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ORIGINAL RESEARCH
PAPER



Automation for structured cabling system in data centers using Building Information Modelling

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ABSTRACT

Building Information Modelling (BIM) involves management efforts, tools and applications for enhancing information flow and, therefore, productivity of projects; adoption of BIM and the increasing use of digital technologies (e.g. data centers) in construction and operation of buildings, as well as in maintenance can transform the way how the industry works. Telecommunication cabinets equipped with large number of components of different types are inevitable parts of data centers having a significant influence on the efficiency and the reliability of data centers. Since the layout of equipment inside telecommunication cabinets is crucial in data centers and the ideal location of equipment inside each cabinet can be unique, an algorithmic and automated process is necessary for the cabinet façade scheme design; manually created diagrams can lead to errors. Furthermore, precise and up-to-date pieces of information about the special layout of equipment in each cabinet are also important for the further operation and maintenance. As an answer to this challenge, a BIM-based approach and method are presented in this article that can result in significant cost savings. When designing data centers, special attention must be paid to the location of telecommunication cabinets, the design of cable routes, and the layout of equipment inside. The novel cabinet family for BIM technology-based method has been developed for the improvement of data center design. Cable trays plug-in can lead to higher quality and efficiency of construction and the facility management as well.

The main goal of the case study: optimization of the design process of structured cabling systems (SCS) in data centers (DC) using new additional BIM capabilities.

The novel dynamic cabinet family have several distinctive features:

- the ability to select in the properties which equipment will be inside the cabinet and which unit will occupy;
- possibility to change and add equipment inside the cabinet;
- creation of cabinet façade scheme based on equipment inside the cabinet;
- automatically created specification;

Cable tray plug-in can improve and automate the design process in the following areas:

- place trays depending on the installation method (wall, floor, ceiling);
- place elements of the trays (hangers, consoles, racks) in a user-defined interval;
- place tray connectors based on selected connector type and tray type at user-selectable spacing;
- adding a tray cover and a partition in the tray properties;
- automatically created specification of all cable trays elements.

The model created in BIM can be used for further operation and maintenance. To reach it, each of the elements or groups of elements contains a unique number that allows to bind its parameters and geometry for further export and use in the production model.

KEYWORDS

Building Information Modelling, structured cabling system, data center, cable trays design, telecommunication cabinets

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1. INTRODUCTION

Building Information Modelling (BIM), a term that is in focus worldwide nowadays and involves management efforts, tools and applications for enhancing information flow and, therefore, productivity of projects [1]. Adoption of BIM and the increasing use of digital technologies in construction and operation of buildings, as well as in maintenance, can transform the way how the industry works.

The most important part of data centers include: telecommunication cabinets with equipment inside and cable trays. During discussion with experts responsible for data centers design and construction, the main questions were identified to answer in case of further design optimization.

The main problems that exist today in the design of data centers:

- layouts of cabinets and trays are created in 2D, which leads to errors when combined with other systems;
- diagrams with the arrangement of equipment inside the cabinets are created manually, design errors occur;
- the equipment for specifications inside the cabinets and the cabinets themselves are counted manually, errors in the number of elements occur;
- plans of cable routes created in 2D do not contain connecting elements, corners and elements of fastening to ceilings or walls;
- in specifications of cable trays, necessary to count the number of trays, connectors and fasteners manually, errors occur;
- classic 2D schemes are not convenient to use for the further operation of the facility;
- changes in the location of equipment or cable trays in the cabinets are administered manually.

Designing data centers using BIM technologies is a new, promising area, and the potential cost savings due to this methodology can be significant.

Telecommunication cabinets equipped with a large number of components of different types are inevitable parts of data centers having a significant influence on the efficiency and reliability of data centers.

Since the layout of equipment inside telecommunication cabinets is crucial in data centers, and the ideal location of equipment inside each cabinet can be unique, automated process is necessary for the cabinet façade scheme design; manually created diagrams can lead to errors. Furthermore, precise and up-to-date information about the special layout of equipment in each cabinet is important for the further operation and maintenance as well.

The available design methods do not provide a function that creates the 3D model of cabinets with automatic filling of equipment and then serves the schemes of cabinet façades. As an answer to this challenge and automate specification of equipment, a novel cabinet family is presented in this article. When designing data centers, special attention must be paid to the design of cable routes and this question also solved by using special and optimal plug-in, that is

described in the article. This plug-in allows to automatically add all necessary elements (connectors, corners, fasteners) in the model and specify them.

The BIM-based method presented for the improvement of data center design that can lead to higher quality and efficiency of the construction and the facility management as well. These tools include a novel cabinet family that automates the placement of equipment inside the cabinet and plug-in to optimize cable tray design.

The issues of design automation for structured cabling system and equipment inside telecommunication cabinets are discussed and solved in this article, presenting a new methodology where a novel cabinet family with a dynamic set of various elements is defined.

The model created in BIM can be used for further operation and maintenance. To reach it, each of the elements or groups of elements contains a unique number that allows to bind its parameters and geometry for further export and use in the production model.

2. MATERIAL AND METHODS

2.1. Research methodology

The aim of this article is to provide a new method for improvement of data center design by using BIM. The research answers to the following questions:

- optimize the design of data center cabinets;
- automate the process of creating façade schemes for cabinets, in case of not creating them manually;
- automate the specification of equipment inside the cabinets, in case of not counting it manually;
- automate the process of creating cable trays to cabinets;
- automate the specification of cable trays elements;
- use the created model of the data center for further facility management.

These questions were prepared during consultations with BIM specialists and structured cabling design experts in 'CROC Incorporated' IT company.

The main stages of working on the problem:

- identification of the disadvantages of the usual design process through consultations with experts in a real company engaged in the design and construction of data centers;
- formation of questions to solve the problem;
- development of a new family of cabinets;
- identification of the optimal plug-in for the design of cable routes;
- identifying opportunities for using the model in operation.

Number of tools for creating information models are available. In this research, Autodesk Revit is used for problem solving and implementation as an optimal tool, which allows:

- to design architectural and structural elements and engineering systems by creating the required equipment;



- simultaneous work of several specialists in one information model;
- to download drawings for documentation;
- to create your own families, including dynamic ones with a set of changing parameters required;
- to use special plugins for optimization of designing the process.

The assembly of the final model further clash checking and the addition of the scheduling are implemented primarily with Autodesk Navisworks.

The new methodology was applied in an industrial project Data Center 'Compressor' of JSC CROC. The results obtained in the project are used in this research as a case study.

2.2. Role and structure of data centers

A data center refers to a high-tech and complex object that processes, stores and transmits information to a specific organization, and manages the information system of the organization [2]. It is a specialized facility that includes complex infrastructure, such as the following [3, 4]:

- Information infrastructure includes server equipment and provides the main functions of the data center, such as processing and storage of information.
- The telecommunications infrastructure provides the interconnection of data center elements, as well as data transfer between the data center and users.
- The engineering infrastructure includes a set of systems and equipment that ensure the functioning of the main data center systems:
 - air conditioning and ventilation system;
 - uninterruptible power supply;
 - fire extinguishing;
 - low current systems and access control;
 - other systems in accordance with the specifics of the object serviced [5].

Data centers are engineering systems that can be characterized by a high density of equipment in a confined space.

A data center usually includes the following main systems:

- structured cabling system,
- system of cable trays,
- power supply system,
- air conditioning system,
- smoke detection and automatic fire extinguishing system.

This article touches on the first two items that influence most of the elements in a data center. The methodology used for the design of cable routes, the correct location of cabinets and equipment inside cabinets has a significant effect on the usability, reliability and efficiency of data centers.

2.3. Data center design improvement

A structured cabling system is designed to organize a single cable infrastructure, which later can be used by a local

computer network, telephony systems, video surveillance, access control and other systems for the transmission and processing of information.

Cable trays in the data center perform the following functions:

- provide protection from external influences of sections of cable lines of various systems;
- provide protection of cable lines of horizontal and trunk cable systems (subsystems) from electromagnetic interference;
- physically separate different systems (for example, fiber optic cables and low current cables in separate trays).

Functional elements such as copper patch panels, optical patch panels, cable organizers, copper cables, and fiber optic cables are used to create structured cabling systems in telecommunication cabinets of data centers.

Correct placement in telecommunication cabinets is important, additionally it can be unique in each of them. Today, schemes are created manually in CAD software. Because of the varying requirements for the location of equipment inside cabinets of data centers, manually created diagrams can lead to errors and cannot enable optimization.

Integration of BIM technologies into the design of technically complex objects, such as data centers, has become inevitable recently. The use of BIM makes it possible to place equipment and communications rationally and simulate the influence of various factors in the operation of equipment; moreover it organizes the joint work of project participants effectively, reduces the number of collisions and coordinates their correction in an interactive manner.

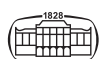
One of the essential parts of Information Modelling is filling the model with various elements called families in Revit. Each family has several parameters, which are important for further use for facility management. Since there can be several hundred cabinets in a data center and each can have unique equipment inside, it was necessary to create a novel family with changing parameters.

A new cabinet family with a dynamic set of various elements is defined which includes various sub-families of typical active equipment (switches, UPS) and allows to simulate the complete equipment of each cabinet. The novel dynamic cabinet family have several distinctive features:

- the ability to select in the properties which equipment will be inside the cabinet and which unit will occupy;
- possibility to change and add equipment inside the cabinet;
- creation of cabinet façade scheme based on equipment inside the cabinet;
- automatically created specification.

The process of creating a dynamic family of cabinets includes the creation of individual families of equipment (optical panels, cable organizers, switches, etc.), which will be located inside the cabinet and displayed on the schemes of the façades and various types of cabinets themselves, with different sizes.

The main variable parameters of the cabinet are its dimensions and equipment inside each unit. Within the family



itself, it is possible to create the required number of cabinet types and sizes, depending on the project requirements. Currently, several of the most used are available: $800 \times 1,200$, $800 \times 1,000$, $600 \times 1,200$, $600 \times 1,000$ (width \times depth in mm). Furthermore, the cabinet family contains nested families, which, depending on which unit they need to be installed in, are displayed in the 3D model of a particular cabinet and on the facade scheme. Also, this equipment is automatically included in the specification. Below is a list of the most commonly used nested families available:

- 24-port switch;
- 48-port switch;
- optical panel for 24 ports;
- optical panel for 48 ports;
- cable organizer;
- patch panel for 24 ports;
- patch panel for 48 ports;
- block of electrical outlets;
- shelf for equipment;
- a stub for a unit;
- UPS.

If necessary, we can add any other newly created family to it. As a result, the end user sees a model of the cabinet with a set of changeable parameters, such as dimensions and equipment inside each unit. The example of changeable parameters of cabinet is illustrated in Fig. 1.

The flow chart of design process with the new family is given in Appendix A.

Switching equipment inside cabinets depends on cable routes in trays. To design cable trays, it is possible to use both standard tools for trays in Revit and prepared families of trays or plug-ins developed by trays manufacturers. Today, one of the most successful tray manufacturers are Vegokan, DKC and Ostek. All of them provide free access

for BIM design plugins. In the case of designing data centers, the use of a ready-made solution from tray manufacturers is more convenient, since the number of elements included in the cable route is very large and their article numbers are often updated.

In this article a solution is presented using an automated plug-in from the Ostec company, as the optimal solution.

Comparison of the optimal plug-in with other manufacturers is presented in Table 1 and comparison of design process with the standard features of Revit is presented in Appendix B.

Since the optimization of the cabinet and tray design process can significantly reduce the design time and the potential construction errors, special attention must be paid to this part of the data center design. In the following, a tray design plugin and a novel dynamic family for cabinets are introduced and it is illustrated how the work of engineers can be improved by these tools.

2.4. Main stages of data center creation process

The data center creation process includes four main stages, as follows [9].

1. Drawing up technical specifications

At this stage the purpose and the required functions of the data center of a particular organization are determined. The specialized attributes and design of the data center, the specialized and financial requirements, the strategy and schedule, and the normal outcomes are resolved.

2. Development of technical documentation

In the design process, the tasks posed at the first stage are solved. Technical documentation is developed and agreed with the customer and the regulatory authorities.

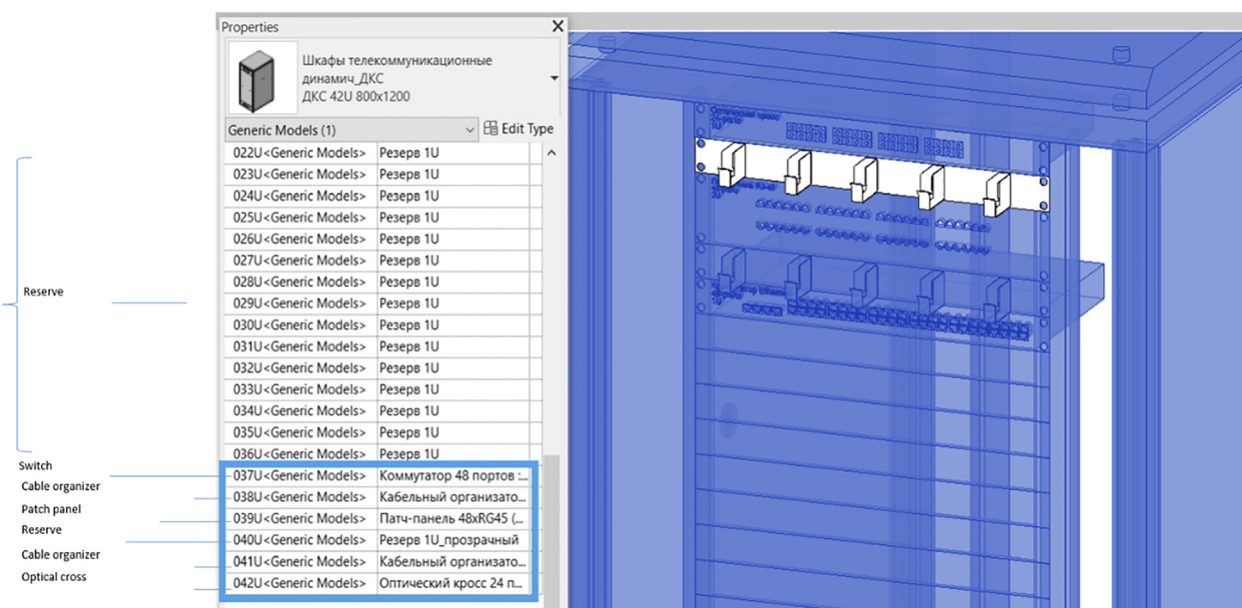


Fig. 1. Properties of telecommunication cabinet (source: project Data Center 'Compressor' of JSC CROC)

Table 1. Comparison of available plug-ins of tray manufacturers

| | Vergokan [6] | DKC [7] | Ostec [8] |
|---|---|-----------------------------|--------------------------|
| | 1 | 2 | 3 |
| Availability of an updatable plug-in in the public access | Only on request from the manufacturer | Available on the website | Available on the website |
| Automatic addition of turns and bends during trays design | No, turns and bends are separated families | Yes | Yes |
| Place trays depending on the installation method (wall, floor, ceiling) | No | No | Yes |
| Place elements of the trays (hangers, consoles, racks) in a user-defined interval | No, fastening elements are separated families | No | Yes |
| Place tray connectors based on selected connector type and tray type at user-selectable spacing | No | No | Yes |
| Adding a tray cover and a partition in the tray properties | No | No | Yes |
| Automatic specification of all tray elements | No | Yes, by standard Revit tool | Yes |
| Export the list of cable trays and components in XLS or XLSX formats | No | No | Yes |

3. Construction

This stage includes:

- preliminary construction work including the preparation of walls, floors, ceilings;
- engineering work – installation of equipment (air conditioning, ventilation, power supply, etc.).

4. Commissioning

At this stage all systems are configured and launched in test mode and the performance is checked.

In this study, a real data center of CROC "Compressor" is used as a test model. To assess the efficiency of using the solutions described in the article, a novel family of cabinets and a plug-in trays was applied for the BIM model of this data center. Results were provided for further use to engineers of CROC Incorporated. The data center is certified by the Uptime Institute at TIER III level, which corresponds to a fault tolerance ratio of 99.982%. Data center "Compressor" with a total area of 5,000 square meters allows to locate 800 racks. The average electric power of one rack is 6 kW. The total power supply capacity of the data center is 8 MW.

Uptime Institute is the most reputable certifying organization in the world, which has the rights to certify data centers in accordance with the Tier-system for design, construction and operation [10]. The Uptime Institute standard is a sequential assessment of the various capabilities of data centers in terms of uptime and infrastructure efficiency [11]. Certification can be carried out starting with the design documentation and continuing with stages of launching and operation (Design, Facility, Operations programs). Certification does not impose requirements on design solutions and

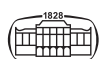
technologies: any of them can be recognized as acceptable. The crucial stage is that the certification must meet the requirements of reliability, redundancy and fault tolerance [12].

2.5. Benefits of Information Modelling in data center design

The quality and continuity of the services provided by an organization directly depend on reliability of data centers. Advantages of BIM in planning and performing the data center design process are the following:

1. Creation of a standardized information file for all project participants (blanks, templates, standards, quick exchange of information, library of families and groups) which leads to the reduction of design errors.
2. Modeling engineering systems.
3. Variability in the selection and layout of equipment.
4. Reducing design time due to the teamwork of designers.
5. Simplification of planning and organization of design work, control of intermediate results.
6. Visualization of design solutions, visual information about the state of the objects in the model.
7. Reducing the data center design costs.
8. Reducing operating costs.
9. Automatic calculation of the project costs in the model.
10. Considering and preventing technological risks in the digital model.
11. Reduction of possible design errors (collisions) [13].

After the commissioning of the facility, the customer is provided with its BIM model, which reflects the technical condition of all systems of the facility, which minimizes operational problems.



3. RESULTS

In this research a novel dynamic cabinet family was created and was tested for the potential use for manufacturer of cable trays plug-ins in an industrial project Data Center 'Compressor' of JSC CROC. The real data center of CROC "Compressor" is used as a test model. The cabinet family and the data center information model itself were created in Revit. Ostec plug-in was chosen as an optimal and trays in the test model was created by using it. Navisworks was used to check for intersections between systems.

3.1. A novel dynamic family of telecommunication cabinet

A novel dynamic family is developed with different sizes and parameters. The specific features of the new family are summarized in the following part.

Location of the equipment in cabinets depends on its type and is determined at the design stage. All elements must be included in the specification phase and this information is also necessary for further operation of a data center.

In the 'properties' of the new dynamic family inside the telecommunication cabinet, the user can choose equipment to be located in each unit, that allows to create the correct cabinet façade scheme and specification.

Each unit includes subfamilies that have their own unique parameters and can be changed, if necessary. The cabinet façade schemes are presented in Fig. 2. They show how telecommunication cabinets are equipped with patch panels, crosses, cable organizers, blocks of electric outlets, active equipment. Each cross, for example, has its own unique number, which makes it possible, to quickly identify its location at the stage of data center operation.

The process of working with the novel cabinet family in comparison with a standard family provided by the manufacturers is presented in Appendix A.

3.2. Cable trays

Figure 3 shows a section of a cable tray with various elements (turns, corners, cable tray covers). Each element has certain parameters, e.g. size, name, ID, which are important at the stage of model creation. In the modelling process, firstly, the size change of the tray may be required. Secondly, all this data is necessary to draw up an accurate specification of products and materials.

The goal of the research is the optimization of the design process of structured cabling systems in data centers and obtaining more efficient design methods compared with the standard ones. For the implementation and presentation of the methodology a plugin is needed, which provides the correct filling of the required parameters and the possibility

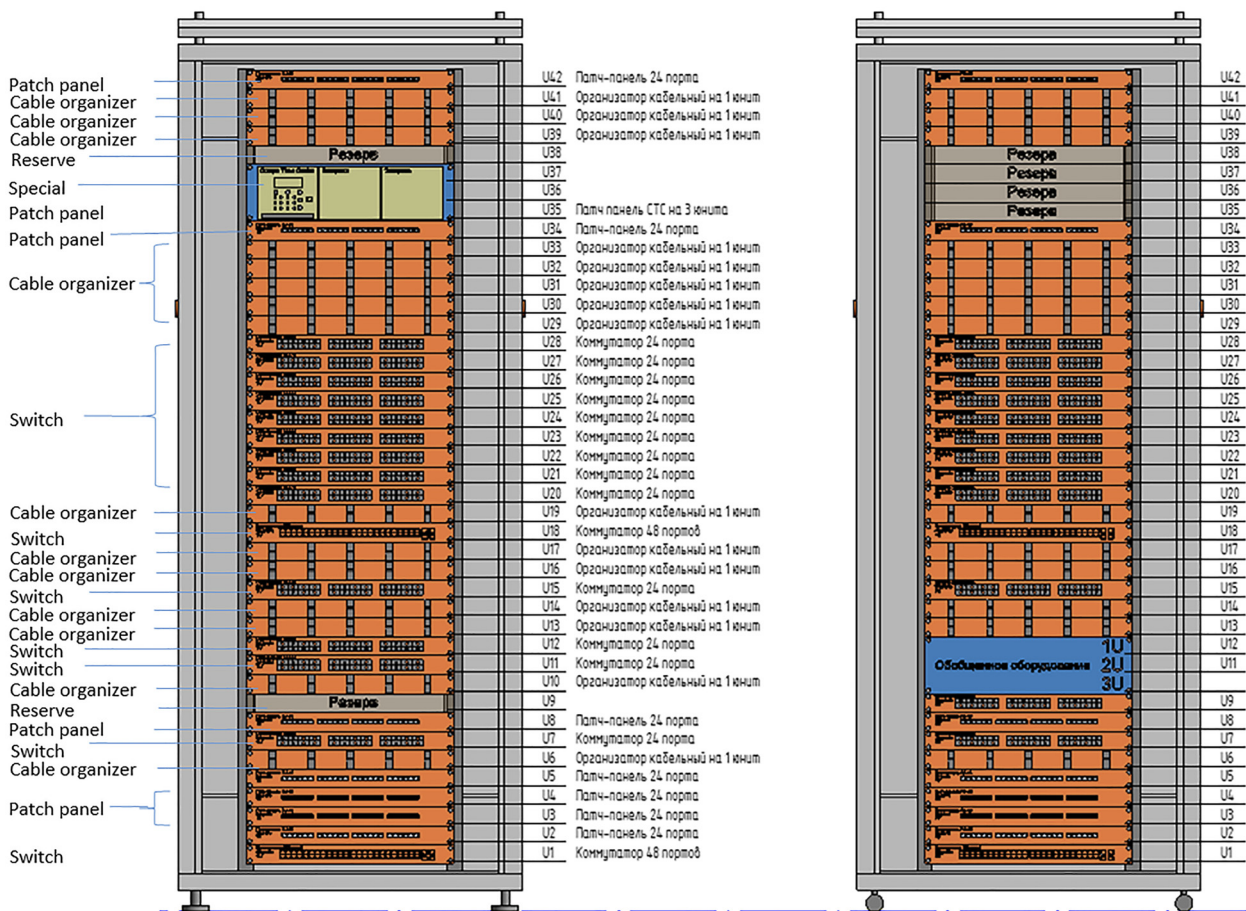


Fig. 2. Telecommunication cabinet façade drawings (source: project Data Center 'Compressor' of JSC CROC)

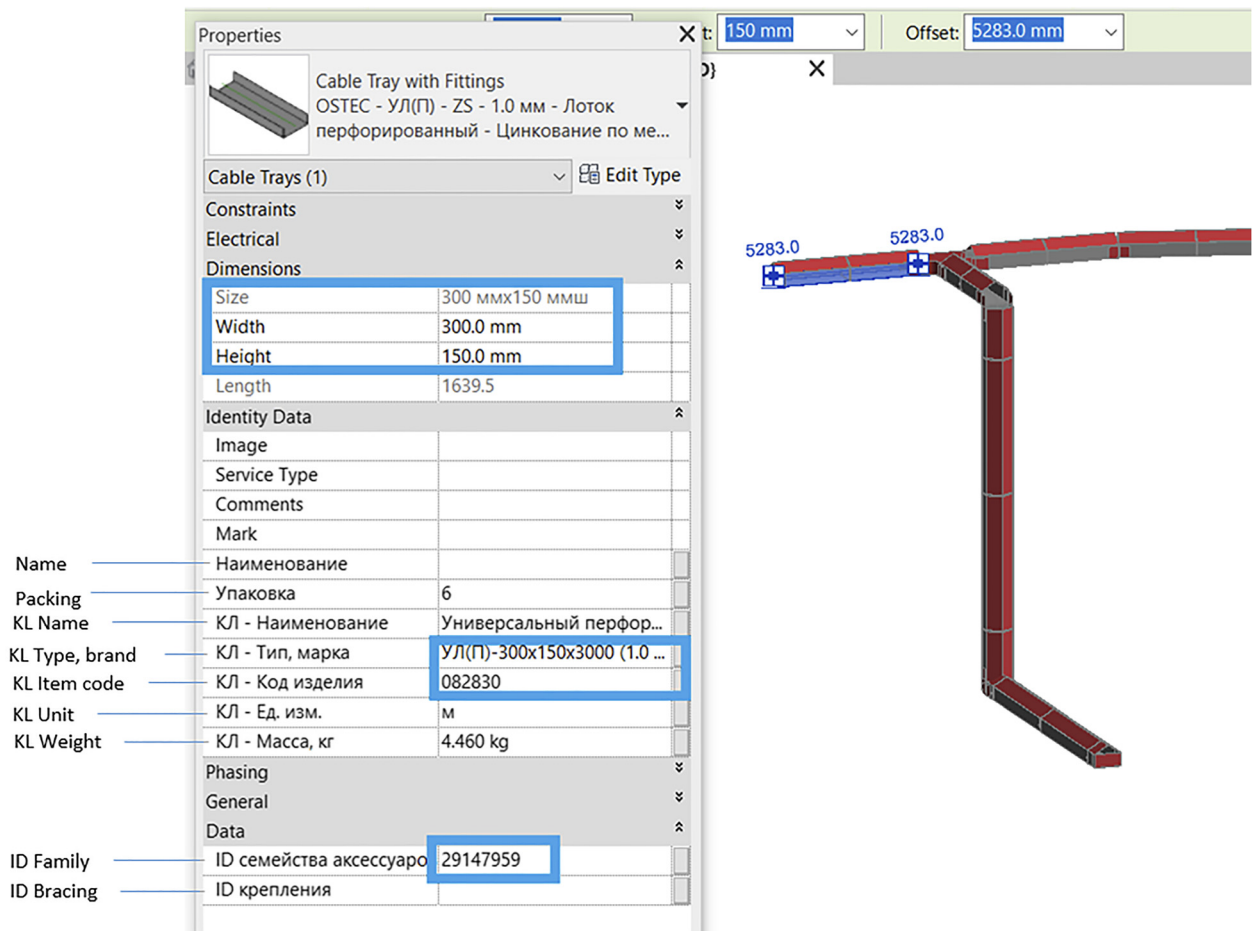


Fig. 3. Some parameters of cable conduits (source: project Data Center 'Compressor' of JSC CROC)

to specify all elements of the trays' routes automatically. For this purpose, a plug-in of the Ostec company is used.

The cable tray plugin can improve and automate design process in next operation

- placing trays depending on the installation method (wall, floor, ceiling);
- placing elements of the trays (hangers, consoles, racks) at a user-defined interval;
- placing connectors of trays depending on the selected type of connector and on the type of trays with an interval equal to the length of the selected type of tray;
- adding a tray cover and a partition inside in the properties of the tray itself;
- exporting the list of cable trays and components in XLS, XLSX formats;
- creating specification automatically.

The specification includes all elements of the cable routes, including the necessary connecting elements. An example of cable conduit specification is presented in Table 2 (Appendix C).

4. DISCUSSION

Data centers are technically complex objects that include many systems. A data center cabling system is part of an end-to-end

complex engineering and information solution that supports a variety of hardware and software products from many vendors.

In this paper a methodology is presented that can significantly enhance the performance of data centers through designing the placement of trays for cables and managing the information related to the cabinets in an efficient way.

The article presents how to

- optimize the design of data center cabinets;
- automate the process of creating façade schemes for cabinets, in case of not creating them manually;
- automate the specification of equipment inside the cabinets, in case of not counting them manually;
- automate the process of creating cable trays to cabinets;
- automate the specification of cable trays elements.

The use of BIM technologies in data center design makes it possible to facilitate and speed up the work significantly during the design phase and further operation. The systematic development of data centers is the foundation of further effective operation for many years, while saving technical and material resources. Information modelling allows to ensure the fulfillment of the main criterion: the reliability of the object.

The plug-in makes it possible to automate the construction of cable routes between cabinets, fastening elements will be placed depending on the selected surface (wall,

floor, ceiling) automatically and all elements (including bolts and nuts) will be included in the specification.

The new family of cabinets allows us to select automatically the required equipment and its location in the 'properties'. Thus, each cabinet can have a unique filling, which eliminates the error of creating façade diagrams. Also, all equipment is automatically included in the specification.

All of these improvements can significantly optimize the design process, reduce errors, and help to prepare the model for operation and maintenance.

The framework of BIM data being used for facilities management was predicted on the assumption that information transfer from the information model to the building management systems can be easily achieved by using standard tools. There are several ways to transfer information for operation: through conversion to an IFC file and directly to a specialized program. These methods have their advantages and disadvantages.

The authors are going to focus on this question in their future work.

5. CONCLUSION

Nowadays data centers play an important role in industry. Since enhanced efficiency of data management is a source of cost savings, optimization of data center design and operation is in the focus of a lot of research projects.

In this paper, a BIM technology approach is used for the improvement of data center design, in order to reach a significant level of design time and operational cost savings.

The presented method (novel cabinet family and plugins of cable trays) is a contribution to the solution of some problems appearing in the design of data centers today, namely

- 2D cabinet and tray layouts frequently lead to errors when systems are combined;
- constructive errors occur due to manually created diagrams of the equipment arrangement inside cabinets;
- 2D trays plans do not contain connectors, corners, or ceilings or walls;
- counting errors occur due to manually counted elements when specifying cable trays;
- classic 2D schemes are inconvenient for the further operation of the object;
- changes to the location of equipment in cabinets or cable trays are made manually.

Comparison of the design process by standard Revit tools with the cable trays plug-in and the novel family of cabinets (Figs 4 and 5 see in the flow charts in Appendixes A and B) shows the benefits of the application of the proposed methodology.

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Appendix A

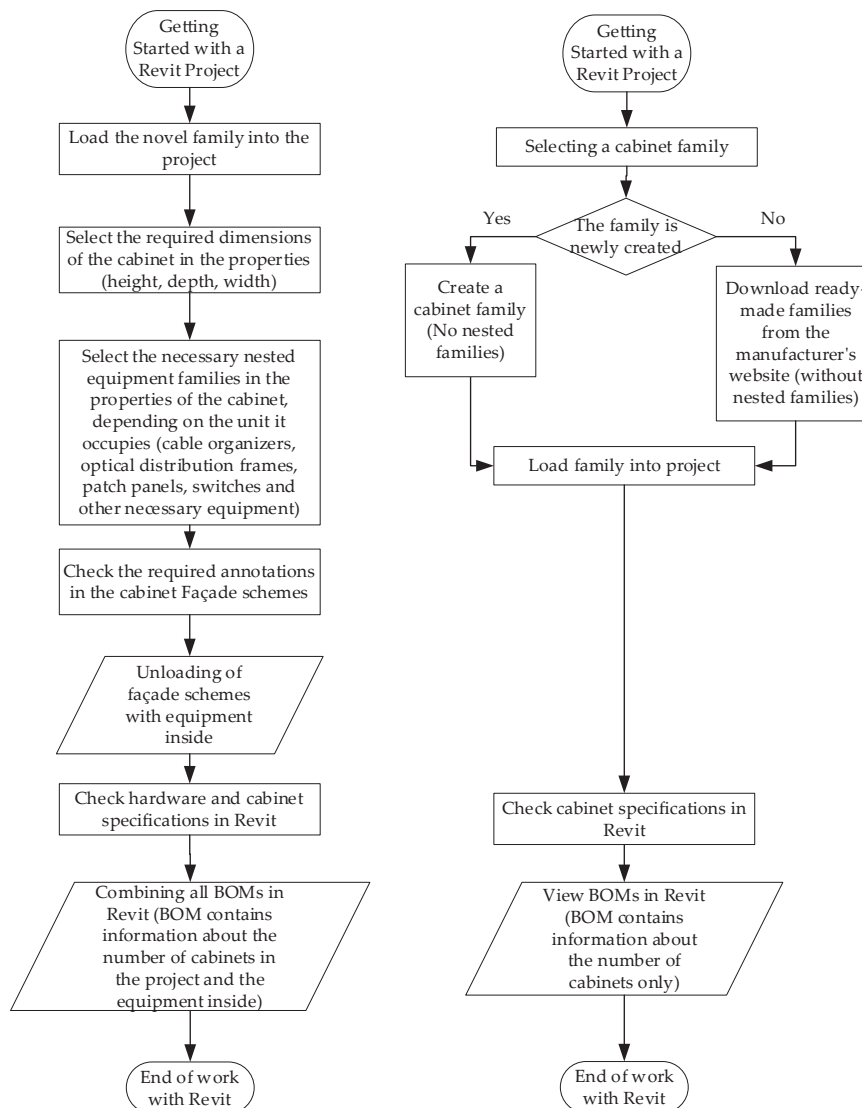


Fig. 4. Flow chart: Design process with the novel cabinet family and with a simple family (source: project Data Center 'Compressor' of JSC CROC)

Appendix B

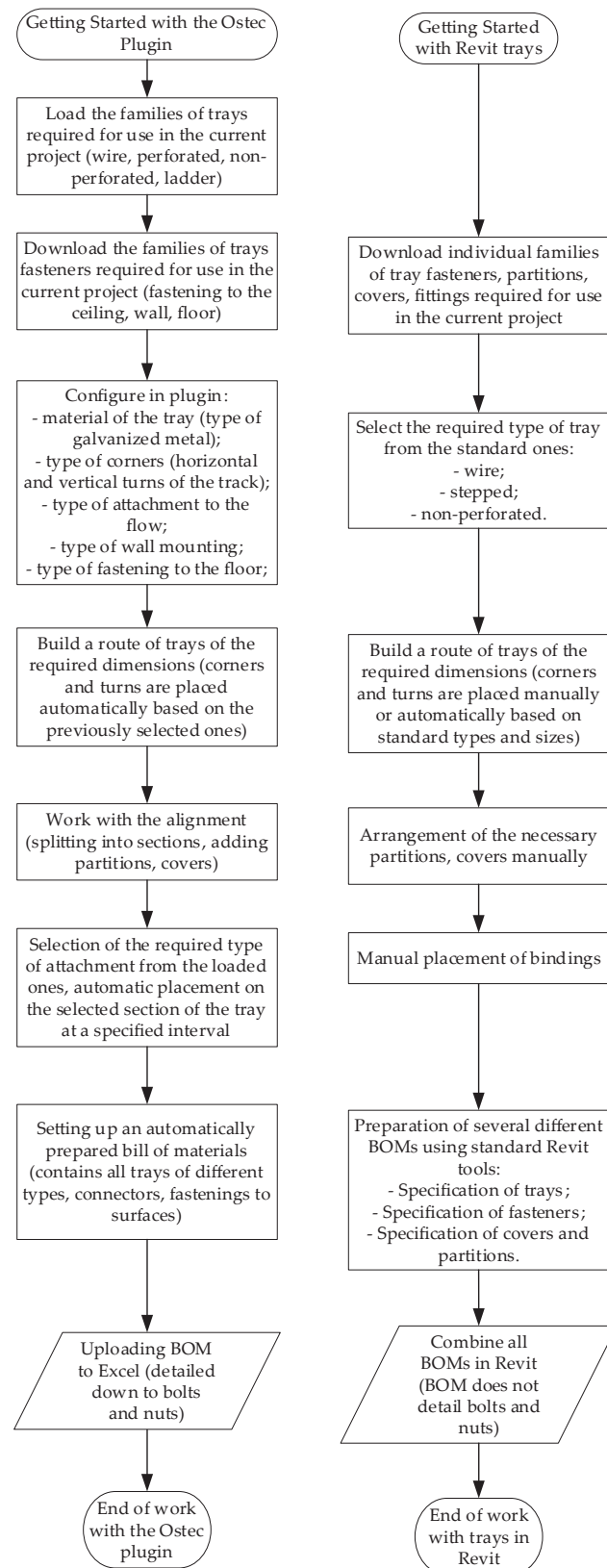


Fig. 5. Flow chart: Design process with the method based on an Ostec trays plug-in and standard Revit tool (source: project Data Center 'Compressor' of JSC CROC)

Appendix C

Table 2. Example of cable conduits specification (source: project Data Center 'Compressor' of JSC CROC)

| No | Name | Type, brand | Item code | Manufac-turer | Unit rev. | Number | Weight, kg | Packa-ging |
|-------------|--|------------------|-----------|---------------|-----------|--------|------------|------------|
| Cable trays | | | | | | | | |
| 1 | Non-perforated tray LN series 50×50×2500 | ЛНМТЗ(М)-50×50np | 012551 | OSTEC | Meter | 97.5 | 0.77 | 30 |
| Details | | | | | | | | |
| 2 | Mounting profile PP100 | ПП100 | 051901 | OSTEC | meter | 16 | 0.5 | 60 |
| 3 | Swivel bar for tray height 50 | ППС | 040351 | OSTEC | unit | 8 | 0.04 | 100 |
| 4 | Changeable universal tray connector for a tray with a height of 50 | СЛУИ-50 | 032851 | OSTEC | unit | 6 | 0.06 | 150 |
| Fasteners | | | | | | | | |
| 5 | Split anchor M8×30 (brass) | АЗМ830л | 063089 | OSTEC | unit | 186 | 0.013 | 100 |
| 6 | Semi-cylindrical head screw DIN 7985 M6×10 | ВМ6х10 | 066109 | OSTEC | unit | 56 | 0.005 | 500 |
| 7 | Nut with lock collar DIN 6923 M6 | ГМ6СБ | 067609 | OSTEC | unit | 56 | 0.003 | 500 |
| 8 | Nut with lock collar DIN 6923 M8 | ГМ8СБ | 067809 | OSTEC | unit | 372 | 0.007 | 250 |
| 9 | Connecting nut DIN 6334 M8×28 | ГСМ8 | 069089 | OSTEC | unit | 54 | 0.04 | 100 |
| 10 | Threaded rod DIN 975 M8×2000 | ПП8-2 | 064829 | OSTEC | unit | 213 | 0.6 | 25 |

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