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BIM-Concept for Design of Engineering Networks at the Stage of Urban Planning

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***Abstract*—This study describes a new approach to creating a Central Project Database based on the BIM-concept for designing engineering networks at the stage of urban planning. This approach is based on systematic access to the process of developing urban planning documentation at the pre-design stage of construction. Comprehensive information support of the planning territory corresponds to modern trends in the transition of urban planning to digital construction. An information model of the project of planning territory for construction at the stage of urban design is proposed. The content of each layer of the planning territory information model is described in detail. The conceptual BIM model of spatial data for solving design problems of engineering networks is presented in the form of three main blocks. Block 1 is data sources that are taken from the operating system and external sources. Block 2 is data storage in which operational and external sources supply spatial data and metadata. Block 3 is consumers of information that generate requests for data to the means of presenting the information. The BIM structure of the Central Project Database for comprehensive information support of the design of engineering networks is presented. As the study results are shown, a summary plan of engineering networks was made using BIM-based design software and a digital 3D model of the consolidated plan of engineering networks, made using AutoCAD Civil 3D. The use of BIM-concept at the stage of urban planning design is a new direction of its development. The implication for further research studies on the development of complex BIM-based design for urban infrastructure.**

***Keywords*— BIM; central project database; design of engineering networks; spatial information.**

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I. INTRODUCTION

Modern trends in the development of systems engineering in construction dictate the need to use and develop innovative approaches to organizing the process at each stage of the life cycle of a construction object. The most famous approach is BIM (Building Information Modeling) technology. It provides the ability to partially simulate the construction process, creating all the necessary layers with structures, life support systems, and information attributes [1]. Such a BIM model is developed to form a package of working documentation and is often used in project activities [2]. Its main advantage lies in a systematic approach to the technical organization of a construction project, which allows minimizing the number of errors made during design [3]. One of the development directions of this technology is its spread to other stages of the life cycle, for example, from the pre-design stage of urban planning to the development of working documentation. At this stage, the initial information data on the design object are its shape, volumes, spatial planning solution, binding to the relief, networks, and infrastructure. Such information is the starting point for further design stages, which determines the relevance of including this stage in the BIM design process. To develop a model of information space of integrated planning territory for construction at the stage of urban design requires at least the construction of a single computer network. This integrated model determines the creation of a single database and all software that automates the process and must work with it in a single automated system [4].

The amount, structure, and detail of information about the land plot are its information potential, which determines its attractiveness to the developer. The adaptation of the land plot

to the development goals begins with the planning and placement of elements of the master plan. For each of them, to perform its functional purpose, there are certain requirements for placement. It is necessary to consider the factors that affect their location and orientation in space for the territorial binding of these elements. There are some different software approaches to describe the concept of BIM models.

This study is based on a systematic approach to developing urban planning documentation at the pre-design stage of construction, based on the current trend of transition to the digital economy.

Urban planning includes the following stages, which are discussed in detail in the works [5]-[8]:

- Preparation of a technical assignment for a territory planning project;
- Development of options for spatial planning solutions for the territory;
- Development of materials to justify the project;
- Coordination and approval of urban planning documentation and their transfer to the next design stage.

The use of BIM technology makes it possible to form an information model of the territory, which contains information:

- On the existing and planned use of land plots, as well as information about the copyright holder;
- On regulatory and urban planning documentation that determines the nature of the use of territories, requirements for the placement of facilities, landscaping, planned development, restrictions on territories with special conditions of use, etc.;
- To be entered into the information system for ensuring urban planning activities, including plans for ground and underground communications, the position of the territories of the street and road network, etc.;
- On the cost and timing of work on the development of the territory.

The analysis of articles [9]-[12] allowed classifying the requirements for the layout of the elements of general planning and the main environmental factors that affect their location. The authors in [13], [14] propose models by which it is proposed to specify information flows to achieve consistency in all elements of the automated system. Specialists in the works [15], [16] prospect of creating integrated and specialized data warehouses on all aspects of the municipal economy are considered.

This topic was further developed in the manuscripts [17]-[21], which include the infrastructure of three-dimensional spatial data in the mechanism of accessibility, standardization, accumulation of information exchange, taking into account primarily geodata about the study area by terrain, hydrology, engineering networks, and administrative boundaries.

The integration of information is formed in such a way that the quality of data is determined at the time of their receipt rather than application. The content and structure of Data Bases (DB) are formed by digital data on spatial objects, examples of such structures are given in [22]-[24].

Both primary and secondary data form information support of DB. The accuracy of the primary data determines the resolution parameter when conducting photo fixation, probing, scanning, and other types of measurements. Such examples are given in articles [25]-[28]. The study aims to develop the approach to creating a Central Project Database based on the BIM-concept for designing engineering networks at the stage of urban planning.

II. Materials And Method

The conceptual plan of the main research consists of some stages to achieve the purpose. All stages are associated with the process of creating a Central Project Database based on BIM design of engineering networks at the stage of urban planning. Fig. 1 illustrates a block diagram of the creation BIM-structure of Central Project Database.

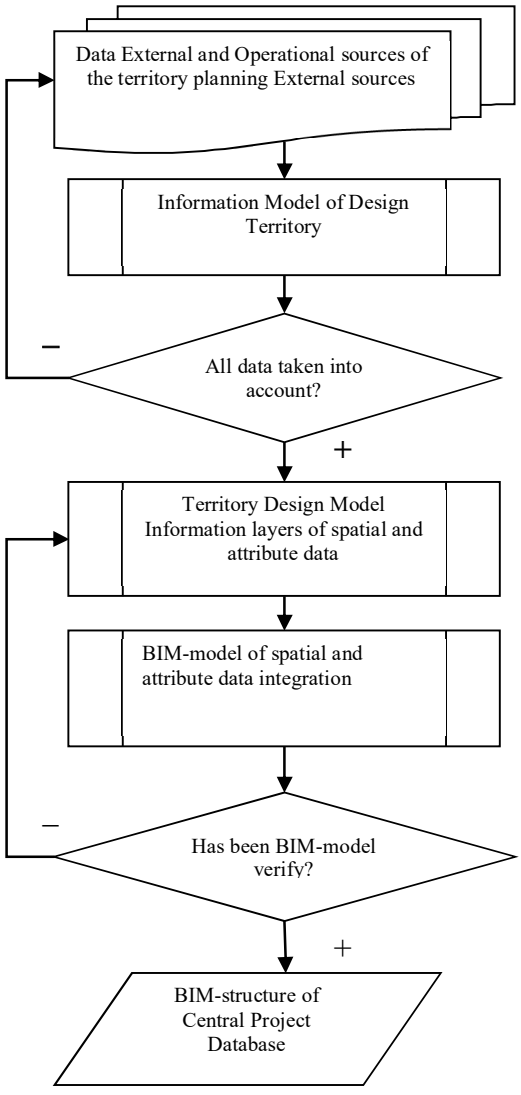


Fig. 1 Block diagram of the creation BIM-structure of Central Project Database

The data system required to form the territory of urban planning design is given in [16] and shown in Table 1. The introduction of such a model of the territory with the objects to be placed and the accompanying infrastructure allows expanding the capabilities of BIM technology and increasing the efficiency of the design and construction process.

A. Information Model of Design Territory

The model in Table 1 makes it possible to establish relations between the design stages: pre-design, design and the stage of working documentation, which makes it possible to manage the quality of development of territories.

In the course of studying the possibilities of using BIM-technology in master planning, the software AutoCAD Civil 3D was used in the implementation of the project for planning the territory.

At the same time, the possibilities of the software package were studied for solving problems of developing urban planning documentation, such as:

- Formation of a package of documentation for a territory planning project in a single file with the integration of various information layers according to the relevant sections;
- Binding the planning solution to the geo-digital terrain model;
- Development of interrelated materials to justify the spatial planning solution.

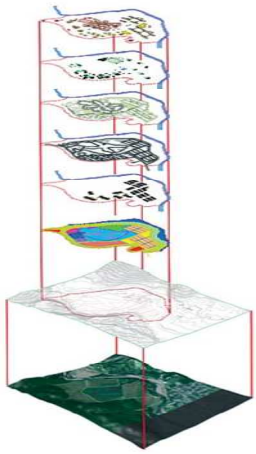
The functional and planning solutions of the territory based on integration with a digital terrain model (DTM) and data from satellite elevation surveys are shown in the information model of the territorial cluster of urban planning.

Binding to elevations of buildings and structures, roadways, and utilities allows forming a ready-made planning solution in one file and all accompanying sections for the project stage.

This serves as the basis for further BIM-modeling of each of the buildings with vertical and horizontal reference to a specific territory with certain parameters. Thus, a digital model of the projected territory is created, which is the basis for the development of the planning solution itself and the justification materials, requiring reference to elevation marks and integrated into a single constructive, engineering and technological solution.

In accordance with the developed information model in Table 1, stage 2 of materials for substantiating the functional planning solution for the territory of the educational center includes the following information layers, performed in one digital model of the projected territory.

TABLE I
INFORMATION MODEL OF THE PROJECT OF PLANNING TERRITORY FOR CONSTRUCTION AT THE STAGE OF URBAN DESIGN

Stage number	Typical content of the territory planning project	Information layers of spatial data
Stage 1. Assessment of current situation and prerequisites for the development of the territory	Existing use of the territory and prerequisites for its development The current state and prerequisites for the development of transport services for the territory The current state and prerequisites for engineering support of the territory Functional planning organization of the planning territory	
Stage 2. Urban planning documentation (project proposals)	Plan of architectural and planning organization of the planning territory Transport service of the planning territory Engineering support of the planning territory Architectural planning solution Proposals for the preservation, development and limitation of the use of land plots in zones with special conditions of use	

B. Territory Design Model

The territory design model consists of three information layers of spatial data:

1) Information Layer № 1: It is the scheme of transport services, the development of which includes:

- Routing of the road network of the projected territory concerning the elevation marks of the buildings being placed and the existing relief with the appointment of slopes and parameters of the transverse and longitudinal profiles under the standards of urban planning;
- Linking the entrances-exits from the territory to the external street network;
- Automatically built longitudinal and transverse profiles, as well as vertical layout of the road network, output of black and red marks of trays.

2) Information Layer №2: It is the scheme of engineering support of the territory with containing:

- The scheme of the vertical planning of the territory with reference to the tracing of the road network and engineering communications;
- A summary plan of engineering networks with marks of laying relative to the red marks of the earth;
- Automatically generated cartogram of earth masses.

3) Information Layer № 3: It is architectural and planning solution of the territory, which includes plans:

- 1st floor and floors located below, requiring the implementation of work underground or at ground level with a height reference to the red marks of the vertical layout of the territory;
- Insolation of facades and adjustment of the placement of buildings in the absence of standard lighting times;
- Typical floors, roofs, typical section, etc., giving an idea of the functional purpose of the construction object;
- Isometric views of facades for visualization of design solutions.

C. Conceptual BIM-model of Spatial Data Storage

On the example of the educational center, work was carried out to simulate the pre-design stage of urban planning in developing a territory planning project under the requirements of the national standard of urban planning. This experience should contribute to the development of BIM technology in urban planning and the expansion of the modeling field from a specific construction site to its location. Summarizing the approaches used to form information support in design systems of construction, the conceptual model of spatial data storage for solving general planning problems of the territorial cluster can be represented in the form of three main blocks, which are presented in Fig. 2.

1) Block 1: Some data sources are taken from the operating system and external sources.

2) Block 2: Data storage uses operational and external sources to supply spatial data or metadata. Data storage consists of data banks and metadata repositories.

3) Block 3: There are consumers of information that generate requests for data to the means of presenting information, which, in turn, generate a request sent to the data warehouse.

The main components of the data warehouse are:

- operational data sources;
- design/development tools;
- means of data transfer and transformation;
- DBMS;
- means of access and data analysis;
- means of administration.

For automated systems of integrated general planning of territorial clusters, it is important to have "feedback" with the data storage, allowing notifying the user about the appearance of the required information in the repository and automatically sending this information in the form converted to the customer data model. Table 2 shows examples of different types of spatial data.

TABLE II
DIFFERENT TYPES OF SPATIAL DATA

Name/type of spatial object	Set of some attributes of the spatial object	Data description
Tree/***Point***	ID, planning geometric coordinates, breeD, Height, Age, Growth parameters	(IDt, X,Y,Z), (D, H, A,G)
Drainpipe/ ***Line***	ID, planning geometric coordinates, Name, Function, Material, Diameter of pipe	(IDd, {X,Y,Z}, (N, F, M, D)
Building/ ***Polygon***	ID, planning geometric coordinates, Destination status, explication Number, Zero mark	(IDb, {X,Y,Z}), (D, N, Z)

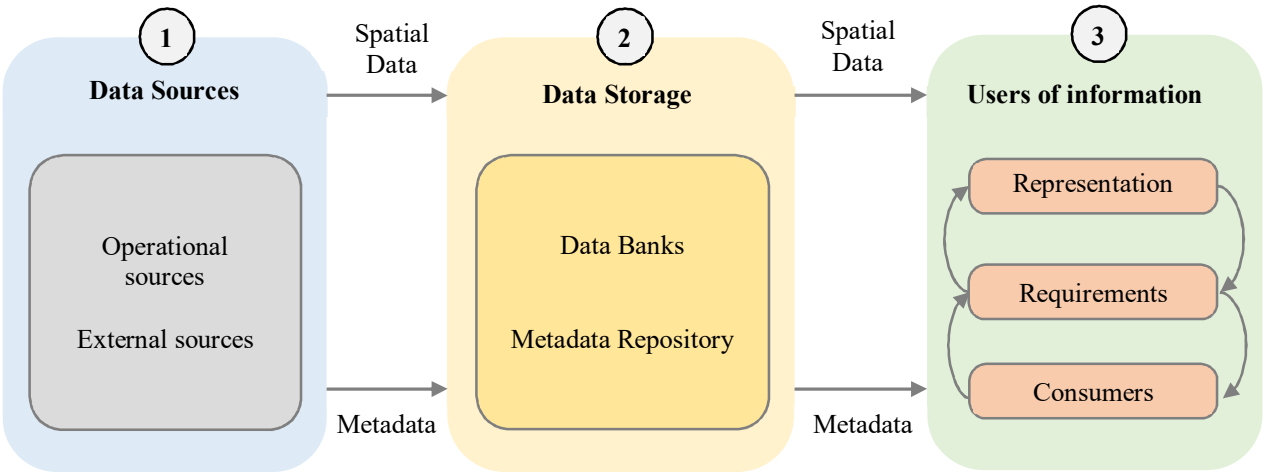


Fig. 2 Conceptual BIM-model of spatial data storage

D. BIM-model of Spatial and Attribute Data Integration

Fig. 3 presents the BIM-model of spatial and attribute data integration. The multidimensional presentation of information characterizes Datastores. This structure determines the set of actual and measured data. This is due to the desire to identify individual entities that facilitate business intelligence data from the required information sections of the organization. In contrast to the multidimensional information model of general construction tasks, for the storage of cadastral information of architectural and construction design, the model requires a multilayer, and its main element should be a cadastral object.

The aggregated data on the object will represent an information slice for all layers relevant to the object at a certain point in time. Thus, in the system of organizational preparation for construction, the data warehouse for the subject area of the urban cadastre must meet the following requirements:

- Perceive and recognize cadastral information through procedures for extracting, converting, and uploading data to the repository;
- To ensure long-term storage of information and keeping a history of its accumulation;
- Create and store matching schemes of the source operating system metadata and storage metadata;

- Provide services for automatic updating of storage data into the operating system, converting information in accordance with the client's metadata;
- Protect information from unauthorized access; have an open architecture that is easily integrated and expandable; provide access to metadata and data from analytical information systems.

E. Main Advantage of Data Exchange in BIM-model

Thus, the main difference between the data exchange of BIM-model in Fig. 3 from the traditional storage is determined by information accumulation: data in the database should be organized in an optimal way not for analysis but for consolidation of information different automated systems.

Thus, a conceptual model of information support of the process of general planning of territories for complex, concentrated construction has been developed. The developed conceptual model of information support of the process of general planning of territories for complex, concentrated construction envisages the creation of a single methodological and technological base for integrated information space with maximum use of already existing databases and available technical means.

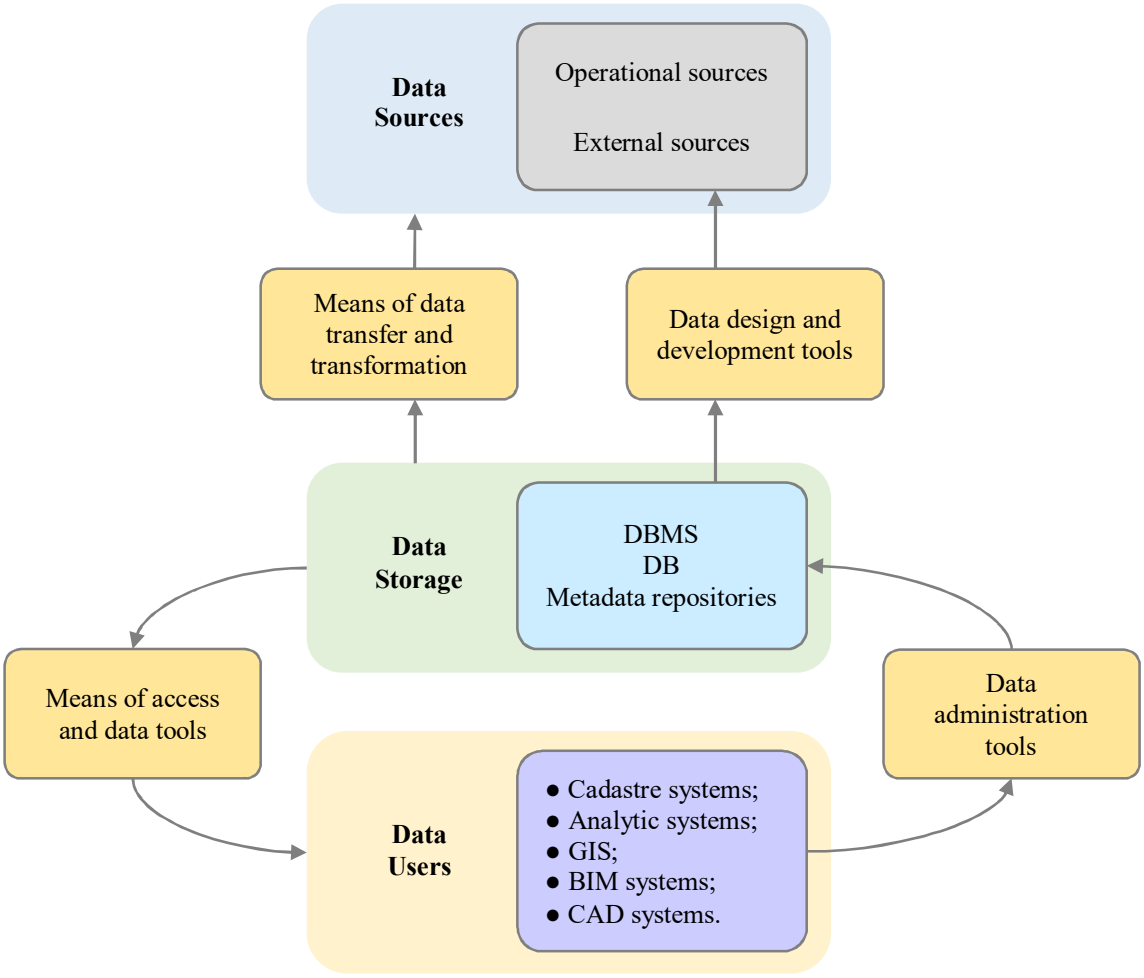


Fig. 3 BIM-model of spatial and attribute data integration

III. Results and Discussion

It is offered to use the software of Ukrainian developer GeoCAD, which works in the BIM-environment AutoCAD Civil 3D based on comprehensive information support for automated creation of the summary plan of engineering networks.

A. Central Project Database

The single information system base is created to implement the principle of integrated data processing. Information links are made through the central service of the system, and the computer center interacts with it. The complex of interconnected means of transmission, storage, accumulation, and processing of information is the technical basis of such a system, in which the central place is occupied by automation.

The workplaces of the project executors are equipped with computers that meet the technical requirements of AutoCAD Civil 3D, integrated into a local network. To perform the work on designing the consolidated plan of engineering networks, a computer is allocated, which performs the functions of a server, on which a common project directory is created, to which all project participants have access. All work on the project is carried out only in it.

As a result of joint work, each employee has operative data of a condition of networks of the adjacent are coordinates, diameters, marks in points of intersection. Networking with the digital geodetic survey, which is presented in 3D vector

form, is provided. Surveys of networks are in the thematic plan of the organization of projects, are placed on the server where the software product is started, and on other computers, local workplaces are opened.

The BIM-structure of Central Project Database and performers for the provision of spatial information for the organizational training of the territory is presented in Fig. 4.

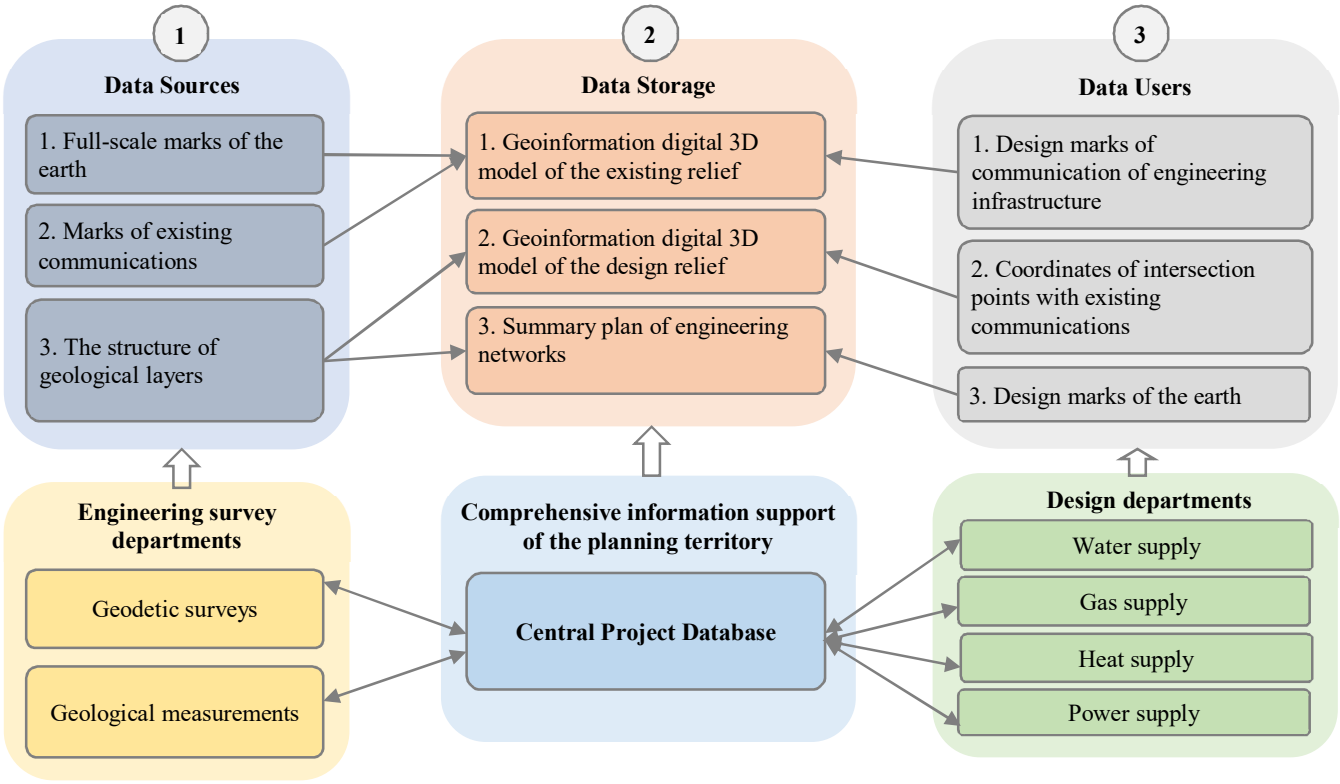


Fig. 4 BIM-structure of Central Project Database

B. *Summary Plan of Engineering Networks*

Users design with the software GeoCAD in BIM environment AutoCAD Civil 3D, which automatically interpolates the natural marks of the earth from the substrate opened on the server, recognizes communications passing at acceptable distances, detects characteristic points of intersection assigns design marks to engineering networks.

The result of the application of BIM-concept for the design of engineering networks at the stage of urban planning is Central Project Database. BIM-structure of Central Project Database is used to data sources, storage, and users based on BIM-software and integrated system. The result of automation is a summary plan of engineering networks. Fig. 5 shows an example of such a plan, which was made using BIM-based design software.

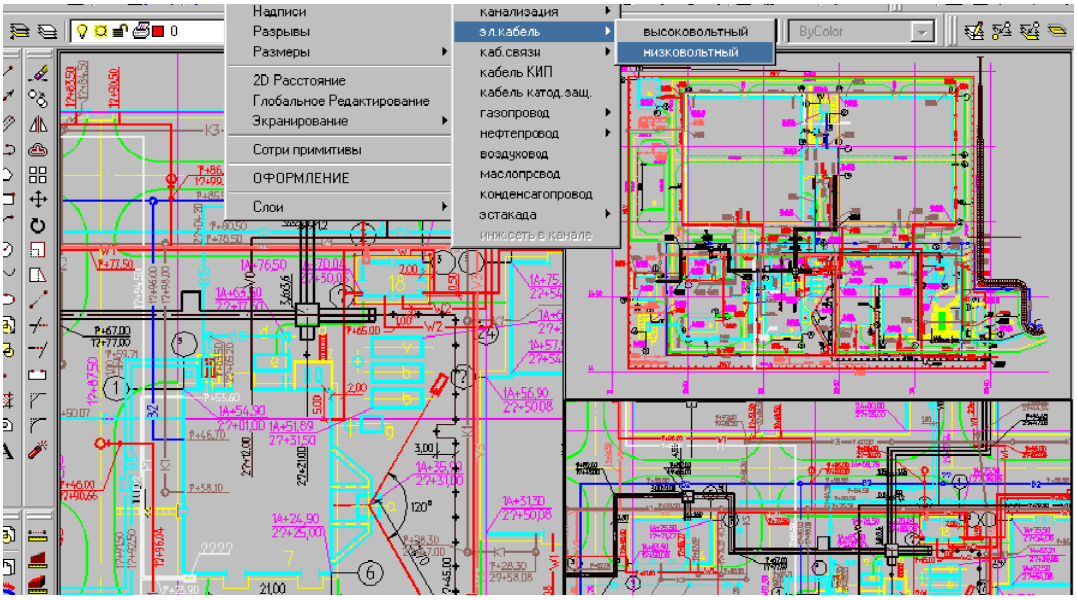


Fig. 5 Summary plan of engineering networks, made using BIM-based design software

The practical implementation of the information modeling tool for complex urban planning of territorial clusters of concentrated construction for the development of digital 3D-model of the consolidated plan of engineering networks is carried out on the basis of modern software IngCAD, which works in 3D modeling AutoCAD Civil 3D. Fig. 6 shows a digital 3D model of the consolidated Kiev city plan of engineering networks, made using AutoCAD Civil 3D.

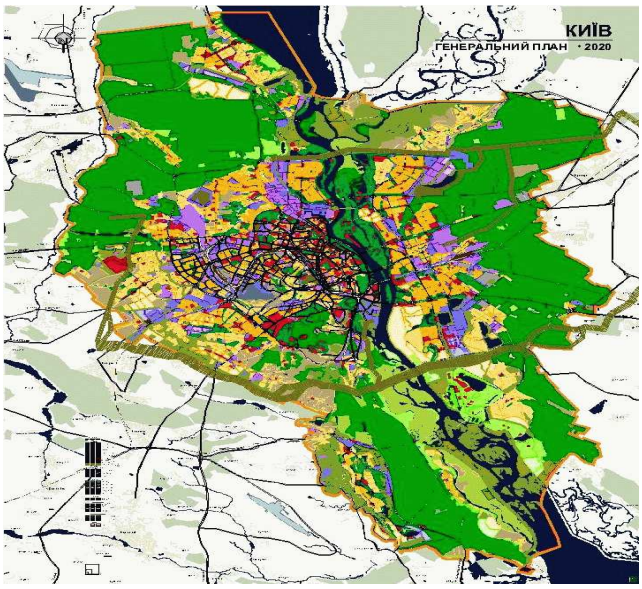


Fig. 6 Digital 3D model of the consolidated plan of engineering networks, made BIM-based design software

Databases of information modeling should be developed in a single system for different stages of the life cycle of the territorial cluster, including the following elements:

- Formation of cadastral information data;
- Geoinformation survey;
- The comprehensive urban planning of the territorial cluster for construction, taking into account the factors of influence of the adjacent territories.

IV. Conclusion

This study presents a new Central Project Database approach to describe the concept of BIM for the design of engineering communications at the stage of urban planning. BIM-structure of Central Project Database is used to data sources, storage, and users based on BIM-software and integrated system. The novelty of this approach is that spatial and attribute data of planning territory can be organized and managed in one Central Database. Any modifications at the stage of urban design immediately appear in the information model of the project of planning territory, and coordination issues can be detected.

At present, the development of the digital economy and systems engineering in construction is prioritized by information cloud technologies aimed at introducing an integrated approach to constructing buildings and structures at all stages. The use of BIM technologies at the stage of urban planning design is a new direction of its development. It is noted that the design of any object is impossible without its interaction with the territory of location and urban infrastructures.

The quality of this interaction will determine the effectiveness of the construction solution as a whole and the comfort of the urban environment for the users of the facility, which fully corresponds to the modern trends in the development of the urbanized environment.

The recommendation of this research results requires further study on the development of complex BIM-based design for urban infrastructure. It is noted that the design of any building is impossible without its interaction with the location, territory, and urban infrastructures. The quality of this interaction will determine not only the effectiveness of the construction solution as a whole. However, the comfort of the urban environment for the users of the facility, which fully corresponds to the modern trends in the development of the urbanized environment

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