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# Methods for implementing the concept of “Smart City” based on Bayesian Intelligent Technologies

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**Abstract.** Information systems based on Bayesian intelligent technologies make it possible to implement monitoring, control and management tools within the framework of the “Smart City” concept. Such tasks are connected, on the one hand, with the processing of large arrays of various types of information, on the other hand, with difficult conditions for solving problems due to uncertainty. This article discusses the methodological aspects of the application of the regularizing Bayesian approach and Bayesian technologies focused on uncertainty and information processing both in the form of data and in the form of various knowledge. It is shown that such systems can be implemented in the form of intelligent cognitive networks with the processing of different types of measurement, statistical, reporting information, integrated with the assessments and decisions of experts and specialists. Examples of using the proposed approach and technologies for solving applied problems of digitalization of urban economy are given.

## 1. Introduction

The demand for methods and means of artificial intelligence in solving problems of urban management – housing and communal services, energy, economic, social city services and systems and processes has significantly increased at the present time in connection with the adopted concept of “Smart City” and the programs implemented within its framework and investment projects.

The public value of new technical and organizational smart grid solutions is determined by issues of energy independence, increased reliability and benefits for energy consumers. For example, experts from the analytical company McKinsey estimated the social value of the combined aspects of the smart grid for the United States at \$ 130 billion. In these conditions, the President and the Government of the Russian Federation set the ministries, departments, and energy corporations of our country the task of developing and implementing projects for the transition of the Russian power industry to “intelligent network”.

One of the key issues in this case is the development of methodology and technological platforms for the implementation of smart networks for urban management (smart grid). Currently, the successful implementation of such projects is taking place mainly in the energy sector of the economy. However, there is a shortage of development of methodology and methodological base of intellectualization. This is explained by the specificity of information flows, their diversity, the complexity of the structures and interconnections of the systems of the municipal economy, which determines special requirements for the methods and means of collecting and analytical processing of information in the municipal economy. Due to the uniqueness of the information received from the



systems of the urban economy, its significant uncertainty, strong variability and many influencing environmental factors. It turns out to be unlawful to use traditional statistical methods of data processing based on homogeneity and repeatability of statistical data from samples. The existing solutions within the framework of modern concepts of BIG DATA, IoT, BI, DATA SCIENCE, on the one hand, have not yet been sufficiently developed for wide practical application, on the other hand, they are aimed at solving methodological problems of data processing by means of universal information technologies associated with a technogenic approach to data processing by using various means of collecting information, systems of sensors and communication means, databases, server equipment and other computer technology, which is certainly necessary, but refers to the stages of implementation of methodological approaches and solutions, but does not replace them. To successfully solve the problems of digitalization and intellectualization of urban economy, it is necessary, first, to develop methodologies and applied methods of intelligent data processing, focused on the specifics of information flows of urban economy.

However, despite the developed capabilities for the transmission and storage of numerical, textual, graphic, audio, video and other information, in all these technologies there is no possibility of folding such information, its integration into a single information stream, which carries the most reliable and complete knowledge about the object, or its properties in specific conditions, as well as analytical processing of information in order to support management decisions.

In addition, in the known network technologies, there is no, not only the possibility of quality management of the solutions obtained on their basis, but also of control, metrological substantiation of incoming and stored data, in real conditions does not allow determining or guaranteeing the stability, convergence and reliability (risk) of the solutions obtained. ... In other words, the lack of principles of the measuring approach in information technologies of modern distributed data processing associated with various systems of sensors and collection of primary information leads to the impossibility of their effective use for solving a significant range of problems in the energy sector and housing and communal services.

Note also that in real conditions of monitoring or controlling the generation, distribution and consumption of energy resources based on intelligent network, there is a need to adapt technologies and network structures to the changing properties of objects and processes and their environment, development in accordance with the development of objects and network structure. In this formulation, the problem arises of optimizing the technologies and structures of network information processing during the operation of systems, which means the need to develop and apply technologies of self-organization, adaptive changes in the network topology, dynamic formation of a circle of customers, distribution of functions between them and their intellectualization.

Thus, the need to develop a methodology and a platform is due, on the one hand, to the requirements of practical tasks (usually solved in conditions of significant a priori uncertainty) for the generalization and use of the entire available amount of information, on the other hand, the possibilities of the above-mentioned modern concepts and network technologies that allow collecting and processing large arrays of different types of remotely distributed information resources.

## **2. BIT methodology for creating intelligent network**

This article discusses the methodology of building intelligent network for the integration, digitalization and intellectualization of existing production and management resources within the framework of the concepts of “Smart city” and “smart grid – models”, which ensures their transfer to a qualitatively new level of intelligence of mechanisms for managing a set of distributed urban economy and power facilities.

At present, Bayesian intelligent systems of a new generation have been developed and are being applied in practice to control distributed power generating systems under conditions of uncertainty. Such systems, inheriting the basic principles of BII and BIT, (namely, the integration of different types of data and knowledge flows, metrological justification and the possibility of managing the quality of solutions, flexibility and development in the process of functioning), together with promising information technologies for network transmission, collection and distributed processing of information, represent a new type of system called Bayesian intelligent networks (BIN).

The BPM methodology, the algorithmic base of the BII and BIT served as the basis for creating a methodological base for the LSI for the tasks of energy and housing and communal services. The BIN implementation diagram is shown in figure 1 and 2.

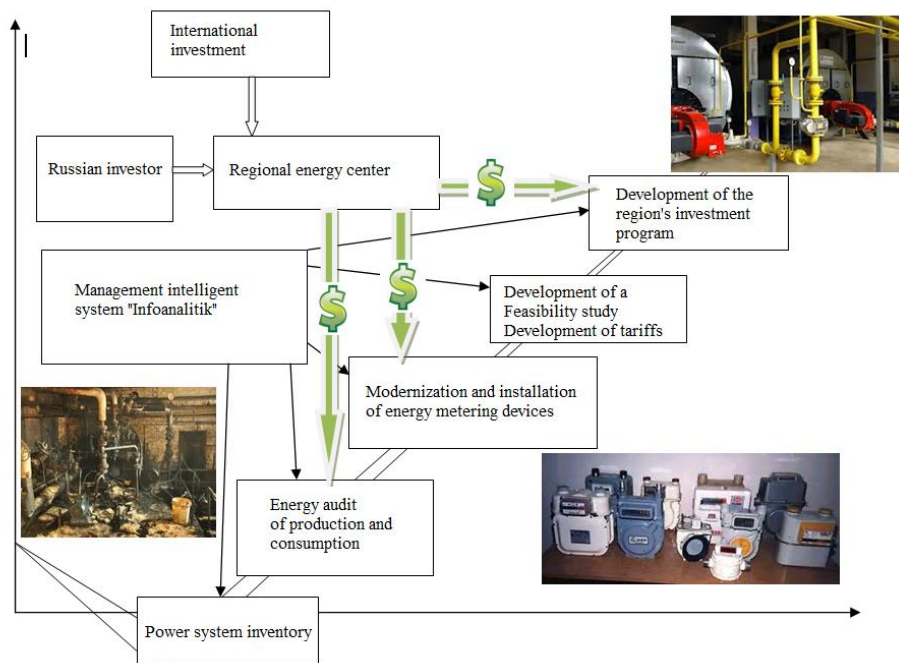


Figure 1. Scheme of implementation of the functionality of smart grids of regional energy.

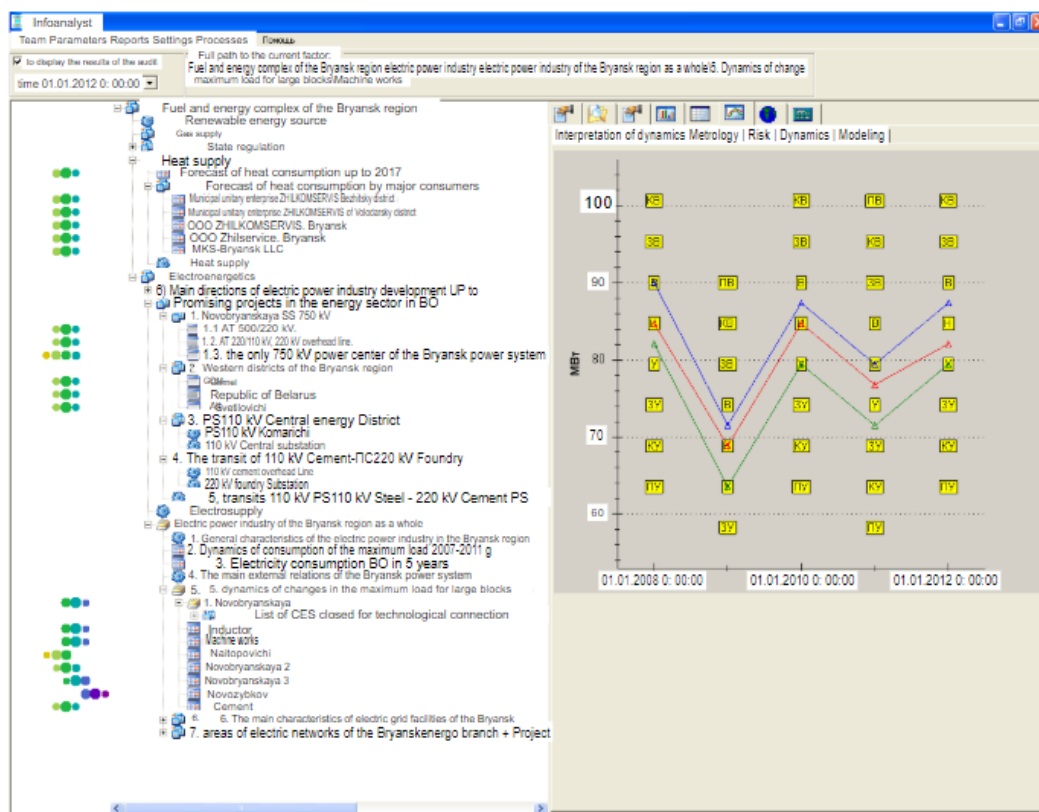


Figure 2. Dynamics of the number of closed power supply centers for technological connection.

The methodology of direct BIT on homogeneous three-link scales with dynamic constraints (SDC), (otherwise, direct BIT) is the basis of the technology for integrating the same type of multi-current information flows (for example, convolution of measurement results received and stored in the archive (database) or convolution of measurement results of the same parameter on different accuracy devices).

The methodological foundations of the construction of SDC and their application for evaluating, measuring, controlling (auditing) processes and situations, forecasting and generating management decisions are discussed in detail in [1] and other works of this scientific school.

Values, linguistic expressions, audit or management decisions, functions, recommendations, conclusions, or other information objects can be used as reference points for SDC.

As a result of the BIT implementation for the above problems on the corresponding SDOs, solutions are obtained in the form of regularized Bayesian estimates (RBA)  $\{h_{k_i}^{(Q)} | \{MX\}_{k_i}\}$ , which are a set of possible solution alternatives with their inherent, defined a posteriori probability. Alternatives are determined in accordance with the BIT optimization equation in the form:

$$\{h_{k_i}^{(Q)} | \{MX\}_{k_i}^{(Q)}\} = \{arg \text{ exstr } C [\varphi_j (\{X_{it}\} * Y_t^{(OE)} * G_t^{(OE)})]\} \quad (1)$$

Where  $h_k$  is the k-th regularized value of the property  $Q^0$  at time  $t$ ,  $X_{it}$  is the incoming information for generating management decisions from information sources.

The sequence of  $F_t$  activities that make up the process of implementing the stages of collection, inventory, and resource management of energy and housing issues can be represented as time – bound BIT solutions to the sequence of  $F_t$  stages:

$$\{h_{k_t}^{F_t}\} = \bigstar_{j=1}^{J_t} \{h_{k_t}^{(f_{j_t})}\} \quad (2)$$

where  $k = 1, k_t, k_t$  is the number of alternative control solutions,  $j = 1, j_t$ .

The decision to implement the next stage is in the form of a list of alternatives ordered by probability as a solution to an equation of the form:

$$\{h_{k_t}^{(f_{j_t})} | \{MX\}_{k_t}^{(f_{j_t})}\} = \{arg \text{ exstr } C [\varphi_{j_t} (G_t^{(OE)} * Z_t * Y_t^{(OE)} * h_{t-1}^{(f_{j_t})})]\} \quad (3)$$

The complex of metrological characteristics  $\{MX\}_{k_t}^{(f_{j_t})}$  includes RBA indicators for accuracy, reliability, and a posteriori reliability of evaluation and management decisions [2], which can be calculated using the Bayes formula modified in the framework of RBA:

$$P(h_{k_t}^{F_t} | G_t^{(OE)}) = \frac{P^a(h_{k_{t-1}}^{F_t} | G_{t-1}^{(OE)}) \circ P(G_t^{(OE)} | h_{k_t}^{F_t})}{\sum_{j=1}^J P^a(h_{j_{t-1}}^{F_t} | G_{t-1}^{(OE)}) \circ P(G_t^{(OE)} | h_{j_t}^{F_t})} \quad (4)$$

If the relations  $\binom{L}{\circ}$  are not probabilistic, but other parametric logic, then such management decisions are called soft according to the definitions given in [3], and the type of management is called “soft management”. When implementing management decisions using this methodology, it is possible to change the parametric logic depending on the goals, priorities of the project, as well as on the individual characteristics of the person making management decisions (MMD).

Uncertainties that do not allow you to accurately plan and implement BIS management processes, process risks lead to a delay in the start of their implementation and an increase in their duration.

In the RBA concept, the processes of production of energy products and services, as well as their duration, are considered as factors with a significant degree. uncertainties and can be estimated in the form of RBE:

$$\{h_{k_t}^{(\Delta t)} | \{MX\}_{k_t}^{(\Delta t)}\} = arg \text{ exstr } C [\varphi_t^{\Delta t} (G_t^{(OE)} * Y_t^{(OE)}) * h_{t-1}^{(f_{j_t})}] \quad (5)$$



### 3. Technological solutions and examples of the BIN

The specifics of the BIN described above define the following additional elements of network technologies. First, it is the presence of Bayesian intelligent servers in the network structure that combine the properties of information servers and application servers, integrating data and knowledge flows at a formal mathematical level, synthesizing technologies with metrological support according to expressions (1)-(5), analytical data processing processes for evaluating States and situations, predicting them, and generating solutions for customer requests. Second, it is the availability of metadata (in the form of SDC). Third, the availability of technologies that manage the development of the network structure based on the results of the previous stages of the implemented information technology. Below examples of the BIN application are presented (figures 3 and 4).

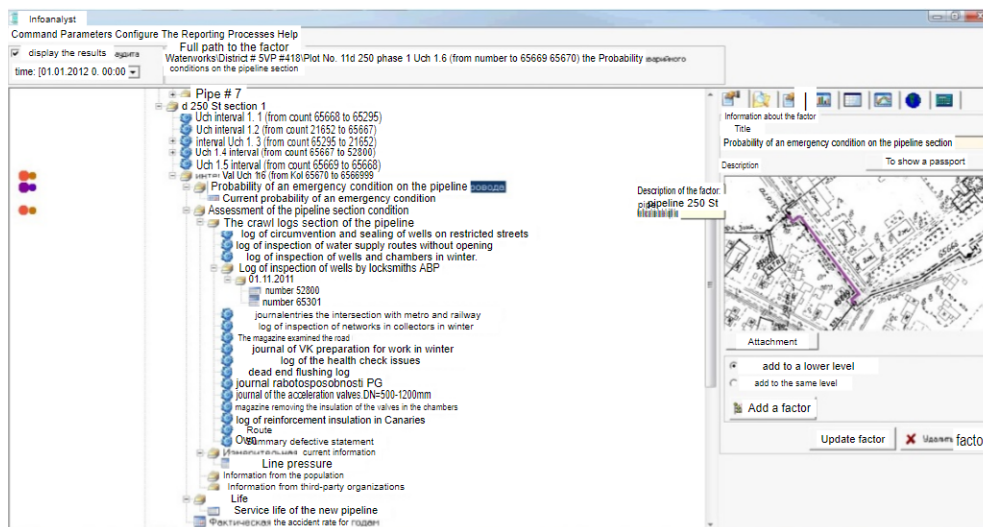


Figure 3. Assessment of the situation on a section of the water supply network based on BIT.

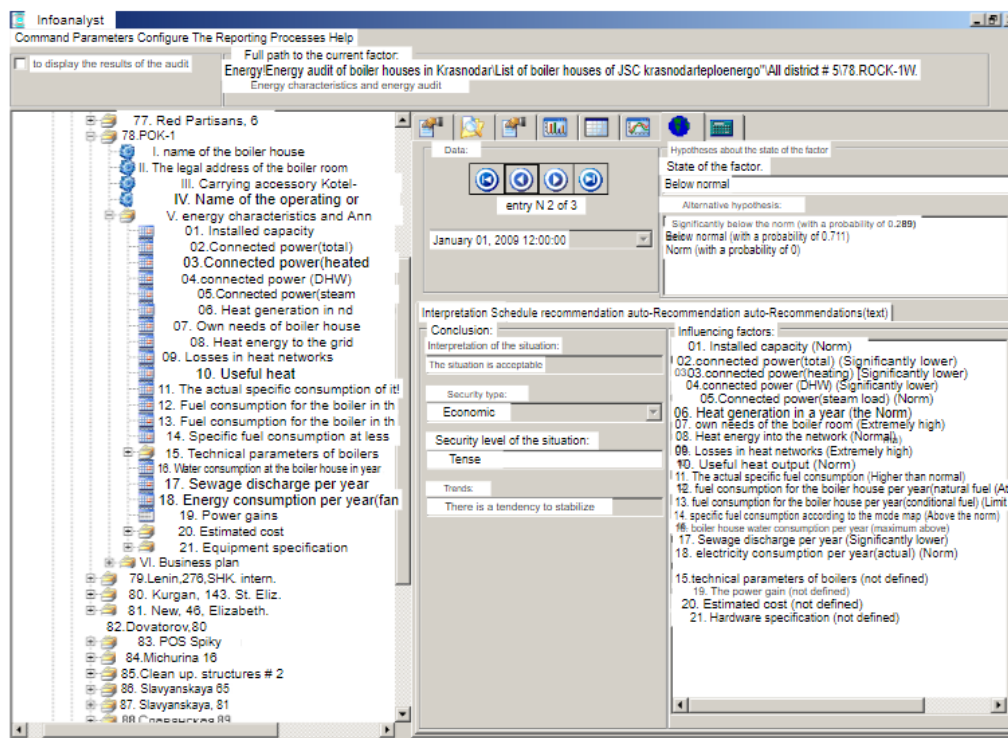


Figure 4. Example of an energy audit of urban energy production by means of a platform based on BIN.

Metrological support of the Bayesian integration network makes it possible during the network operation not only to identify “bottlenecks” where information flows with significant distortions and noise, but also to correct the technology and the list of clients – sources of information resources and consumers, and plan an information experiment.

#### 4. Conclusion

The main advantages and achievable goals of using the platform in organizations for the operation and maintenance of urban facilities (bridges, tunnels, sewers, etc.) can be considered to be the prevention of emergencies and emergencies at city facilities and ensuring their normal operational mode of maintenance based on :

- comprehensive assessment of the instrument, resource and operational potential of the systems listed above;
- determining trends and dynamics of indicators of reliability and safety, operation of facilities;
- normalization of indicators, indexes and indicators of operation and maintenance of facilities;
- comprehensive monitoring of the technical condition of object systems;
- monitoring systems for obtaining current estimates of the total risks of objects;
- based on obtaining estimates and models for developing an optimal maintenance plan;
- formation of investment plans and activities;
- creation of centers for training qualified production and management personnel;
- creation of information networks and systems for various production, management, scientific tasks and SEZs.

The experience of using BIT allowed us to develop a methodological basis for solving these problems, which was implemented in the form of manned and adaptable technologies for applied tasks. The main conceptual idea is to develop based on BITS and platforms “Ecoanalyst” and «Infoanalyst» developing technologies for specific applications. The concept and detailed description of this type of technology is given in the published works of the author and specialists of this scientific school.

The BIN complex generally corresponds to the architecture of urban management complexes and industrial energy systems for solving problems of internal energy audit, accounting for energy consumption, and ensuring energy security of enterprises and territories. In addition, the system can become the basis for the implementation of a training center for energy and housing management.

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