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SPECIFIC FEATURES OF DECISION MAKING IN THE RECONSTRUCTION PROJECTS OF MUNICIPAL WATER SUPPLY SYSTEMS

ОСОБЛИВОСТІ ПРИЙНЯТТЯ РІШЕНЬ У ПРОЕКТАХ РЕКОНСТРУКЦІЇ МУНІЦИПАЛЬНИХ СИСТЕМ ВОДОПОСТАЧАННЯ

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Abstract. The article considers the urgent problem for Ukraine – the development of decision making while managing the reconstruction projects of water supply systems. The analysis of the specific features of such systems and their influence on the processes of decision making in planning and managing of reconstruction projects are shown. The concept of value-driven decision making in the reconstruction projects of water supply systems is suggested. The model for project ranging on the basis of the integrated estimation of projects social benefits based on the use of modified weighed sum method and the project state assessment with the help of neural network classifier is developed. This model allows taking into account the value-driven features during the process of solving the semi structured problem of ranging projects in a portfolio. Also the model that allows determining the optimal content of the portfolio based on the knapsack problem solving and reckoning in value generated by each project is proposed. On the basis of the fulfilled research of structural and informational models of automated decision support system in project management of water supply systems reconstruction is built. The software based on the use of artificial neural network with back propagation, weighed sum method and the model for adding projects to the portfolio based on the information about available resources is developed. The software makes it possible to reduce project schedules and increase the efficiency of communication between project stakeholders.
Keywords: project management; decision making; water supply system; reconstruction projects; decision support; neural network; weighed sum method.

Анотація. Розглянуто питання вдосконалення процесів прийняття рішень у проектах реконструкції систем муніципального водопостачання. Наведено аналіз особливостей подібних систем та їх вплив на процеси прийняття рішень при плануванні та управлінні проектами їх реконструкції. Розроблено модель ранжирування проектів, яка заснована на інтегральному оцінюванні соціальної значущості проектів модифікованим методом зваженої суми та оцінюванні поточних станів проектів за допомогою нейромережевого класифікатора. Запропоновано функціональні та структурні моделі, а також відповідне програмне забезпечення системи підтримки прийняття рішень при управлінні проектами реконструкції систем муніципального водопостачання.
Ключові слова: управління проектами; прийняття рішень; системи водопостачання; проекти реконструкції; підтримка прийняття рішень; нейронна мережа; метод зваженої суми.

Аннотация. Рассмотрены вопросы совершенствования процессов принятия решений в проектах реконструкции систем муниципального водоснабжения. Представлен анализ особенностей таких систем и их влияние на процессы принятия решений при планировании и управлении проектами их реконструкции. Разработана модель ранжирования проектов, основанная на интегральной оценке социальной значимости проектов модифицированным методом взвешенной суммы и оценке текущих состояний проектов средствами нейросетевого классификатора. Предложены функциональные и структурные модели, а также разработано соответствующее программное обеспечение системы поддержки принятия решений при управлении проектами реконструкции систем муниципального водоснабжения.

Ключевые слова: управление проектами; принятие решений; системы водоснабжения; проекты реконструкции; поддержка принятия решений; нейронная сеть; метод взвешенной суммы.

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PROBLEM STATEMENT

Currently, one of the major problems which defines the further development of both individual countries and the whole of humanity remains the problem of efficient use of water resources. The urgency of this problem is due to the growing scarcity of water involved in various areas of industrial activity, as well as drinking water consumption [4, 11, 14, 15].

One aspect of this problem is the development of a set of measures related to the provision of drinking water to municipalities.

For the conditions of Ukraine [13, 16], this problem is exacerbated by significant physical and moral deterioration of basic elements of water supply systems (WSS), the mismatch of technical and technological parameters of the existing WSS in the European Union standards and norms, lack of necessary resources for their renovation, as well as developed evidence-based recommendations for the implementation of projects and programs of reconstruction WSS. This leads to the relevance of research aimed at improving the efficiency of municipal WSS.

LATEST RESEARCH AND PUBLICATIONS ANALYSIS

Current status of value-driven decision making in the WSS reconstruction

The complexity of the problem domain (a lot of technical parameters and characteristics of the WSS, structures complexity, spatial components, a significant number of participants and stakeholders of the projects, high social importance of the projects etc) requires the development of a decision support (DSS) system and corresponding models, which will provide the decision-maker with value-driven information necessary for the WSS reconstruction projects planning and implementation.

Currently on improving the efficiency of WSS municipalities devoted a considerable amount of research [5, 6, 18]. At the same time, the main focus should be regarded as the development of projects and programs of reconstruction on the basis of modern technologies in the field of water purification, energy management methodology, the use of modern materials and equipment, as well as of the theory of project management [7, 9, 10, 12].

There is a wide range of project management and portfolio management software systems. These systems include both Microsoft Project Server® and Microsoft Project Professional®, Oracle Primavera Enterprise Portfolio Management® and open systems like Basecamp®, TeamLab®, Teamwork®, etc. However, these systems are universal and are used either separately or integrated via files or standardized communications interface. The application of the systems to the management of WSS reconstruction project are complicated by the following features of these projects:

– a significant number of simultaneously running projects;

– different specific resources involved in project implementation;

– variability of the projects environment;

– the need for taking into account values delivered by projects.

On the other hand the value-driven project management now is only being developed. For example in the well-known G. Kerzner and F. Saladis work «Value driven project management» the concepts of value driven project management are only postulated [8]. All mentioned above determine the need to develop solutions that would allow effective value-driven management of WSS reconstruction projects with the help of DSS.

THE ARTICLE AIM is to develop the models of the system for value-driven decision support in project management of water supply systems reconstruction and development. The effective work and use of such a system is determined by the presence of tools for assessing the status of ongoing projects in portfolio and estimating result in creating business value.

BASIC MATERIAL

The methodology for decision support in WSS reconstruction projects

The difficulty of assessing the status of ongoing projects is that the attributes of reconstruction projects usually are not clearly specified, qualitative and vague. In addition, the complexity of assessing the value that each project implementation adds to city municipalities complicates the problem solution.

In this context, the determination projects states, in fact, is the task of recognition and classification directed to relation a recognizable image to a known class. The initial data for the solution of classification problems are the limited amount of sample data about the project attributes values that describe the classified situation. One of the goals of classification is to determine the relationship between the signs and symptoms of the classified object class and study this relation. To determine the relationship between the features correlation analysis or artificial neural networks (ANN) are usually used [3]. In this case the ANN has the advantage that it is not programmed and can be trained. Neural networks with error back propagation are the most widely used in classification and pattern recognition. In the simplest case – the single-layer ANN Y can be represented by two: vector X of input signals and vector K of coefficients as follows:

$$Y = \sum_{i=0}^{n} x_i \cdot k_i .$$

To solve the problem of estimating the effect of the implementation of each project requires the use of mathematical tools that provide some generalized value as an integral evaluation of each project. Based on the fact that each project is aimed at improving the quality of some services, there is a possibility of comparing parameters

of the project so that it will be possible to choose projects that will help achieve the best system performance. It may involve a variety of methods, one of the most simple and effective – weighted sum method, which allows to take into account the values of the individual parameters of the projects, and the contribution of these values to the integral value of assessing the projects impacts [2]. For simplicity, we assume that the weight of the criteria set by experts as project types, project priorities and customer types.

Based on the fact that each project is devoted to creating a higher quality of service, there is the possibility of comparing the parameters of the projects in such a way that it will be possible to choose projects that will help achieve the highest business value. For simplicity, we assume that the weights of the criteria are given by experts and are defined as priorities of projects, their types and types of stakeholders. Therefore this weighted sum will be represented as follows:

$$Y_i = w_{0,i} \times \left(w_1 \times w_2 \times \sum_{r=0}^{R} \left(w_{3,r,i} \times p_{r,i} \right) + w_4 \times \sum_{j=0}^{J} \left(w_{5,j,i} \times u_{j,i} \right) \right),$$

where Y_i – integrated evaluation of the project; $w_{0,i}$ – weighting assessment of the project; w_1, w_2, w_3, w_4, w_5 – the weights determine the priority of projects, project declared technological parameters, priority sites and the parameters measured on it, respectively; $p_{r,i}$ – the value of declared parameter r of the project i; $u_{j,i}$ – the value of declared critical parameter j of the project i.

Weighting factor of a project can be calculated as:

$$w_{0i} = \begin{cases} 1, \text{if a project should be envolved} \\ f(i), \text{if a project can be executed} \end{cases},$$

where $f(i)$ – weighting factor evaluation function, obtained as a result of ANN work, $f(i) = [0 \ldots 1]$. If $f(i) = 0$ then a project have to be stopped. If $w_{0,i} = 1$ than a project should be added to current portfolio while if $w_{0,i} < 0$ then it can be excluded from the portfolio.

Thus, it is possible to implement a decision support in municipal water supply reconstruction projects classification and ranging on the basis of integration the use of ANN and weighted sum method.

Integral project value assessment allows taking into account its social aspects. But it is also necessary to take into account economic aspects, i.e. to dispose enterprise resources in such a way that get the best effect from projects implementation. Thus we have to form project portfolio on the basis of information about available resources. This problem can be reduced to the well known knapsack problem: we have to place maximum possible number of valuable items in a fixed volume knapsack, taking into consideration that the total weight of all items that can fit in a knapsack, is limited.

Let $P = p_1, p_2, \ldots, p_i$ – will be the set of projects; x_{t1}, x_{t2}, …, x_{ti} – are income from each project at time t; y_{t1}, y_{t2}, …, y_{ti} – investments in each project in time t; r – discount factor, that does not depend on t. Then weighted integral project value considering their social value may be written as functional:

$$S = \sum_{i=1}^{I} \sum_{t=0}^{T} \left(\frac{Y_i \left(x_{t,i} - y_{t+1,i} \right)}{(1+r)^t} \right).$$

Let C_1, C_2, …, C_n – will be the set of available resources. Thus the task for project portfolio formation can be stated as follows: we have to find the set in I that allowing to maximize S taking in the account the restrictions for C_1, C_2, …, C_n, where $n \in 1 \ldots N$, N – the quantity of resource types. If we use brute force we will need to consider 2^{ITN} variants.

Design and Implementation of Software for DSS in the WSS reconstruction projects

In general, conceptually developed DSS SW reconstruction projects will include logically related blocks: «Water system», «Indicators of reconstruction», «Databases elements SW (DB1, DB2, DB3)», «Component monitoring CB», «Initiate projects», «Project planning», «Limitations in projects», «Artifact projects (knowledge base BD4)», «Formation of a hierarchy of projects» and «Project implementation».

For each of the blocks a decision support system should be developed requirements for their content [1].

It is assumed that in addition to the basic parameters of the existing WSS, obtained on the basis of the monitoring system, as input data will be performing the following technical documentation for water supply system; certification of the results of water systems and sewage systems, and more.

It should be noted that the main task of DSS is to compare each subject area recommended options for solutions, i.e., implemented the scheme [15]: «Situation» → «Option decision».

Because the construction of the DSS, the focus should be directed to the definition of a decision system (DS) (selection of the best alternatives, ranking alternatives, classification or clustering alternatives) and the choice of the appropriate method of decision-making, implementing such tasks. This approach is implemented through incorporation into the characteristics and performance of municipal WSS (DB1, DB2, DB3) master plan of the municipality; statistical forms of socio-economic development of the municipality, the form № 1 – a report about the work of sewage; approved water supply project, the rules of the reception of sewage from tariffs for water supply and structure DSS base methods of decision support (BM).

In accordance with the advantages of the architecture MVC, these subsystems may be arranged as shown in Fig. 1.

Based on the description of the system and a list of parameters to be monitored and measured, the model of the system data as a class diagram was developed. The fragment of the class diagram in UML notation is shown in Fig. 2.

On the basis of systems component model (Fig. 1) and taking into account data model presented (Fig. 2) the application of the DSS for WSS reconstruction projects classification and raging was created. Example of a window form is shown on Fig. 3.

Testing the status of the project by means of an ANN was carried out with the help of the module that is based on a graphical representation of the data distribution works «reliability» of each project to the basis of the data about projects types, jobs and the necessary technological units. The data obtained from the ANN qualifier were transformed into diagrams of distribution of density of estimates of projects statuses (Fig. 4). The diagrams were created with the help of the GnuPlot program.

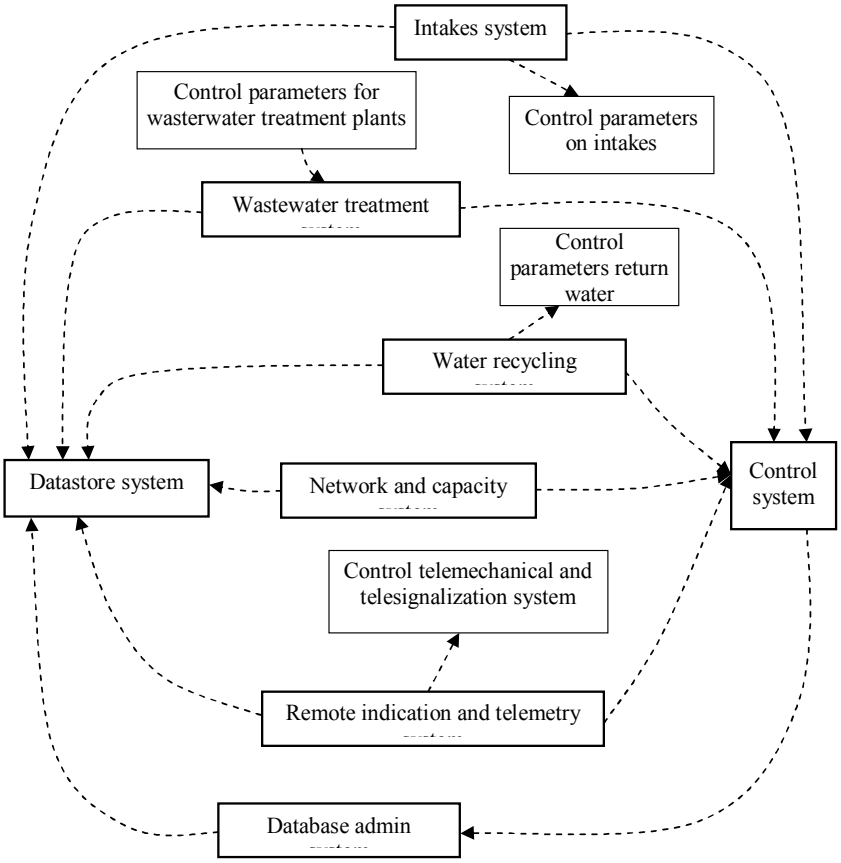

Fig. 1. Component Model of the DSS according to the MVC Architecture

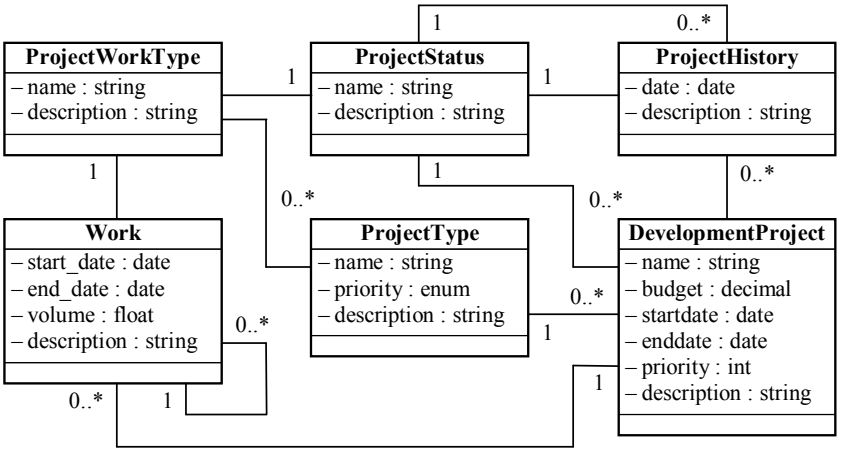

Fig. 2. The Fragment of Information System Class Diagram

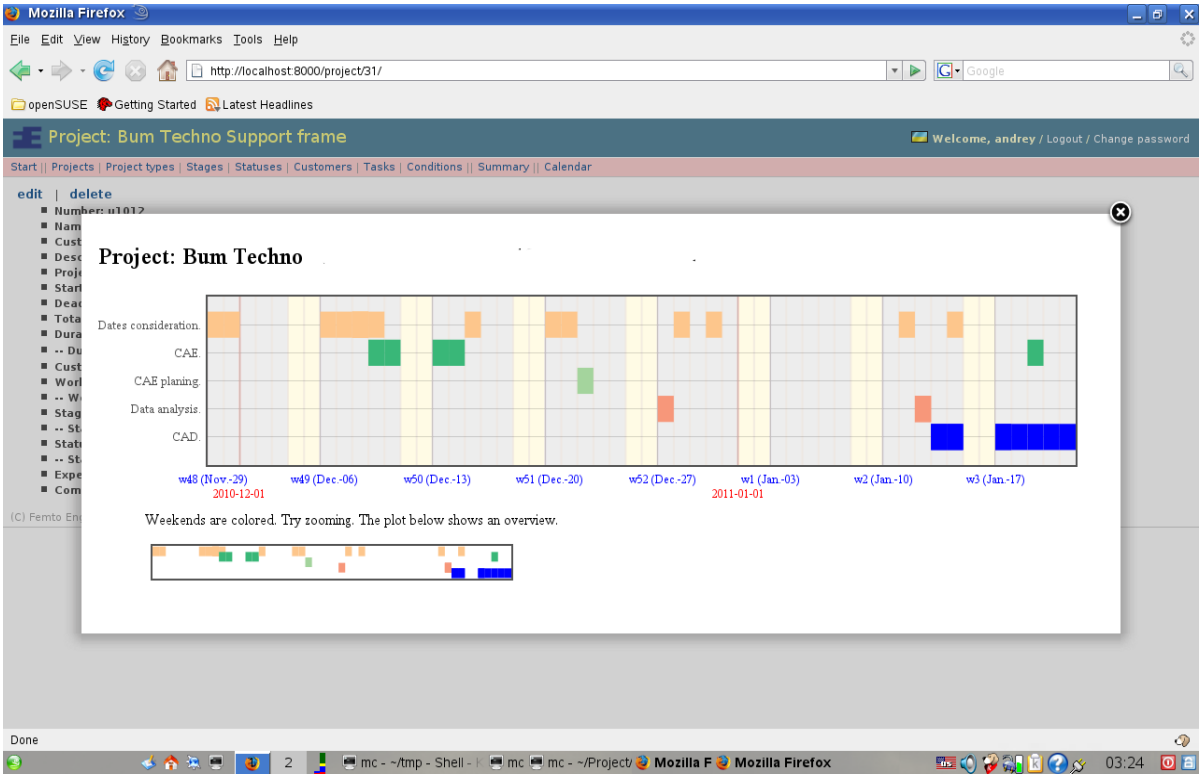

Fig. 3. The Representation of WSS Reconstruction Projects Portfolio

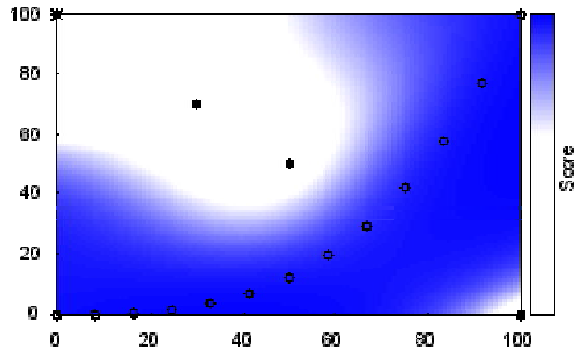

Fig. 4. Graph of the Evaluation of Density Distribution for a Project

CONCLUSIONS

According to the analysis, the concept and appropriate models of the DSS in WSS reconstruction projects classification, ranging and optimization were developed. In order to improve the effectiveness of managerial decision the distributed DSS including a database server, an application server and client terminals was developed. The software based on the use of artificial neural network with back propagation, weighted sum method and the model for adding projects to portfolio based on the information about available resources allows to reduce project schedules and increase the efficiency of communication between project stakeholders. All models and tools are implemented in the open-source free distributed OS Linux.

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