewater networks taking into consideration technical, technological and economical criteria of quality, for modeling and forecasting the water demand and the water-net load

of the water networks, for controlling the pump runs in pumping stations to satisfy demands of the water consumers and to reduce the whole energy consumption.

A particularly difficult but very interesting problem is planning the revitalization tasks which include selection of adequate repair technologies, calculation of the investment and exploitation costs caused by the networks modernization, defining the localization places and the number of the network parts that will be repaired, and at last running the network after its modernization works are finished. The operations that will be realized by separated modules of the computer system when using it to support the generation of the revitalization plans for a water or wastewater network are shown in Fig. 2.

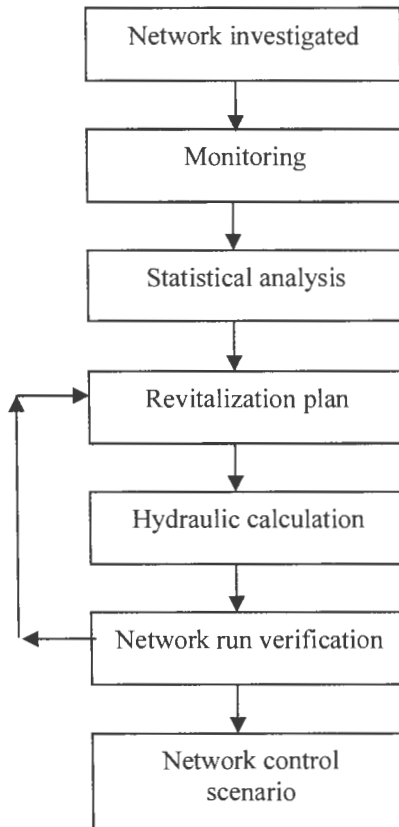


Figure 2. Operations made by using the computer system.

These all tasks are very sophisticated problems which have to be solved with the help of methods of multicriterial optimization. These tasks are also innovative because at the present computer supported systems for making revitalization deci-

sions for water and wastewater networks are not used in Poland and also not so much known outside of Poland.

5. Conclusions

Frequent failures of water nets, especially in case of large urban area, cause significant losses of water that unfavorably affect environmental protection and efficient management of water resources. As an effect of the realization of the project a IT tool will be developed that improve planning and execution of the repair and modernization works of the water and wastewater networks. Application of this tool will reduce the failure frequency, the losses of water and the environmental pollution caused first of all by leakage of sewage from the wastewater networks. The failures of the wastewater networks bring not only large financial losses but they also influence negatively the satisfaction from the life conditions of inhabitants of the city where the networks are located and they cause vandalism of the environment as well.

The reduction of the failure frequency in the water and wastewater networks and of the losses of the water in the water networks after the computer system will be introduced into the waterworks means the improvement of the services provided by the water enterprises and satisfaction of the community of the city concerned. The lower exploitation costs of the networks that will be got as a result of the system use will also cause the reduction of the end user prices of the water.

By the end of the above considerations it would be important to make two remarks concerning the conditions of financing the realization of the project proposed. On the basis of our previous experiences with realization of applied research works of similar kind we could guess that the development of a computer system supporting the management tasks for only one network of water or wastewater could cost ca. 250.000 EUR. It means that if we plan to work out a system that would be introduced into two communal waterworks for supporting the management of both water and wastewater networks in each enterprise, then this whole work could cost ca. 1 mill EURO together.

In our Polish reality it is impossible to get the financing of such the project from the waterworks considered although they will be the beneficiaries and end users of the computer system developed. In such the situation only a support by a research program at the national or international level can ensure a successful realization of the work planned.

Jan Studzinski, Olgierd Hryniewicz (Editors)

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The purpose of this publication is to popularize application of informatics in process modeling and management and in environmental engineering. The papers published are thematically selected from the works presented during the conference '*Multi-accessible Computer Systems*' organized by the Systems Research Institute and the University of Technology and Agriculture in Bydgoszcz for several years already in Ciechocinek. Problems presented in the papers concern: development of quality and quantity methods supporting the process management, development of quantity methods for process modeling and simulation, development of technologies of informatics for solving problems of environmental engineering. In several papers results of research projects supported by the Polish Ministry of Science and Higher Education are presented.

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