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ADVANTAGES OF USING BIM TECHNOLOGIES FOR DESIGNING HVAC SYSTEMS IN CONSTRUCTION

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Abstract

The construction industry is developing every day, and therefore there is a need for new technologies. Knowledge about them is an indisputable advantage, especially when applying for a job. In the construction industry, technologies are developing especially rapidly and in this regard, there is a need to study them.

The main aim of the work is to motivate engineers to further study BIM technologies and to choose the right way to study the necessary programs in this sphere. Also, it aims to provide a valuable resource for engineers looking to expand their knowledge and skills in BIM technology and to stay at the forefront of the construction industry.

Methods of this research include background information about BIM programs, how they are used in the construction industry, designing HVAC systems in BIM and CAD software. Additionally, this thesis also explores the potential benefits of implementing BIM technology in the construction industry, such as improved collaboration and communication among project stakeholders, increased efficiency and cost savings, and how to do more accurate and detailed project documentation.

As a result, the reader has gained the basic and necessary knowledge and skills in the field of BIM technology. The conclusion highlights the importance of continued education and training in BIM technology for engineers in the construction industry to stay current and competitive in an ever-evolving field.

Keywords
BIM, Building Information Modelling, Design, Technologies, HVAC.

CONTENTS

1 INTRODUCTION

The development of the construction industry is closely linked to the emergence of new technologies that improve design and speed up the approval process. Therefore, in order to become a sought-after engineer, it is necessary to constantly monitor the innovations in one's field and to study different programs.

This thesis looks at the history of BIM technologies, the general idea of BIM and examines the main programs that are used together in the design and working phases of a project.

The aim of the work is to help young engineers learn more about BIM and its programs, and to motivate them to learn more about this area of the construction industry. Another aim is to create a very useful resource for those who know nothing about it.

The main methods of working on this thesis have been sourcing information in literature sources and transferring design experience from the author of the thesis.

2 ABOUT BIM

2.1 What are BIM technologies

To understand what will be discussed in the thesis, it is important to understand first of all what BIM technology is. Mankind does not stand still and is constantly evolving, our age has witnessed the rapid development of information technology, which has penetrated all spheres of our lives. Computers and smartphones today are perhaps the most commonly used equipment for work and study.

There have been huge changes in the construction industry over the past 30 years. Every year the population of the Earth is growing at a tremendous pace, all people need somewhere to live, relax, work, study, which is why the pace of construction of buildings increases, a huge number of commercial and residential real estate objects appear, new requirements for buildings are added. In this regard, construction companies have a new task - to accelerate the pace of development of project documentation and implement the project on time. Previously, engineers and architects drew projects of buildings with their hands, they had to spend a lot of time correcting the drawings, it was not always possible to find errors, there was a chance to lose the project, because someone could accidentally spill a cup of coffee on the table, thereby spoiling all the work done. It would be impossible to imagine if we lost from one fallen spark such a wonderful project as the Eiffel Tower, which later became a new wonder of the world. (Figure 1).

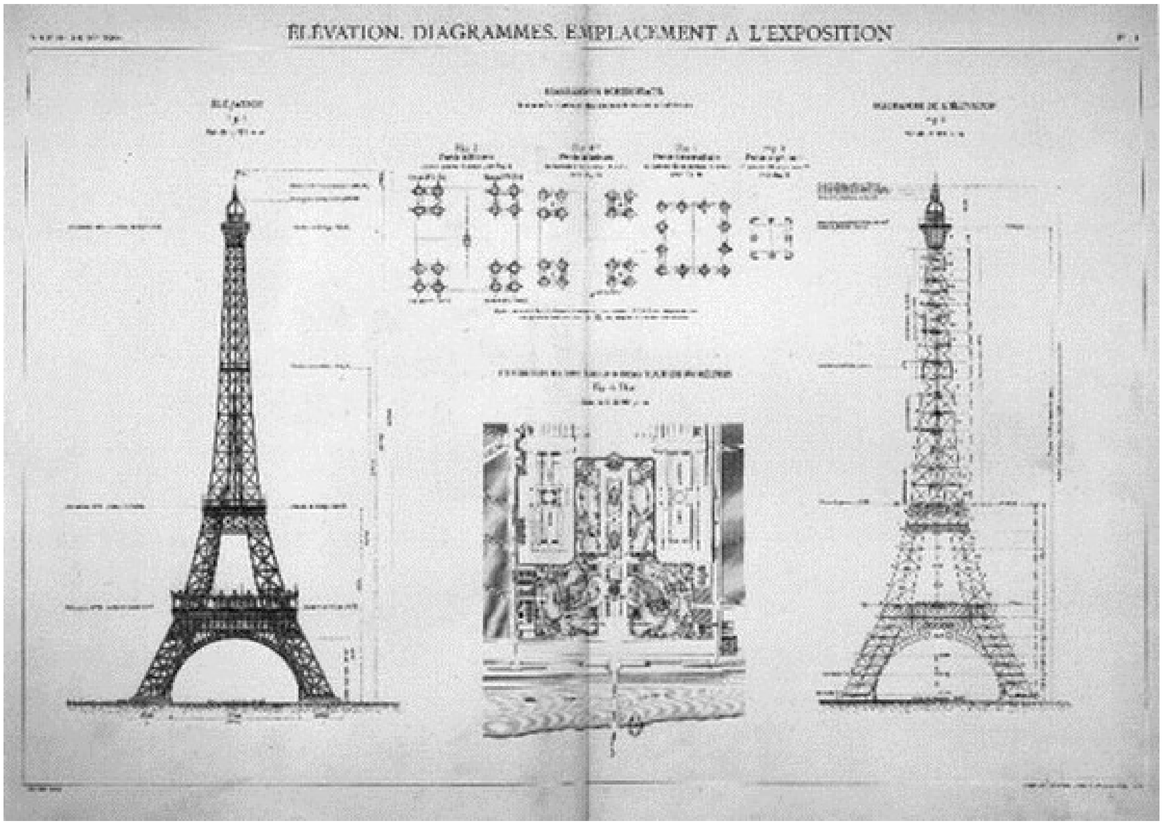

Figure 1. Drawing of the Eiffel Tower on paper

To solve this problem, computer-aided design (CAD) systems were invented /1/. In simple terms, designers were able to forget about drawing on paper with their own hands forever and implement projects of any complexity using only a computer mouse. With the development of these technologies, people learned to design buildings using a computer much faster: drawings could be made faster, and corrections in the project can be made literally in 5 minutes without touching the entire drawing, since at any time you can delete an incorrectly drawn line. After some time, it became possible to make 3D models, but they were not very popular, since they were a kind of solid-state shell of a building or structure that could only be used for a visual understanding of the project. But on drawings and visual 3D models alone, it is impossible to achieve a quick implementation of the project and not lose any information at the coordination stage. A new stage in construction was achieved – BIM technologies.

The abbreviation BIM stands for Building Information Modeling. This technology not only allows one to design intelligent 3D models, but also you to create a complete virtual analogue of the building with all its parts: supporting structures, furniture, windows, doors, any engineering communications with connected devices. In addition, the collaboration feature encourages engineers to work cohesively in a shared information space and implement modifications to the model that will be updated across all project participants. /2/.

2.2 Use in construction

BIM technologies are used not only for the design of buildings, but also for any other infrastructure: airports, bridges, parking lots, engineering networks, railways, tunnels and even ventilation systems for ships. One of the most outstanding non-building projects was developed by the Norwegian company Sweco – this is the Randelva Bridge in Norway (Figure 2).

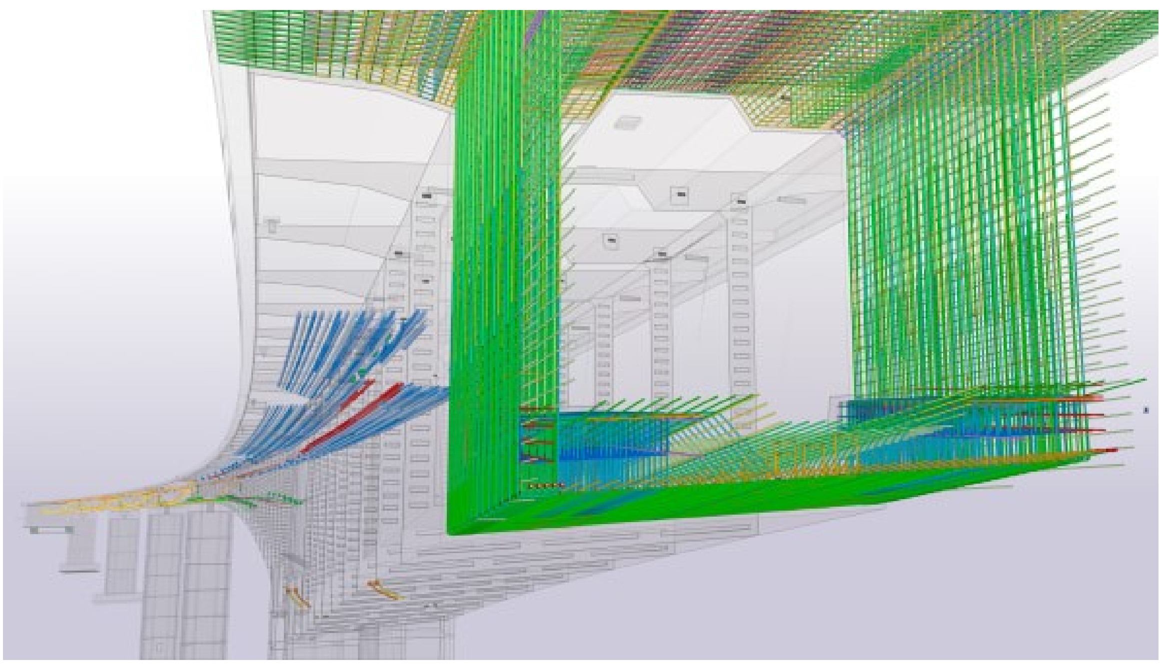

Figure 2. BIM model of the bridge Randselva

This bridge is the longest ever built without the use of 2D drawings. Of the features, it can be noted that BIM technologies help contractors on site to get up-to-date information on the project using VR glasses, tablets or phones. For example, in the presented picture, perhaps the electrical engineer specifies in which place the lighting lamps should be located so as not to make mistakes (Figure 3).

Figure 3. Clarifying the location of lamps using BIM.

At the moment, many construction companies use outdated design tools, such as AutoCAD, and those who have the funds are hiring real BIM professionals who help engineers in the company to switch to these modern technologies.

There are also special firms that, for a fee, transfer an object from drawings to a digital 3D model. This is a very popular business with contractors, subcontractors and developers.

Another example of the use of BIM in construction is the author's observation of the chief engineer of the project on the progress of the works. Arriving at the site, such an employee can put on VR glasses and in real time check any part of the building for compliance with the project, instead of messing with a pack of drawings. Perhaps in the future it will be possible to project the components of the information model of the building directly on the construction site without using devices with monitors, which would significantly speed up the construction process, since everyone would simultaneously see where and what to install instead of passing the phone or tablet from hand to hand /3/.

2.3 Relevance of the topic

As mentioned earlier, BIM technologies are developing and being implemented in the construction industry every day at a faster pace. They help to speed up the process of developing working documentation, improve the process of construction supervision of objects, coordinate work on the construction site faster and calculate estimates.

Now any architect or electrical engineer should know BIM, because they will prevail in the future, and CAD programs will become a thing of the past. Knowledge of such programs at the moment is a plus when applying for work in construction companies. It is important to know what these technologies are. We can say that their appearance is something on the level of the appearance of iPhones on the phone market. Steve Jobs turned the ideas about smartphones upside down by creating such a wonderful product as the iPhone, which is still used by a lot of people and every year they update their device to a new one.

Therefore, the topic of the thesis is more relevant than ever at the present time and will be relevant for a very long time, because it will tell not only about how BIM technologies appeared, but also how to use them in the field of engineering communications and become a sought-after specialist.

3 INTERACTION OF BIM SPECIALISTS AND BENEFITS OF BIM IMPLEMENTATION FOR COMPANIES

3.1 Hierarchy of BIM workers

BIM technologies provide an opportunity to work simultaneously in one model to an entire staff of employees. Each has its own duties and responsibilities for part of the model. BIM workers are not always designers or architects. There is also a place for IT specialists in this field. The composition of the project team is usually made up of qualified specialists with experience in the work and organization of work on BIM design.

Among the specialists involved in the design process using BIM technologies, the following roles can be distinguished:

- Strategic function (BIM Manager)
- Management function (BIM Coordinator)
- Technical function (BIM Master, IT specialist)
- Consulting and training function (Third-party consultant)
- Production function (BIM Designer)

The strategic function is performed by the BIM manager. This function is crucial for the successful implementation and application of BIM technology in the company. A person in this position must both understand all the design processes and the specifics of BIM processes.

The management function is performed at the project level. A project team leader, a BIM coordinator, is appointed responsible for this function. Such an employee must perform both the current work on the project and the tasks related to BIM technology. Basically, one BIM coordinator is assigned to one project area, such as architecture or engineering systems.

The technical function is associated with the creation and adjustment of BIM content (families and templates), as well as the management of network and IT resources. In small projects, a BIM manager can replace this work, but when the project expands and the frequency of use increases, BIM masters and IT specialists are usually hired, who together will perform the tasks much faster.

The consulting and training function is usually performed by a third-party consultant. His tasks include only training employees who have not yet had time to learn new programs or do not know anything at all about BIM technologies.

The production function, namely the creation of the model and the preparation of documentation, is performed by the BIM designer, who usually has experience in the specialty and the skills of using BIM. He is directly subordinate to the BIM coordinator /4/.

Often in the team there is no BIM master or third-party consultants for training and the approximate picture of the tasks looks like this (Figure 4).

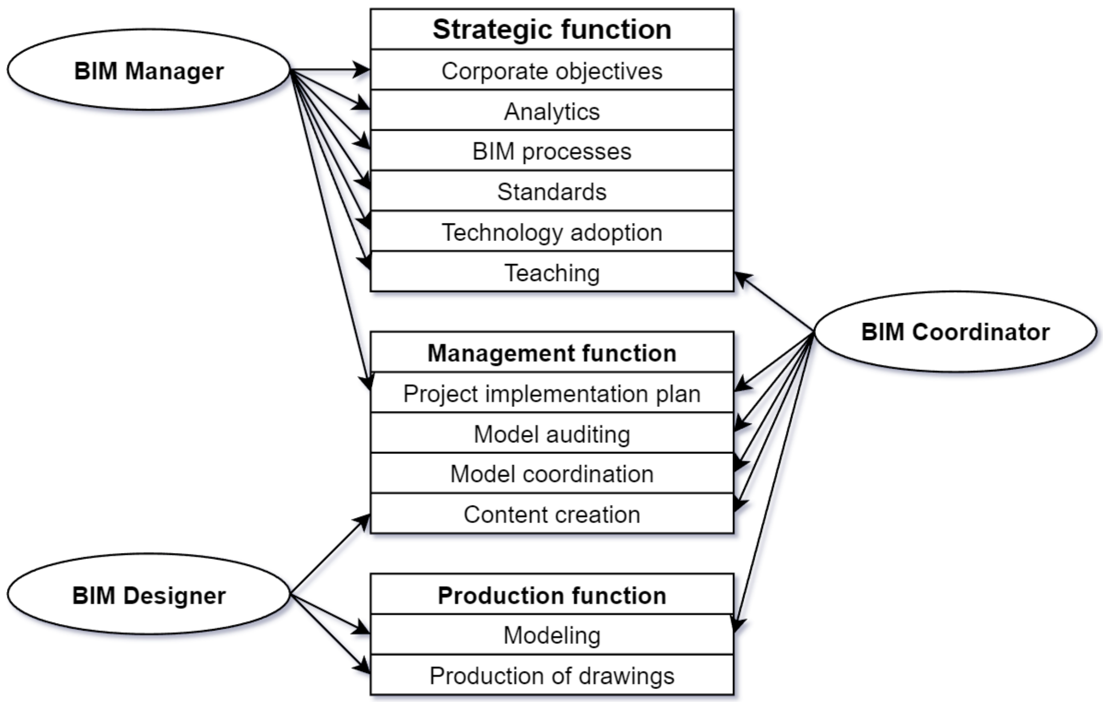

Figure 4. Tasks of the BIM team and those responsible for them

BIM Manager

Even in small projects, there is always communication and mediation between the customer and the contractor directly. The same rule works with project participants. Often the role of the "general designer" is played by the architect.

Due to the increase in the size of projects and the costs associated with them, companies have a need for a separate professional specialist, a responsible and trusted person of the customer. In the case of BIM, this need is further strengthened, as functioning communication and collaboration here, taking into account the advantages, become crucial.

Often, a BIM manager is the same person who develops an AIA for a project or supports customers in this, since he has the necessary professional knowledge in relation to BIM. In addition, his qualifications include the knowledge and skills of a project manager and a construction specialist, social and methodological competences, as well as knowledge of information technology. He monitors and coordinates the entire flow of information, including models, during the entire course of the project. Along with this, a BIM manager can be used not just in a specific project, but in general in the enterprise, since it is advisable to focus its methods of work on BIM, and this requires strategic support.

BIM Coordinator

The BIM Coordinator ranks in the hierarchy one step below the BIM Manager.
Of the features, we can highlight the fact that, depending on the size of the project, a person in such a position can be an executor. Unlike a BIM manager, the coordinator is on the side of the contractor and manages the collaboration and the flow of information. This role can be compared to the same computer-aided design systems coordinator in a design office, but with a wider range of tasks due to the use of BIM in the creation and operation of designed models of a construction site.

The BIM Coordinator, within his professional field, is the first point of contact for all employees, coordinates their work and supports them in creating models of the construction site and project documentation regarding the required quality and the required content of information. They are controlled by him before further transfer, external communication with the BIM-manager and project participants from other sections are also within the scope of his tasks.

Therefore, the BIM coordinator, in addition to extensive professional knowledge of his own software and its features, additionally must have at least basic knowledge in the field of other CAD applications, as well as information technologies in general terms. Equally, the competences of the BIM coordinator include communication and the ability to work in a team, as well as a deep understanding of BIM and related methods and processes in the development of the project.

BIM designer or **BIM modeler**

Any BIM manager or BIM coordinator begins his professional path in this role. The BIM designer occupies the last step in the hierarchy of the BIM team. His main tasks include the development of models and responsibility for the creation and maintenance of models of the construction site and project documentation necessary for design and execution. Therefore, he must know exactly not only his own programs and workflows used for this, but, in particular, also their features in relation to IFC-directed modeling /5/.

In such a position, a person should have a basic knowledge of BIM and related central aspects, processes in the development of the project, in order to coordinate with them their own method of work.

3.2 Economic benefits

3.2.1 Main expenses

Before talking about the economic benefits when using BIM technologies, it is important to understand where the money goes for its implementation and use. (Figure 5).

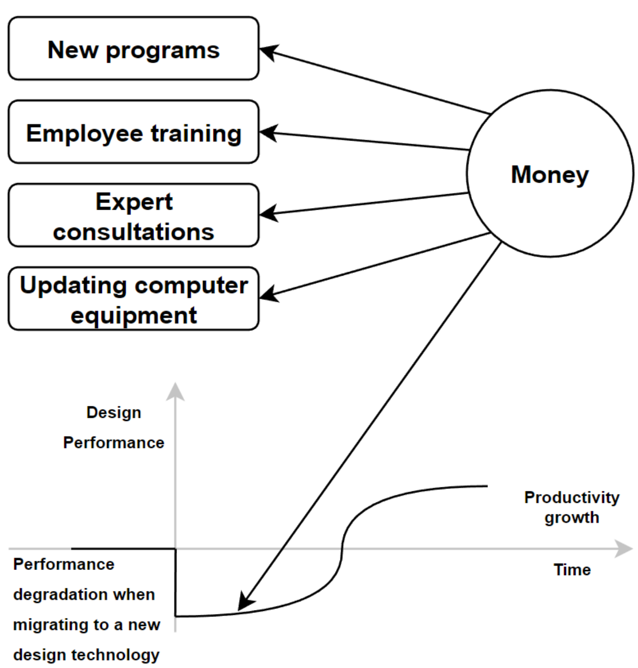

Figure 5. The main costs associated with the implementation of BIM.

Of course, new programs are a considerable source of costs, since if a company does not want to fall under the hands of justice, it should buy a license for the necessary software. Usually the license is bought from 500 to 3000 euros per employee. And if the department has 30 employees, then this already turns out to be a fairly large number.

It is also important to train employees to use these new programs if they have never used BIM technologies. To do this, there are separate companies that provide the opportunity for corporate training on any programs related to BIM. In 1.5-2 hours, an entire department can learn all the features of BIM programs.

In order to properly engage in the implementation of technology, they hire experts in this matter. They monitor how many people have mastered the necessary skills, select programs that are best suited to the company's activities, consult with management and build a further system of digitalization of projects. Such specialists are very much in demand at the initial stages, since not all companies have yet managed to implement BIM technologies.

Updating computer equipment is also costly. It is simply impossible to run some BIM programs on old computers with weak processors, video cards and with low RAM. If the majority of employees in the company work on site, then you should update computer equipment. But if it is possible to transfer employees to remote work, which is very popular currently, then more advanced companies rent special servers with which it is possible to run a virtual desktop from any computer - the main thing is to have a fast and stable Internet. Renting such servers is also very expensive.

At first, when introducing BIM technologies into the company, there may be huge costs and if you do something wrong, it can result in a rather big economic problem, but over time, the team will adapt and everyone will design and work as usual.

3.2.2 Main income

The introduction of BIM brings not direct, but indirect revenues. It will be discussed below. The first and most important advantage of BIM is time. Often there are situations when the project office does not have time to develop a project and coordinate documentation with the customer. BIM technologies come to the rescue, which, according to the results of numerous studies, help to save from 20 to 50 percent of the time during the implementation of the project.

On the graph, you can see that at an early stage of implementation it takes quite a lot of time due to the fact that it is redistributed and due to the inexperience and imperfect organizational work of employees, sometimes it may take even more time for a project than without BIM (Figure 6).

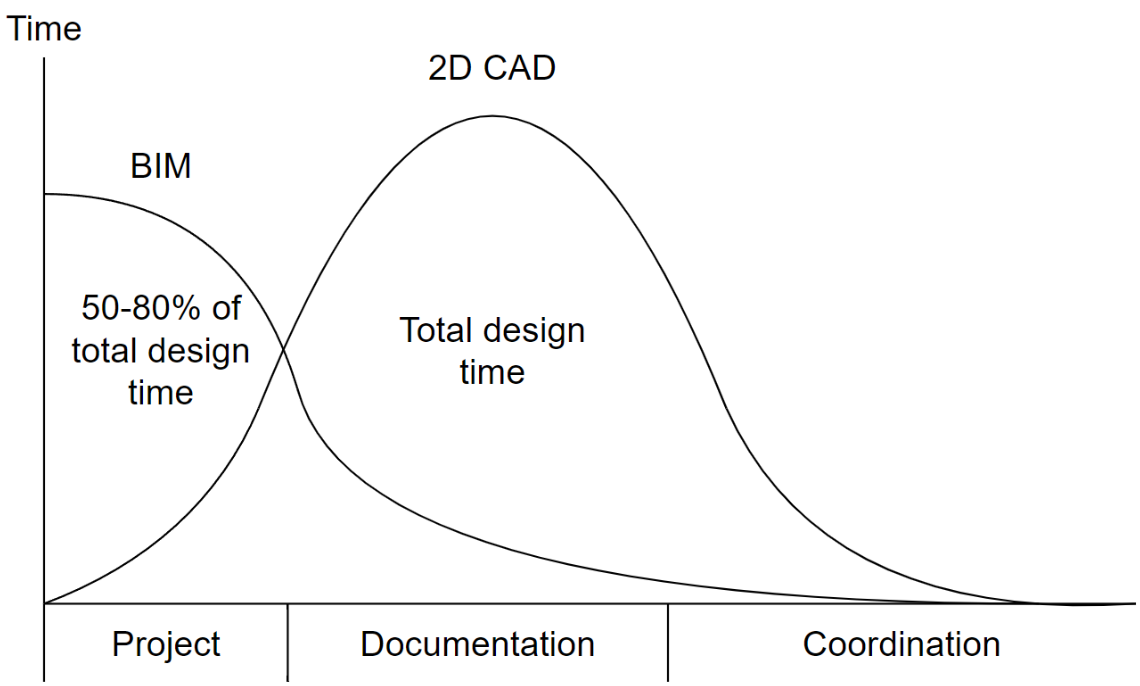

Figure 6. Redistribution of time for design related to the implementation of BIM technologies.

A significant saving associated with the use of BIM is the elimination of design errors and the exclusion of their appearance on the construction site.

Error checking with the help of BIM can be useful even if the main part of the company has not completely switched to new technologies and traditionally works in 2D, and a special employee makes an information model for the developed project, thus testing the project for consistency. This approach improves the quality of the product, requires minimal costs and quickly pays off.

It is very effective to eliminate design errors when checking for three-dimensional intersections in a project that is performed using BIM. Such errors often occur with all control measures on the construction site, and their elimination at the expense of the designer can be associated with very high costs, which can be up to 40% of the project cost.

Also, the use of BIM helps to speed up the design due to the rapid design and selection of engineering systems of the building. It is much easier to create an accurate specification, since each part of the model will be entered into it by default.

Another area of design in which BIM brings tangible benefits is the creation of specifications and especially construction estimates. Estimates are a very time-consuming process, where the main rough work is the collection of data on the scope of work and materials from the project. Current estimators spend more than two-thirds of their working time. But the main nightmare for estimators is changes in the project, especially when they are carried out in parallel with the estimated work. As a result, with traditional design, any estimate will be unreliable.

Another equally important item of income from BIM is associated with the correct definition of the environmental, energy, economic and many other parameters of the future building. The main economic and environmental characteristics of the building are determined already at the stage of the draft design, predicting the cost of its operation. This greatly saves money not only for the company, since the calculation is faster, but also saves the owners of the future structure.

First of all, in construction, BIM allows to receive money "directly from the air", that is, from the correct organization of the very process of erecting a building. Of course, people have done this before, but with the advent of building information modeling, the process of organizing construction production has become more informative, accurate and faster, that is, more efficient. The gain is obtained both in the exact timing and in the correct logistics, as well as in the rationally phased financing of construction.

4 POPULAR SOFTWARE

4.1 Types of programs and specialization

4.1.1 AutoCAD software

In the construction industry, there are many different programs for conventional and BIM design. But until recently, a program not related to BIM - AutoCAD (Figure 7) was especially popular among construction companies. It is a program for 3D computer modeling and 2D drawing from Autodesk.

Figure 7. AutoCAD logo.

AutoCAD is still used to compile and draft project documentation.
In the program there are many tools for drawing which will be discussed below.
Below you will also see a drawing of the formwork systems made in this program (Figure 8).

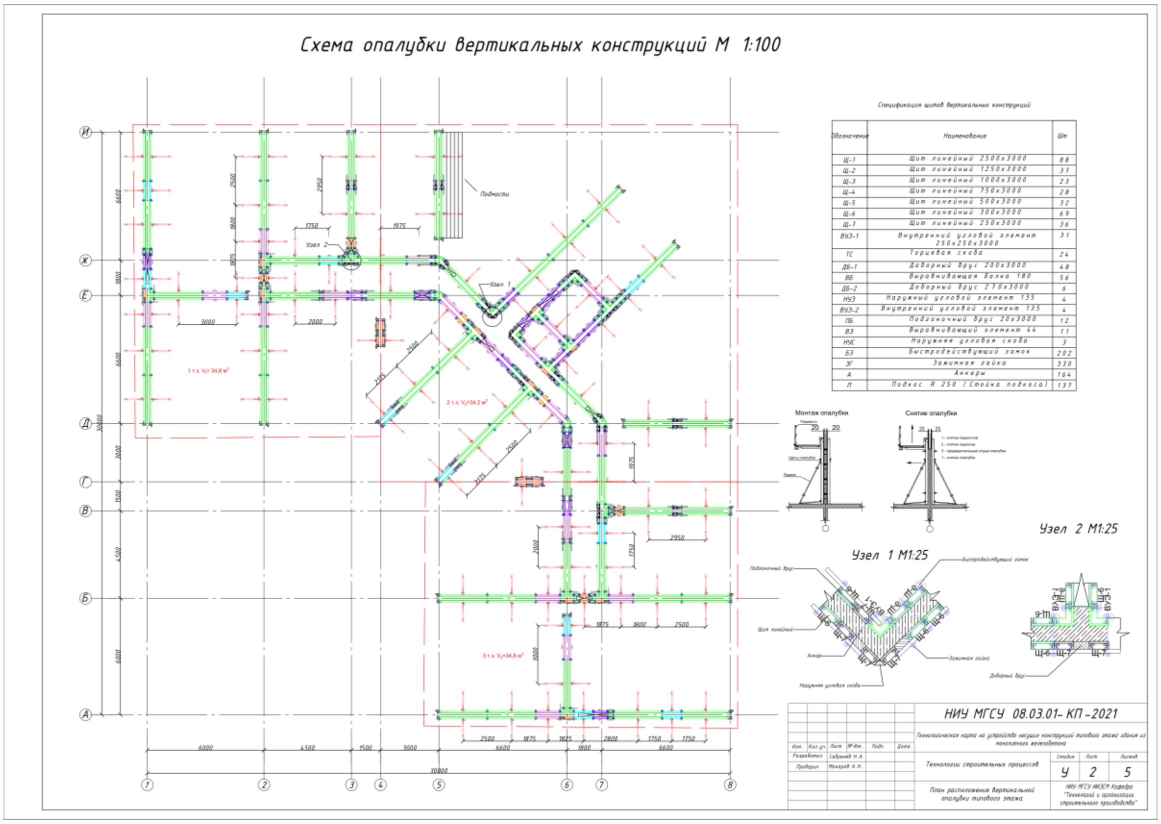

Figure 8. Drawing of the formwork of vertical structures made in AutoCAD

The default AutoCAD interface consists of 10 tabs (Figure 9).

The first tab contains all the drawing tools: straight lines, polylines, circles and arbitrary lines. There are also hatching tools. On the second tab, you can edit lines, rotate and move objects, change the scale, which is very convenient when measuring the size of an object on a scaled area. The third tab helps you customize the font of the text according to standards, arrange sizes and create specification tables. The next tab is perhaps the most important, because in order to properly hide unnecessary objects in the drawing, they must be assigned a special layer and here you can do this. You can change the color of the layer, transparency, and so on. This helps, for example, if you want the architecture to stand out less in the drawing and more utility networks. On the fifth tab, you can create blocks of objects. Usually the blocks are some drawings (supply and exhaust units, cars, windows, everything that can be drawn). Then you can view the properties of the object. Change the layer of the block in the drawing, or for example its scale. On the Group tab, you can add some objects to a group; for example, you can add windows to a group and then hide or insert them in a new floor drawing. The next tab is the most useful tab for calculations. Here you can measure the length from point to point, quickly measure the area or angle. The «Calculator» tool is very helpful in calculating the sum of the lengths. And this is only the main, but the most necessary part of the tools for creating full-fledged building plans and specifications /6/.

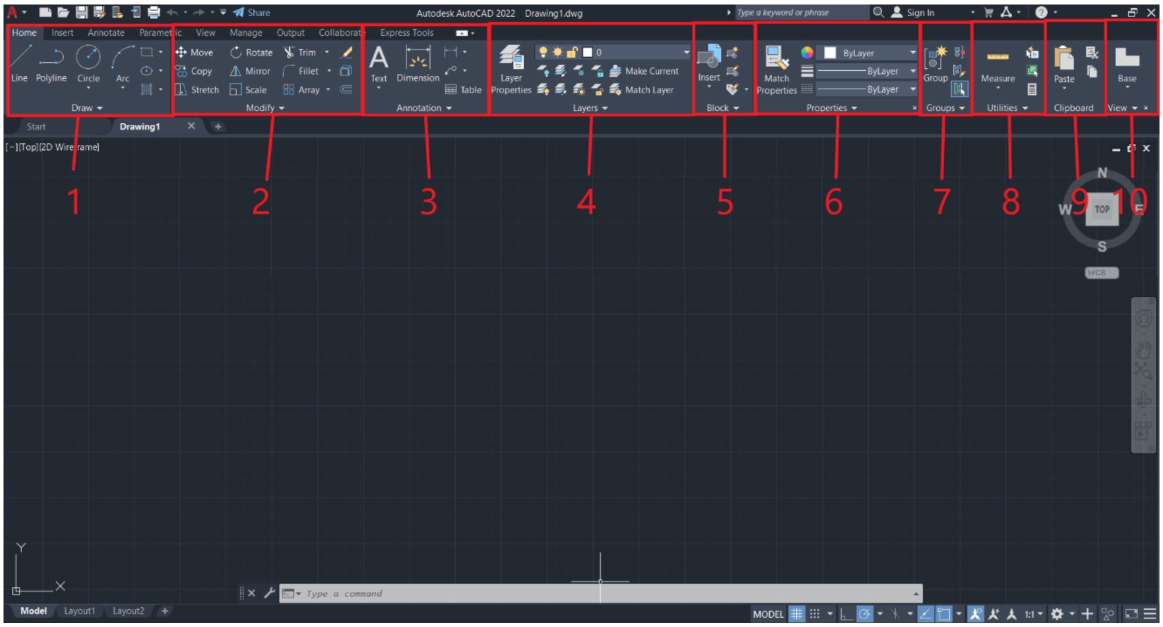

Figure 9. AutoCAD Interface

Of the features of the program specifically for 3D modeling, the following can be distinguished:

- Users can add lighting and materials to their 3D models to achieve realistic appearance and rendering. They can also control edges, zippers, and shading in their models.
- The software allows users to analyze the interior details of 3D objects. AutoCAD allows them to import data from PDF files so they can work together with their teammates when reviewing their models and drawings. Last but not least, they can customize the user interface of the software to simplify their tasks and greatly facilitate access to its functions and parameters.
- AutoCAD helps users prevent product failures and warranty issues, innovate and improve product performance, and win more offers by giving them the tools and workflows to design and build great products.
- The goal of AutoCAD is also to assist in the processing, printing, inspection, and fabrication of quality parts such as parts of automobiles, wind turbines, and airplanes. In addition, the program helps them design the best buildings, implement scalable and sustainable infrastructure projects, manage construction costs and predict project outcomes.
- AutoCAD offers three-dimensional modeling and visualization features. One of them is the ability to apply various 3D modeling techniques to create

realistic 3D models of products and their parts. Thus, the program allows you to create three-dimensional frames, solids, surfaces and grids.

4.1.2 MagiCAD software

In 2011, the MagiCAD program was born, which is an application to AutoCAD MEP and Revit MEP, or more simply, a kind of addition to existing programs, in which it became possible not only to draw various engineering systems, but also to download various models and system parameters from the cloud library, as well as to share one's own work with other users.

Figure 10. MagiCAD logo.

MagiCAD adds additional tabs to AutoCAD. Each tab is a mini-program for a specific calculation or modeling (Figure 11).

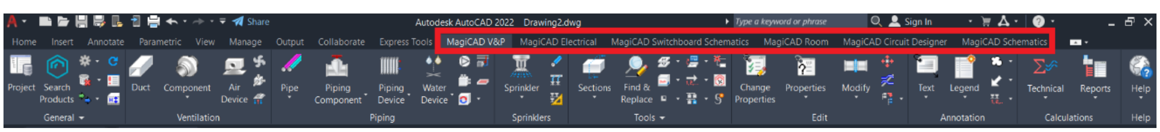

Figure 11. MagiCAD

Before beginning, a project file should be created, where its data will be stored. For example, to design ventilation, you need to give the name of the project and the path to it in the MagiCAD V&P tab. (Figure 12).

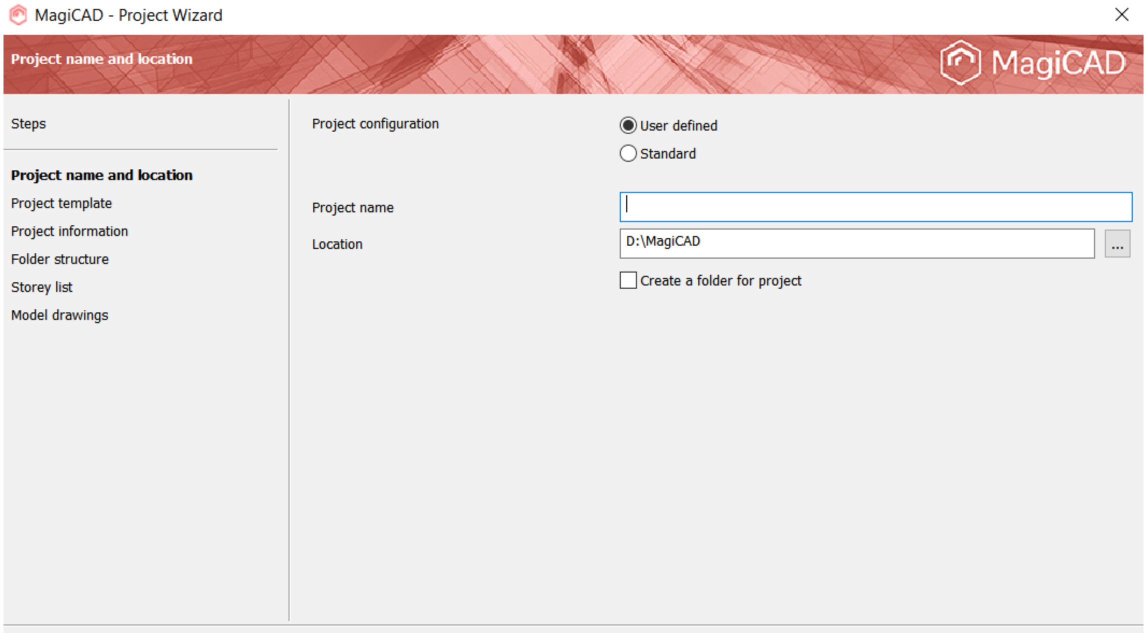

Figure 12. MagiCAD V&P tab.

The first tab has everything related to heating, ventilation and air conditioning. Here you can create heat supply and cooling pipes, air ducts, add various piping and ventilation fittings, as well as devices. In addition, you can change the properties of the devices or move an entire section of pipes without disturbing the collision. MagiCAD also allows you to summarize in the network, select the size of pipelines or air ducts based on the necessary conditions, automatically balance the system by changing the diameters of the pipelines, as well as calculate the sound volume in the air ducts, which significantly speeds up the process of designing networks. (Figure 13).

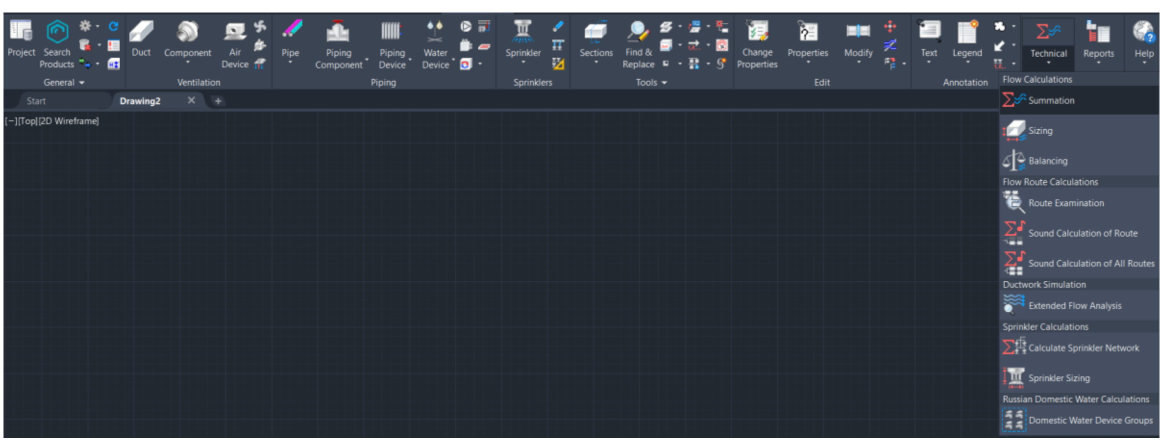

Figure 13. MagiCAD Ventilation & Piping.

On the MagiCAD Room tab, you can create a project for quick calculation of heat loss in the building for further design of heating devices. Here the building shell is created, walls, windows and doors are designed. In each room, air and temperature parameters are set and already according to them MagiCAD automatically calculates heat loss and air consumption in the premises, which is used to select the power of heating devices and air consumption for air devices (Figure 14).

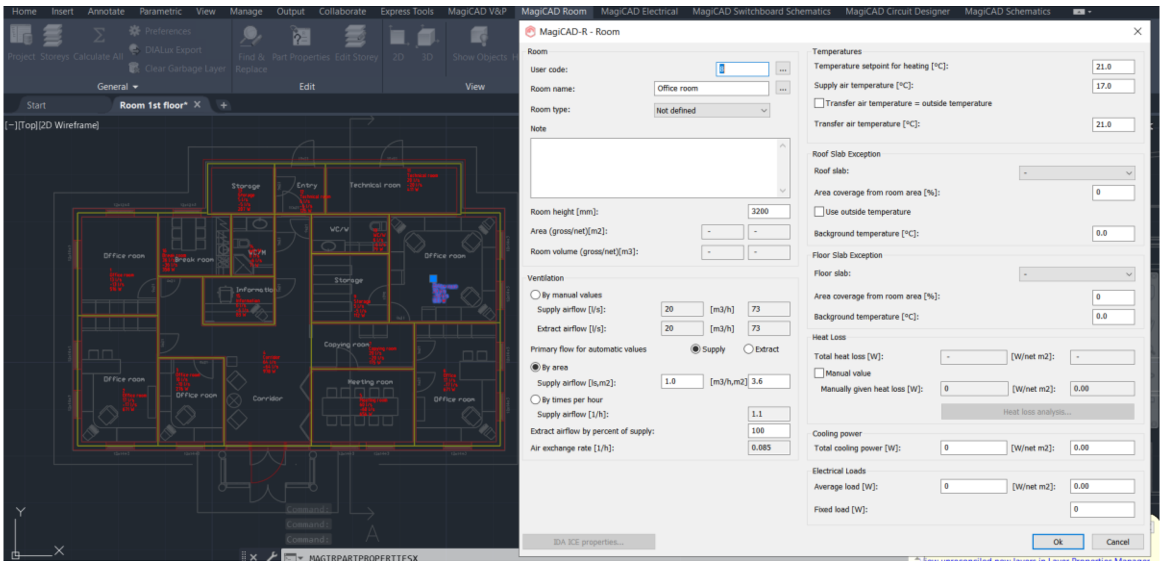

Figure 14. MagiCAD Room.

The composition of other tabs depends on the user's choice, since it is not necessary to download all the disciplines when installing the program, but only those directly related to the designer's specialty. However, the main feature of MagiCAD is that it allows you to model (draw) engineering networks and automatically calculate the necessary parameters /7/.

4.1.3 Revit software

The most popular software using BIM technologies in the field of building construction at the moment is Revit from Autodesk (Figure 15).

Figure 15. Revit logo.

Autodesk's Revit is a computer-aided design system that is employed by design engineers, designers, architects, and related professions. The software allows a team of specialists to simultaneously work on one object, using the technology of information modeling of buildings.

The software can be used for generative design, in which there are strict restrictions and specifically prescribed goals. The program is suitable for simultaneous work of several specialists within one project (Figure 16), while all changes and data will be saved in a single centralized file. The approach helps to reduce time costs and improve communication between designers. Revit Autodesk allows to create detailed specifications that give an idea of each model from the entire project.

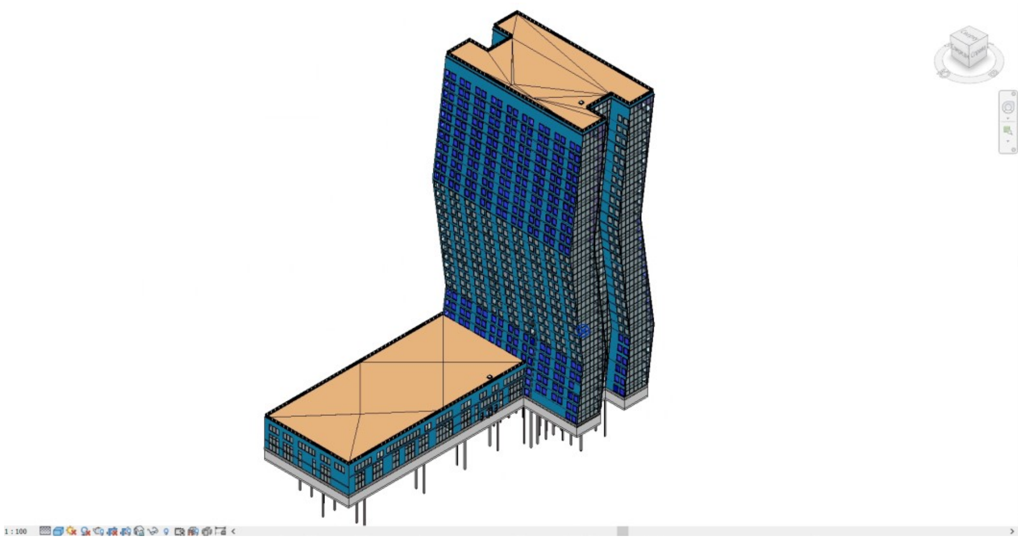

Figure 16. An example of an office building in Revit.

Revit's interface is pretty simple, and it is easy to understand, even if someone does not have much computer knowledge. The standard interface consists of 13 tabs. The first tab contains the architecture tools (Figure 17). With the help of the tools in this panel, it is easily and quickly place walls, doors, windows, fences and stairs of any shape, as well as pre-arrange rooms and zones in which the volume of the room, the area and other parameters will be automatically calculated. Also here the user can specify a working plane to, for example, place architectural letters on the facade.

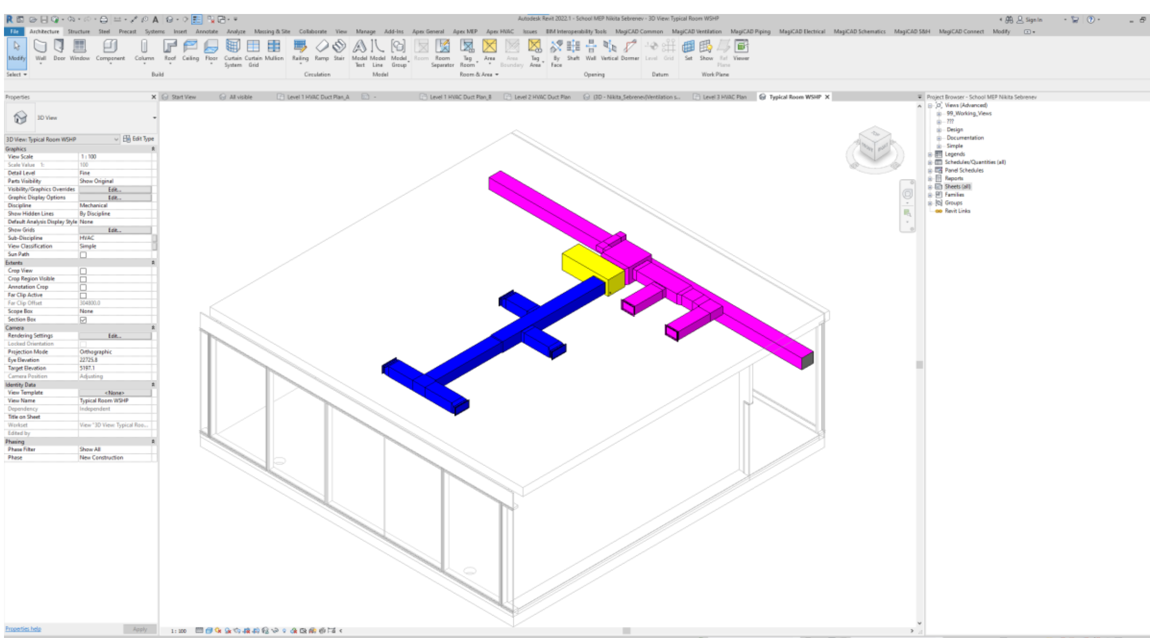

Figure 17. Revit interface and architecture tab.

The second tab allows to place the elements of the supporting structure of the building (Figure 18). For example: Beams, columns, trusses, braces, etc. This is suitable for structural engineers.

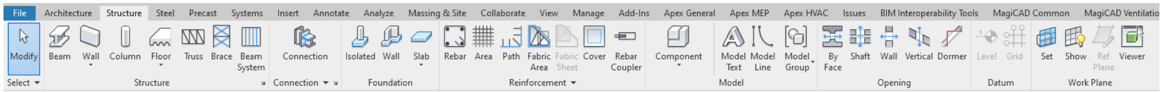

Figure 18. Structure tab.

In the "Steel" tab there are tools for working with steel elements (Figure 19). Here the user can cut out parts of metal structures, as well as add various welds.

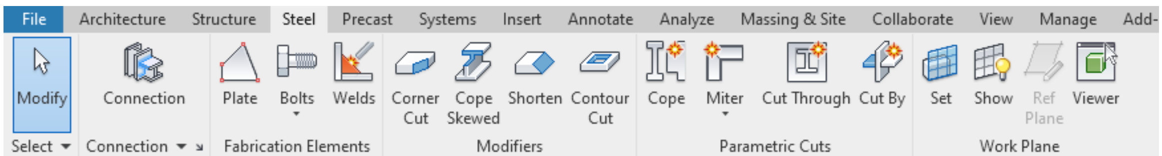

Figure 19. Steel tab.

The "Systems" tab is the main one for heating, ventilation and air conditioning designers, as well as for electricians (Figure 20). Here the user can place direct and flexible air ducts, ventilation and pipe fittings, air distributors, as well as various plumbing fixtures and electrical networks.

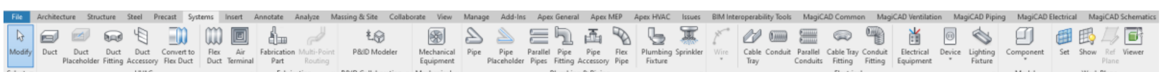

Figure 20. Systems tab.

The “Insert” tab is very important because this is where the user can create a link between a Revit file and, for example, an AutoCAD file (Figure 21). It is also possible to add topography or decal, import CAD, PDF and IMG files. There is a link manager that helps to enable or disable any links. Also on this tab the user can insert the Revit family into the project.

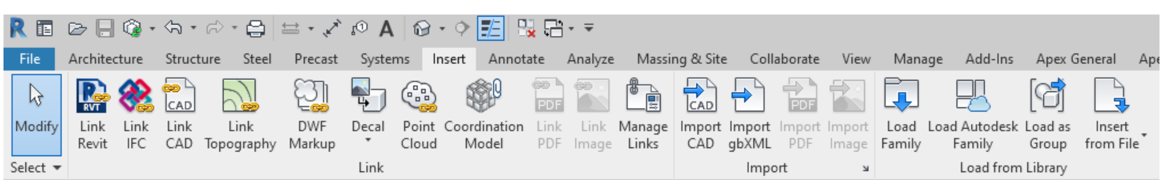

Figure 21. Insert tab.

The Annotations tab helps you quickly and efficiently arrange family sizes, elevations, or stamps (Figure 22). It is a very important tool in the design of drawings.

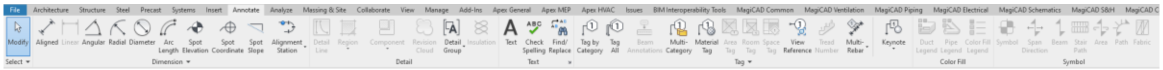

Figure 22. Annotations tab.

The next tab allows to read the loads on the load-bearing elements of buildings, arrange spaces and zones for counting areas and volumes, create reports and specifications of elements (Figure 23). Also a necessary tool is to check systems for errors, which helps when designing a large object. This tab also has a small functionality for calculating the energy consumption of the building.

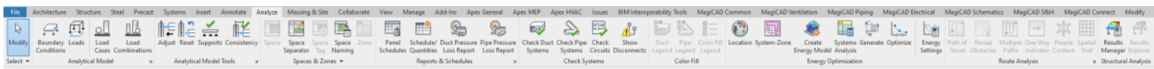

Figure 23. Analysis tab.

The "Massing & Site" tab provides tools for creating conceptual forms, which is commonly used by architects to calculate the required volumes in a building (Figure 24). Tools for creating a site and adding components help in coordinating the location of the object on the ground.

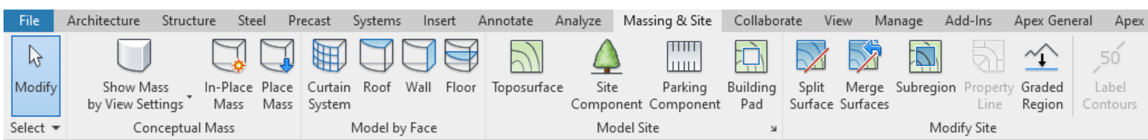

Figure 24. Massing & site tab.

The most important tab when working on a project is the Collaborate tab (Figure 25). Usually, so that engineers do not get confused and accidentally change the elements in the model that are not part of their discipline, special working sets are created. For example, architectural engineers create a special set of architectures where they all work and can modify and add elements only from their own set, without affecting elements of other disciplines. A repository file is created for the project, which is a regular Revit file, but it is constantly updated when any of the design participants click the synchronize button. The idea is that each participant creates a local copy of the project on the computer in which he is running and, when synchronizing, only those elements that were occupied by any of the designers change in the storage file, and at the same time, during synchronization, elements that were not occupied in each local file are updated.

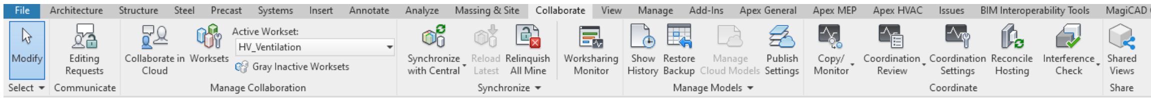

Figure 25. Collaborate tab.

The “View” tab is very extensive (Figure 26). Here the user can adjust the visibility of items, for example, to hide some working set. Revit also has a visualization tool. The user can customize the 3D view (rotate to the desired angle), create a section on the plan, create a drawing sheet, legend or specification, split the working windows and also change the interface.

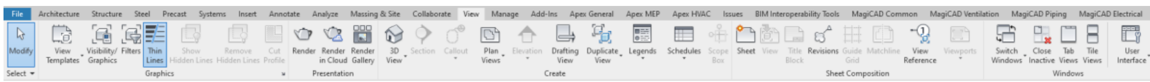

Figure 26. View tab.

On the Manage tab, the user can configure any project settings, such as units of measure (Figure 27), change project location, stage, add macros. Also a very interesting tool is "Dynamo". This is a mini-program that allows to create plugins or, in other words, logic elements for controlling the model, for example, automatically place air valves on the air ducts, which undoubtedly speeds up the design process.

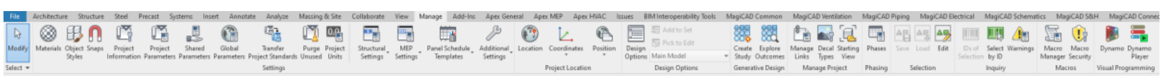

Figure 27. Manage tab.

On the next tab, the user can open Revit Help, print a stack of worksheets and convert the model to FormIt format (Figure 28). FormIt is a piece of software for architectural modeling of 3D sketches at the conceptual design stage.

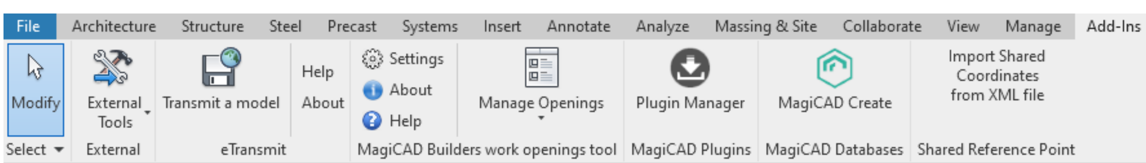

Figure 28. Settings tab.

The Modify tab is the most used because there the user can connect the geometry of the model, move, lengthen, cut walls and ducts, create arrays of elements, draw lines, measure distances, angles and volumes, and create groups of elements and families (Figure 29).

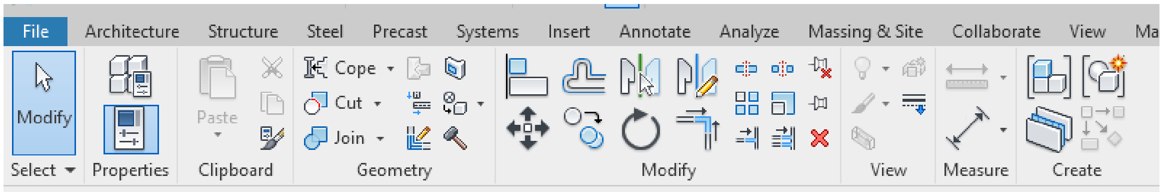

Figure 29. Modify tab.

Above, the main elements of the program interface are fully discussed for a better understanding of its capabilities. Revit is a very demanding program, so the user should have a fairly powerful computer before using it /8/.

4.2 Comparison

To compare programs, a small table can be made, where each function is evaluated on a scale from 1 to 5, where 1 is poor, 2-3 is satisfying, 4 is good, 5 is excellent (Table 1). The evaluation of programs is a subjective opinion of the author of the thesis, based on work experience. As one can see below, Revit is the most user-friendly and most functional compared to AutoCAD.

	AutoCAD	**MagiCAD**	**Revit**
Design speed	2	4	5
Identify and fix bugs in the project	1	3	4
Ability to collaborate on a project	2	2	4
Design automation	1	1	5
Quality of drawings	4	5	5
Calculations	1	5	4
Difficulty in mastering	4	4	4
Compatibility with other design programs	2	5	4
Storing information about project objects	1	5	5
Program performance	3	4	5
Availability of intersection check	1	4	5
Smooth navigation	2	5	5
Technical requirements	5	5	4
Price	4	4	4
Average rating	**2.91**	**4.00**	**4.50**

Table 1. Evaluation of the capabilities of AutoCAD, MagiCAD, Revit.

5 RESULTS

The research conducted in this thesis aimed to identify and analyze the main advantages of using BIM technologies in the construction industry. Through a literature review and case studies of BIM and CAD programs, several key benefits were identified.

One of the most significant advantages of using BIM technology is improved collaboration and communication among project stakeholders. By using a common platform for project information, all team members have access to the same data and can easily collaborate on design decisions, reducing the potential for mistakes and misunderstandings. Furthermore, BIM technology allows for better coordination among different disciplines and improves the overall project workflow.

Other important advantages are increased efficiency and cost savings. BIM technology allows for more accurate and detailed project documentation, which can reduce the need for rework and change orders. Additionally, BIM technology allows for better scheduling and resource management, which can lead to faster project completion and reduced costs.

BIM technology also improves the overall quality and safety of construction projects. By providing detailed and accurate information about the project, BIM technology allows for better construction planning and execution, which can lead to fewer mistakes and potential safety hazards. BIM technology can facilitate the identification and resolution of potential conflicts and issues during the design phase, reducing the risk of problems arising during construction.

In addition to these benefits, BIM technology also offers several other advantages such as sustainability, better performance and outcome of the construction projects, improved documentation and 3D visualization of the building.

6 BIM FOR HVAC DESIGNER

6.1 Designing of systems

In order to understand how engineering systems are designed using BIM technologies, below the design methodology using the Revit program will be presented.

Figure 30 below shows a school building.

Figure 30. Example building.

The building consists of many rooms with different layouts. In the example, the ventilation design for this building is presented. Depending on the chosen discipline, the elements on the plans will have different color and transparency. For example, on the floor plan, the "Architecture" discipline is set to the properties of the view, so the walls are highlighted in bold black (Figure 31,32) /9/.

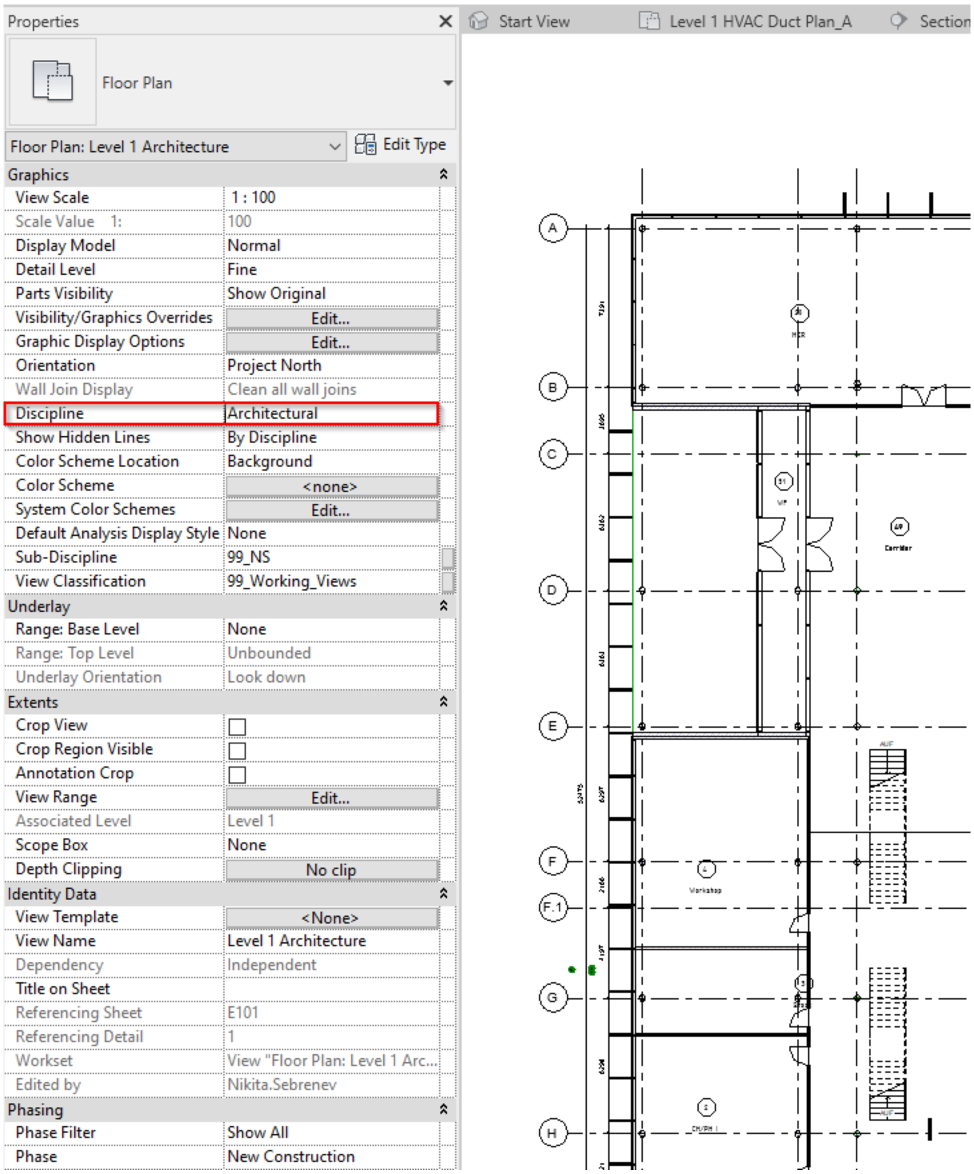

Figure 31. Properties tab.

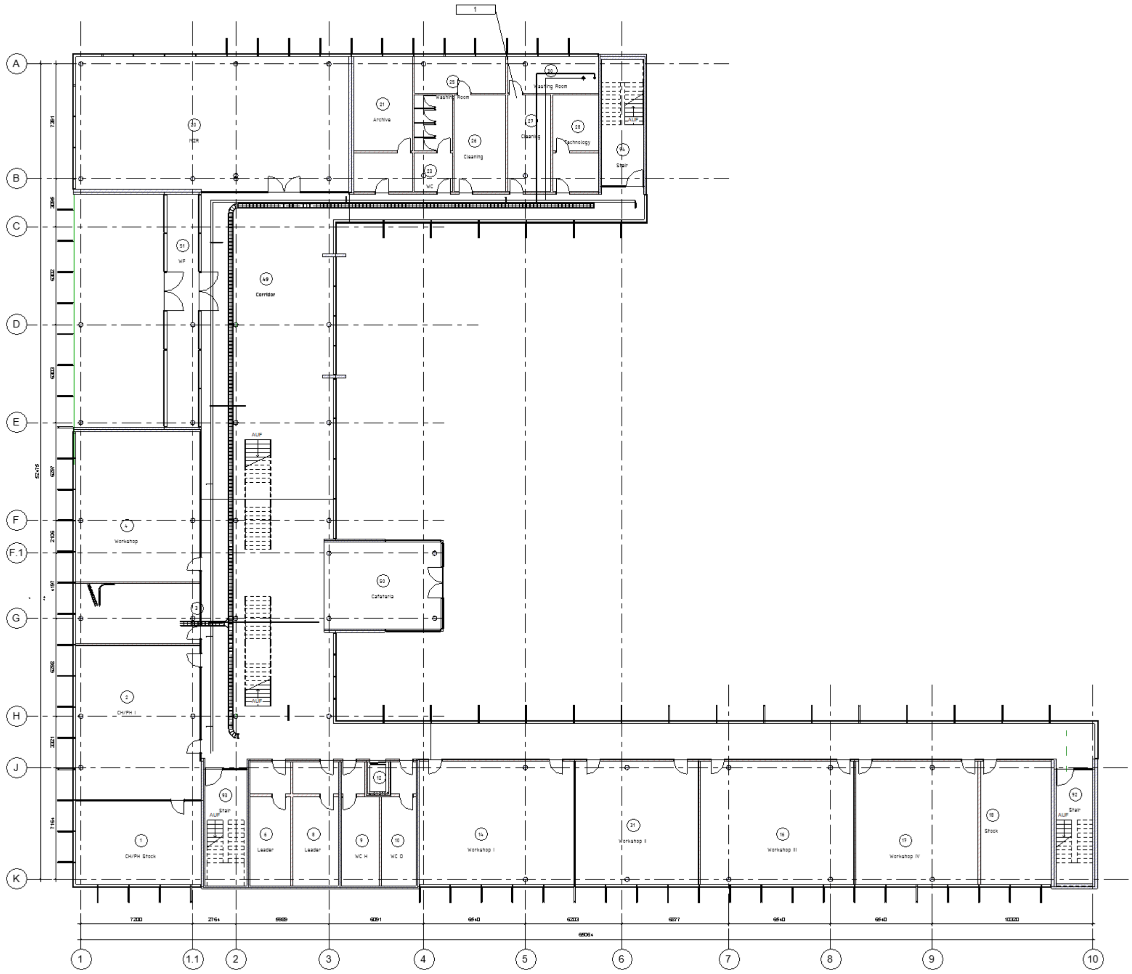

Figure 32. Floor plan.

Before starting the design, it is important to determine where the main services will be located. In our case, the ventilation ducts in the calculated part of the building will be located in the corner of the laundry room in the ventilation shaft running from the 1st to the 3rd floor.

The first step is to determine the area of the room. It is very convenient to use the Revit program for this, as it automatically calculates the area based on the internal surface area of the room's walls. (Figure 33).

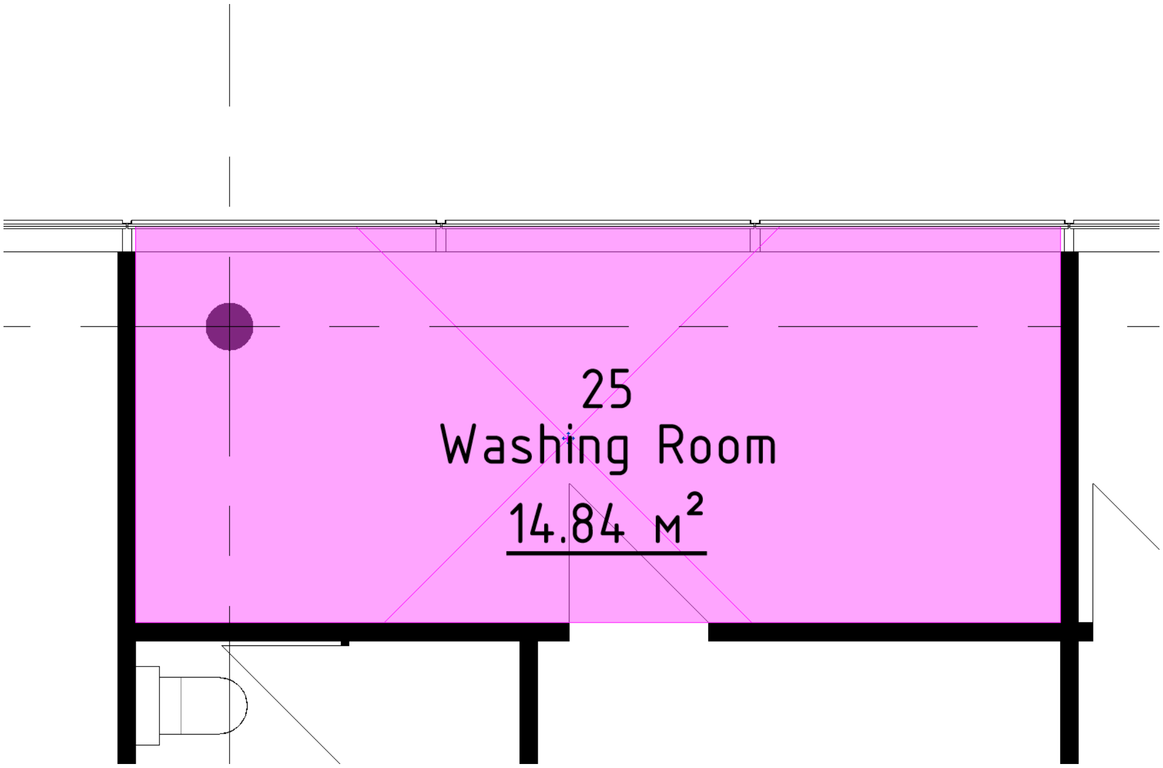

Figure 33. Determining the area of a room in Revit.

Revit simultaneously calculates the area of all spaces in the model (Figure 34).

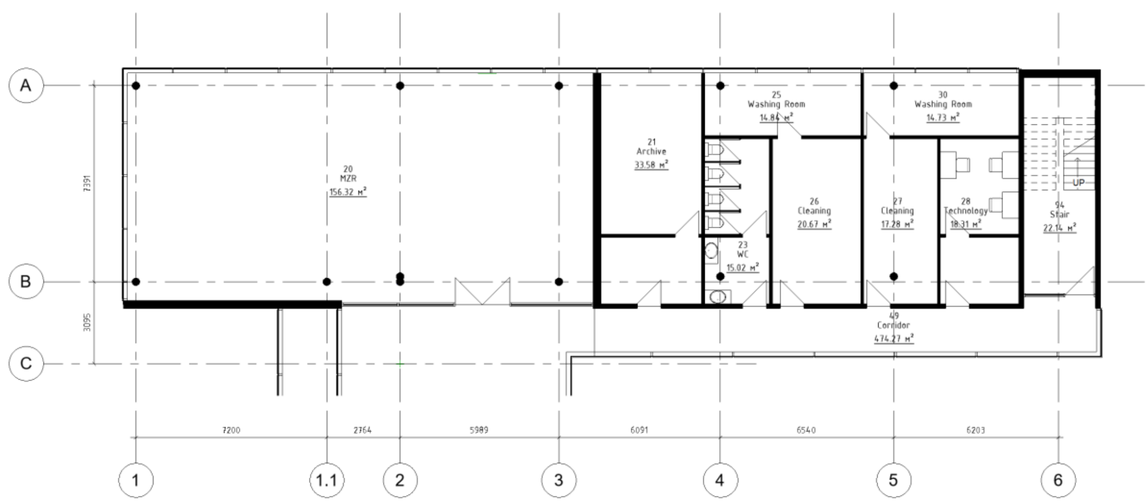

Figure 34. Area of all rooms.

We also need to calculate the air exchange in the building. To do this, we need to know the air supply rate for the room, or for each person in the room, according to local building standards. The basic rule is that the air flow rate for the supply air in the building should be equal to the air consumption for the hood.

Once we have determined the multiples for each room, we calculate the required air exchange rate by multiplying the volume of each individual room by its respective multiplicity. To compensate for air exchange imbalances in the zone, we also add any missing supply air to the corridor space.

Airflows in an HVAC zone in the building will look like this (Figure 35).

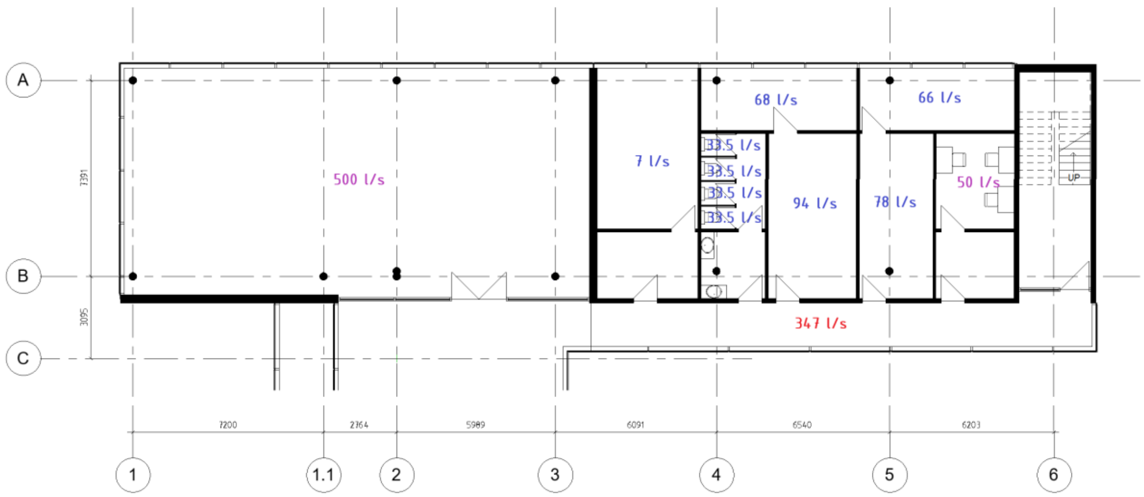

Figure 35. Airflows in the building.

The air ducts can be placed in Revit in two clicks. First select the "Duct" tool from the "Systems" tab (Figure 36).

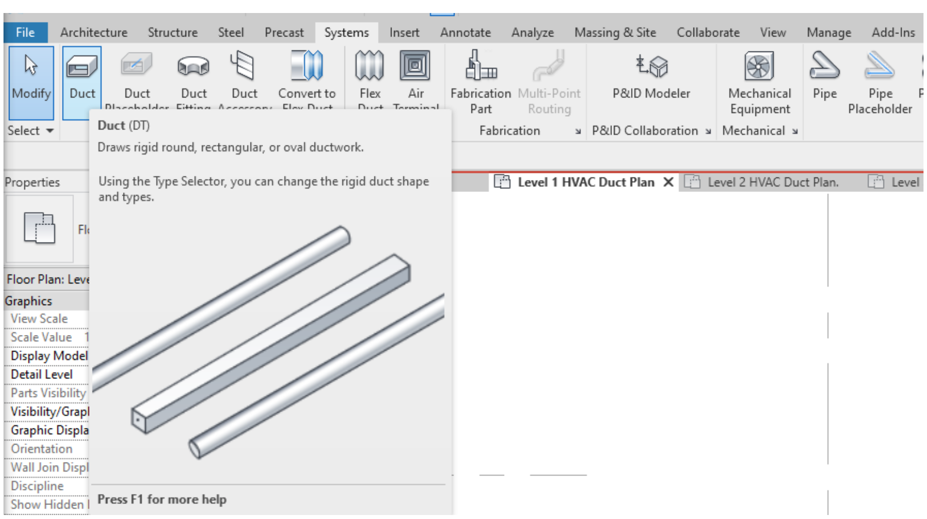

Figure 36. "Duct" tool.

If the duct is a square shape, select its measurements for width and height. Then select the start point with the first click and the end point with the second click. (Figure 37).

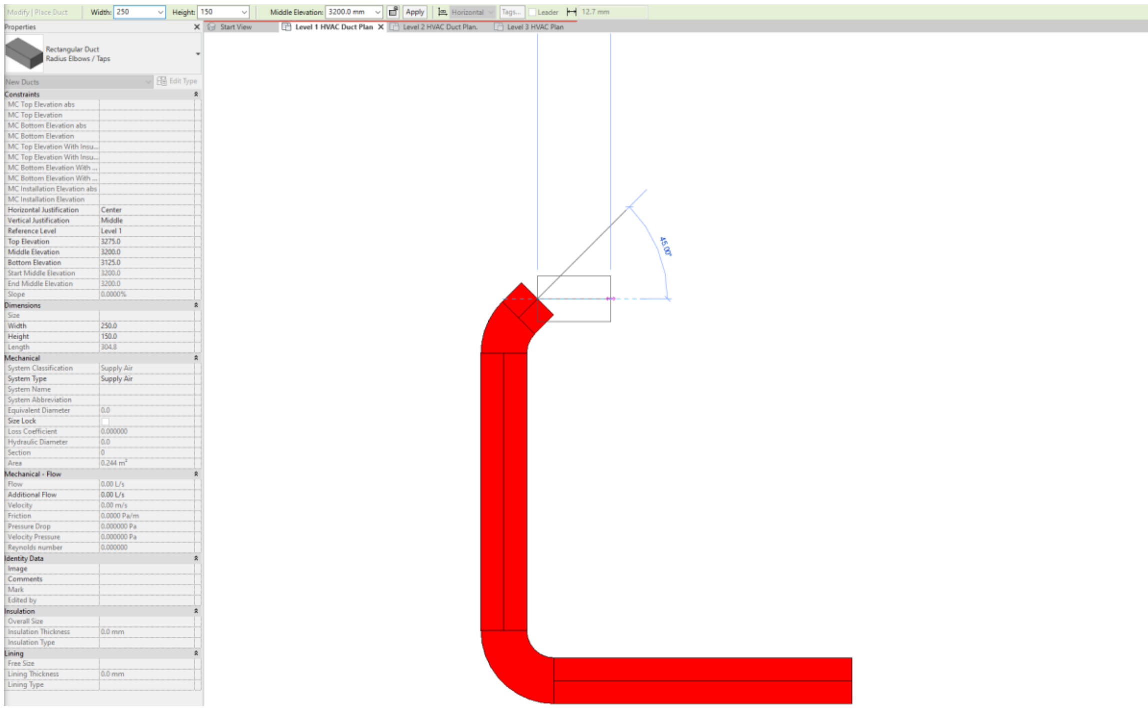

Figure 37. Placement of the air duct.

Air grates and air valves must be installed. They are located in the same tab as the ducts. (Figure 38).

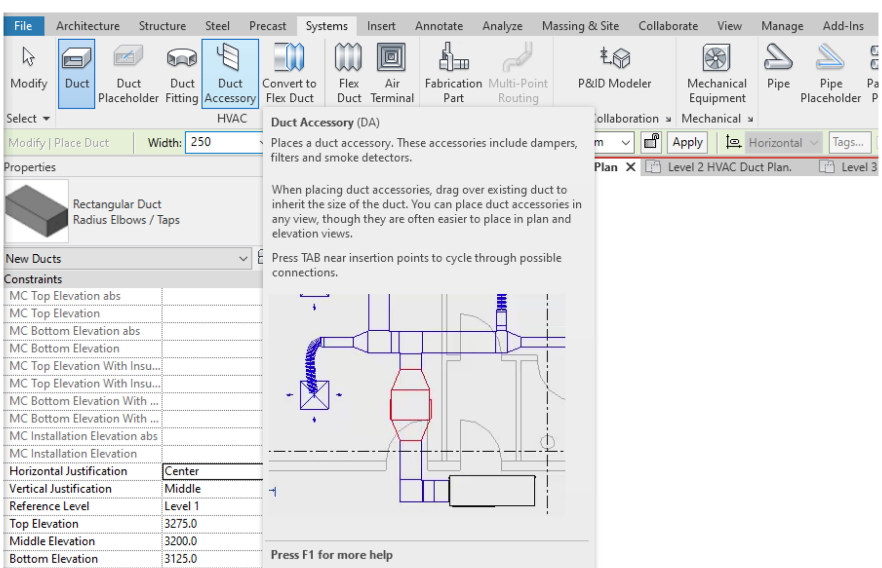

Figure 38. Duct fittings instrument.

Two separate supply and extract air systems designed for the conference room. (Figure 39).

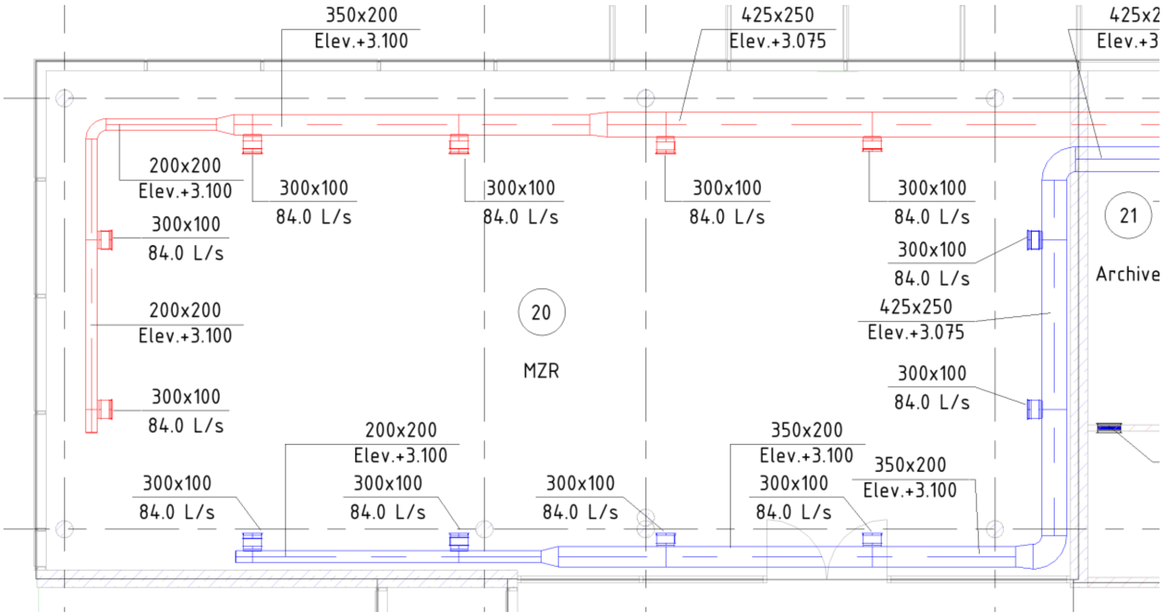

Figure 39. Conference hall ventilation.

Ventilation for other rooms is designed according to the requirements of the standards, depending on the multiplicity. The diameters are based on the velocity in the duct. Revit also helps to automatically dimension the ducts (Figure 40).

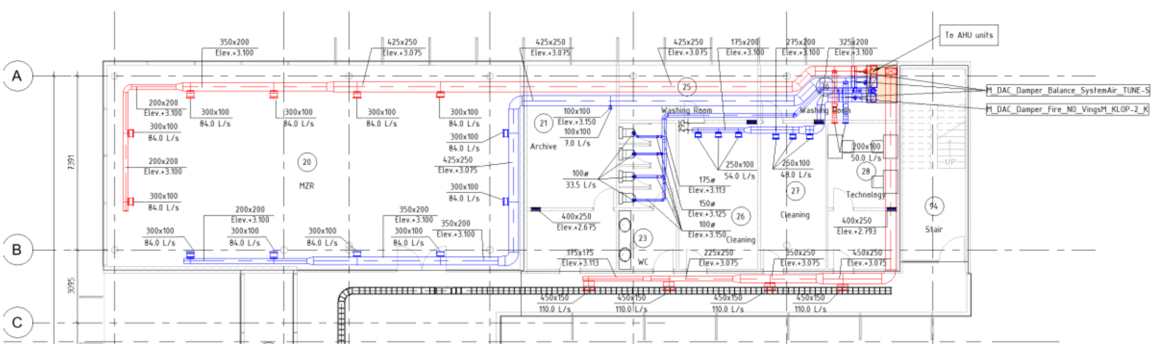

Figure 40. Floor ventilation.

Once the designing of all utilities is complete, we can create a 3D view to see all the systems to check where there are intersections or unnecessary elements (Figure 41).

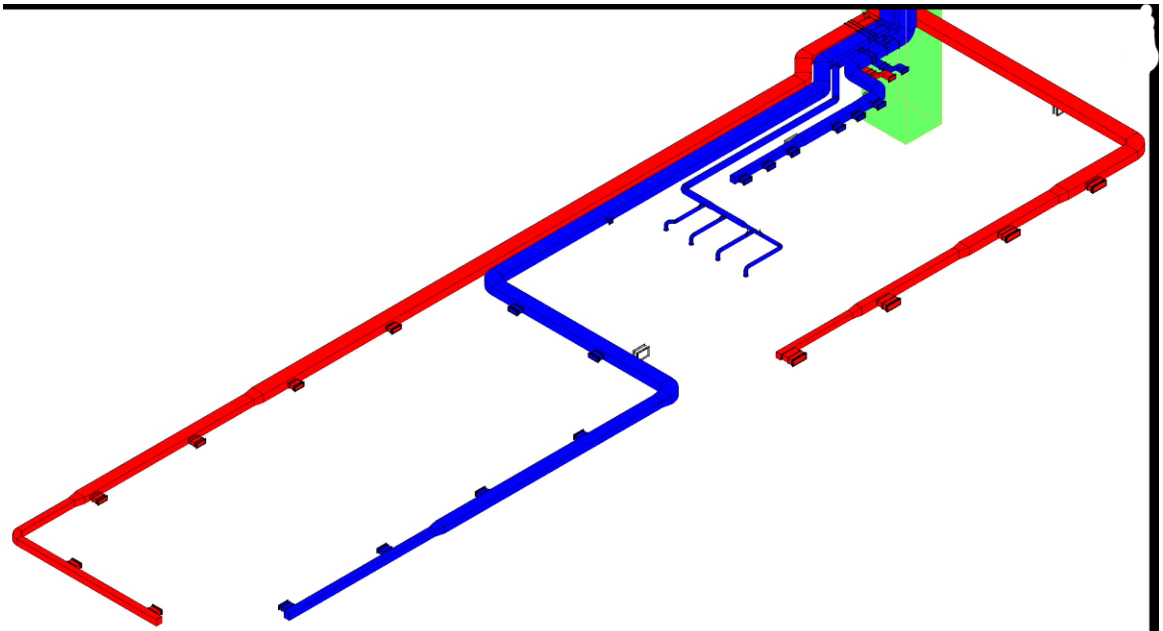

Figure 41. Vertical apartment ducts.

Air valves are installed on each duct to regulate air flow and balance the system (Figure 42).

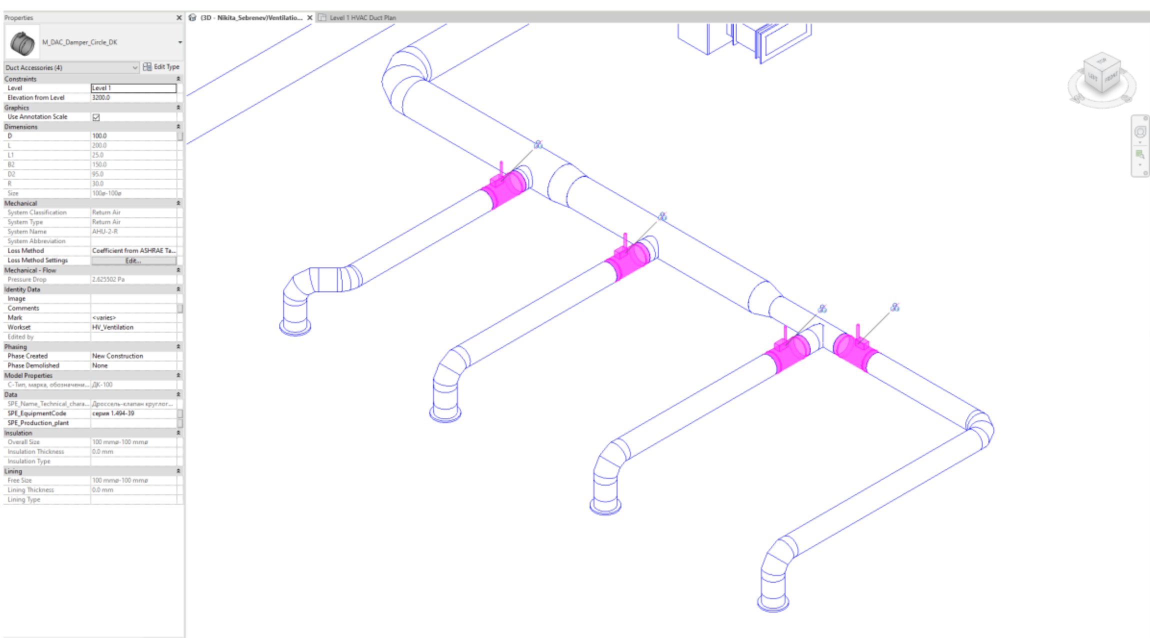

Figure 42. Balancing valves.

Fire dampers are installed on each floor branch of the duct systems, depending on the fire category of the premises, to prevent the spread of combustion products in case of fire. Insulation for ventilation risers is also added. To install any fitting - select the element and press once on the duct. (Figure 43).

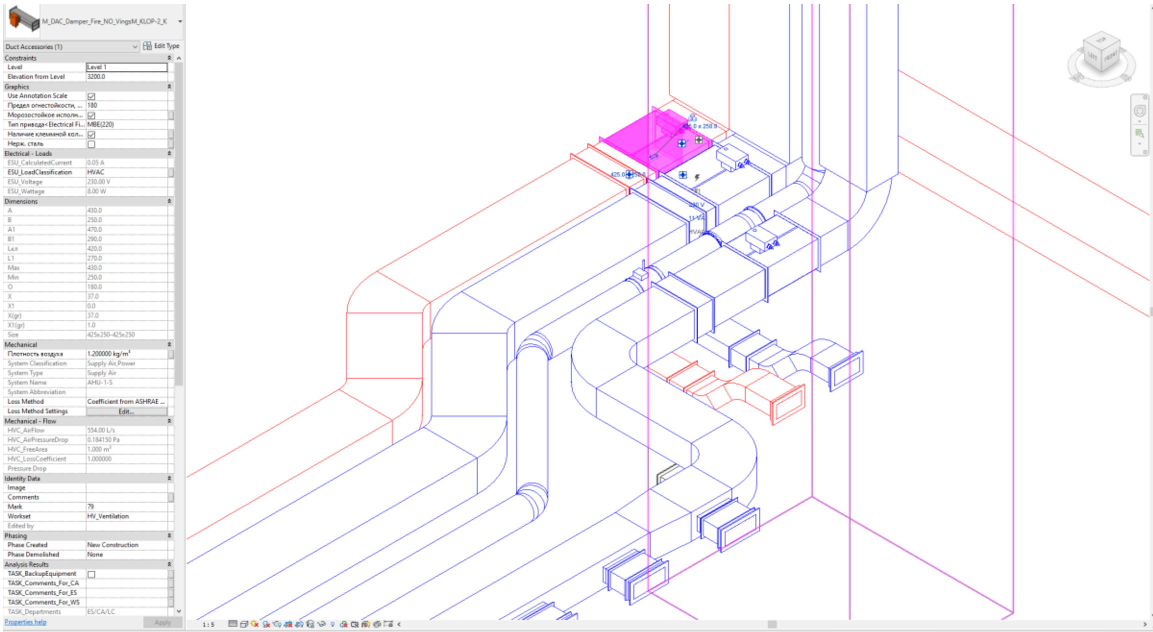

Figure 43. Fire dumpers.

To select the fan power, it is necessary to calculate the pressure losses in the system. If this is done manually, it is necessary to calculate from the most distant unit, considering which local resistance coefficients to use on each element. Revit allows you to automatically calculate the pressure losses in the system. To do this, go to the "Analysis" tab and select "Duct Pressure Loss Report" (Figure 44).

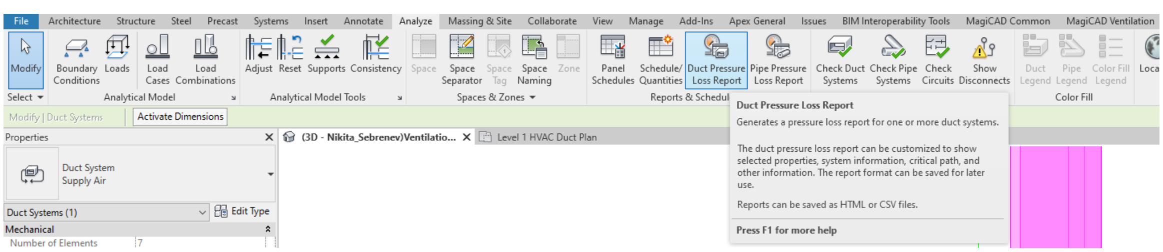

Figure 44. Duct pressure loss report instrument.

The next step is to select the system for which the report is to be generated (Figure 45).

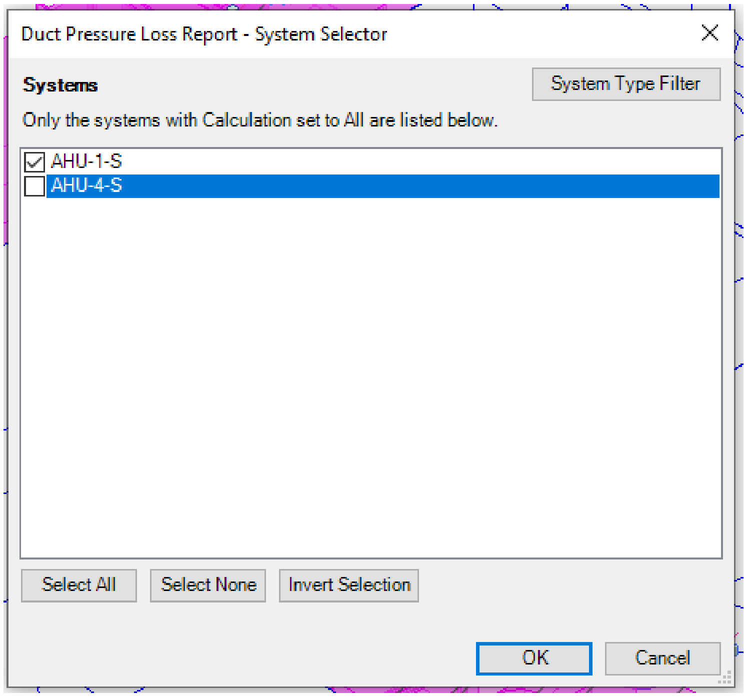

Figure 45. Choose of system for report.

The report form can be customized in detail. Add or delete the necessary information about the system (Figure 46).

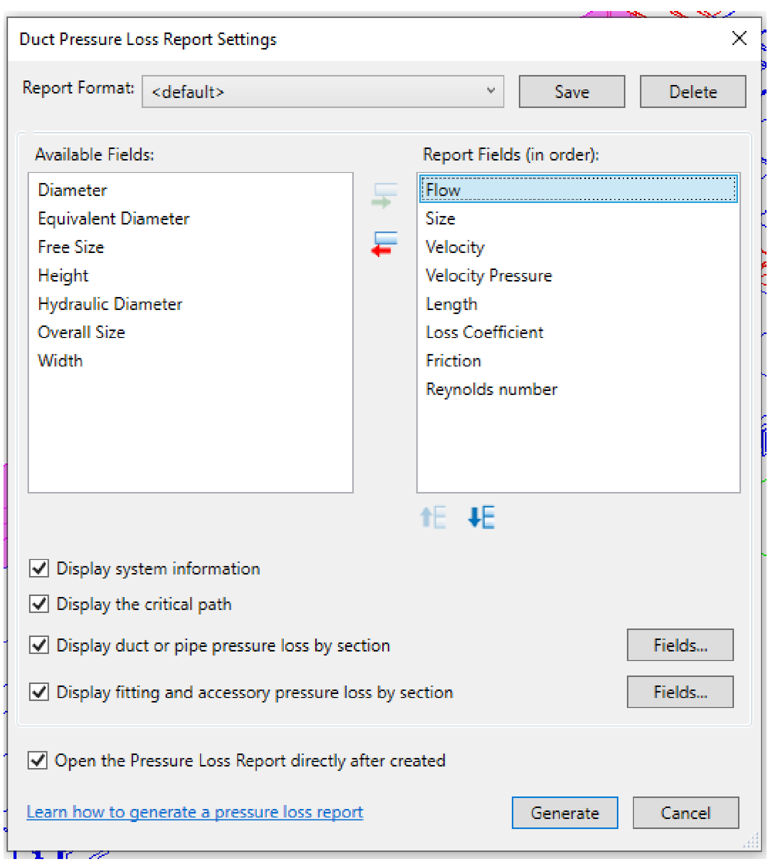

Figure 46. Report settings.

In the report one can see the flow rate, diameter, pressure loss by length, operating pressure, Reynold's number and local pressure losses for each element of the system (Figure 47).

Detail Information of Straight Segment by Sections								
Section	Element ID	Flow	Size	Velocity	Velocity Pressure	Length	Pressure Loss	Total Pressure Loss
1	1197589	33.5 L/s	100ø	4.3 m/s	10.9 Pa	136	0.4 Pa	5.2 Pa
	1197592	33.5 L/s	100ø	4.3 m/s	10.9 Pa	1105	3.0 Pa	
	1223076	33.5 L/s	100ø	4.3 m/s	10.9 Pa	110	0.3 Pa	
	1238424	33.5 L/s	100ø	4.3 m/s	10.9 Pa	597	1.6 Pa	
2	1223076	67.0 L/s	100ø	8.5 m/s	43.8 Pa	273	2.5 Pa	2.5 Pa
3	1223359	67.0 L/s	150ø	3.8 m/s	8.6 Pa	587	0.8 Pa	0.8 Pa
4	1223359	100.5 L/s	150ø	5.7 m/s	19.4 Pa	503	1.3 Pa	1.3 Pa
5	1222880	100.5 L/s	175ø	4.2 m/s	10.5 Pa	141	0.2 Pa	0.2 Pa
6	1222712	134.0 L/s	175ø	5.6 m/s	18.7 Pa	5306	11.3 Pa	35.6 Pa
	1222720	134.0 L/s	175ø	5.6 m/s	18.7 Pa	1326	2.8 Pa	
	1222880	134.0 L/s	175ø	5.6 m/s	18.7 Pa	732	1.6 Pa	
	1223509	134.0 L/s	175ø	5.6 m/s	18.7 Pa	353	0.8 Pa	
	1236846	134.0 L/s	175ø	5.6 m/s	18.7 Pa	712	1.5 Pa	
	1237137	134.0 L/s	175ø	5.6 m/s	18.7 Pa	437	0.9 Pa	
	1237541	134.0 L/s	175ø	5.6 m/s	18.7 Pa	7825	16.7 Pa	
7	1198020	33.5 L/s	100ø	4.3 m/s	10.9 Pa	136	0.4 Pa	2.9 Pa
	1198023	33.5 L/s	100ø	4.3 m/s	10.9 Pa	55	0.1 Pa	
	1238476	33.5 L/s	100ø	4.3 m/s	10.9 Pa	880	2.4 Pa	
8	1198302	33.5 L/s	100ø	4.3 m/s	10.9 Pa	136	0.4 Pa	2.8 Pa
	1198305	33.5 L/s	100ø	4.3 m/s	10.9 Pa	30	0.1 Pa	
	1238570	33.5 L/s	100ø	4.3 m/s	10.9 Pa	880	2.4 Pa	
9	1198353	33.5 L/s	100ø	4.3 m/s	10.9 Pa	79	0.2 Pa	2.7 Pa
	1198365	33.5 L/s	100ø	4.3 m/s	10.9 Pa	136	0.4 Pa	
	1198371	33.5 L/s	100ø	4.3 m/s	10.9 Pa	18	0.0 Pa	
	1238796	33.5 L/s	100ø	4.3 m/s	10.9 Pa	783	2.1 Pa	

Figure 47. Pressure losses report.

The user can also see the pressure loss in the element by highlighting it and going into its properties (Figure 48).

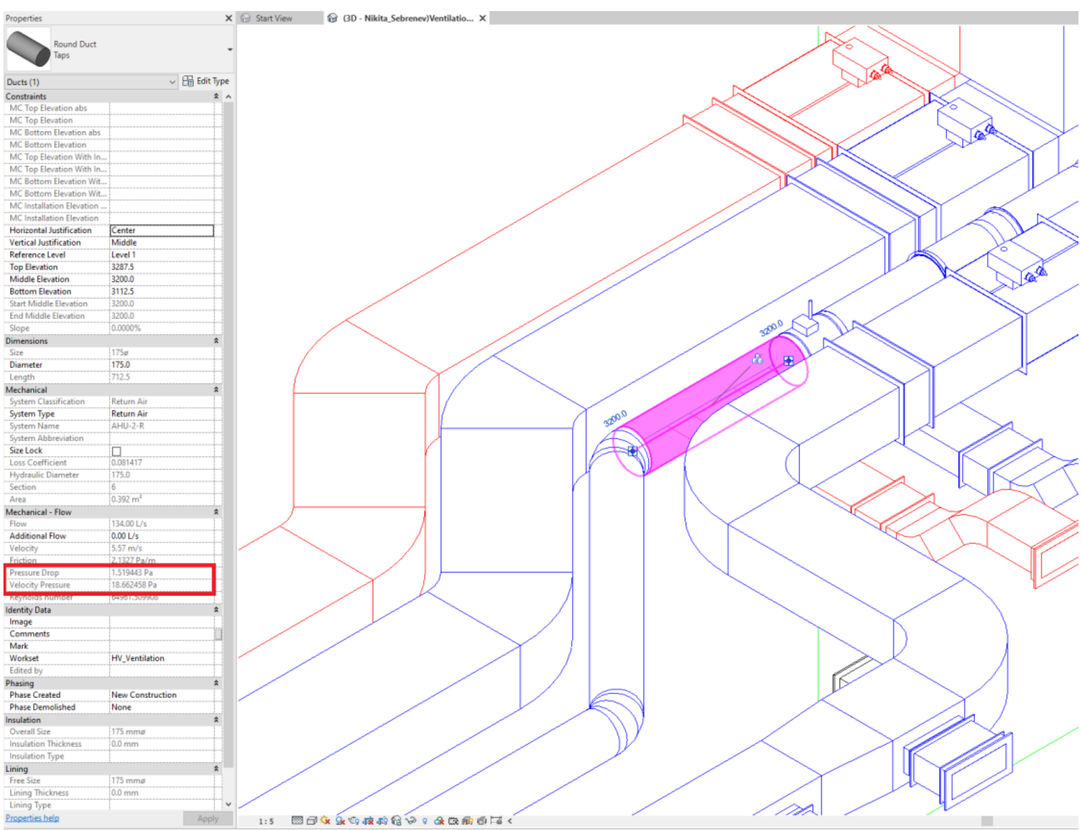

Figure 48. Pressure losses in the element.

Based on the total air flow rate in the system and the pressure loss, an exhaust fan is installed on the roof of the building. Additional air flow can also be added to the exhaust fan family (Figure 49).

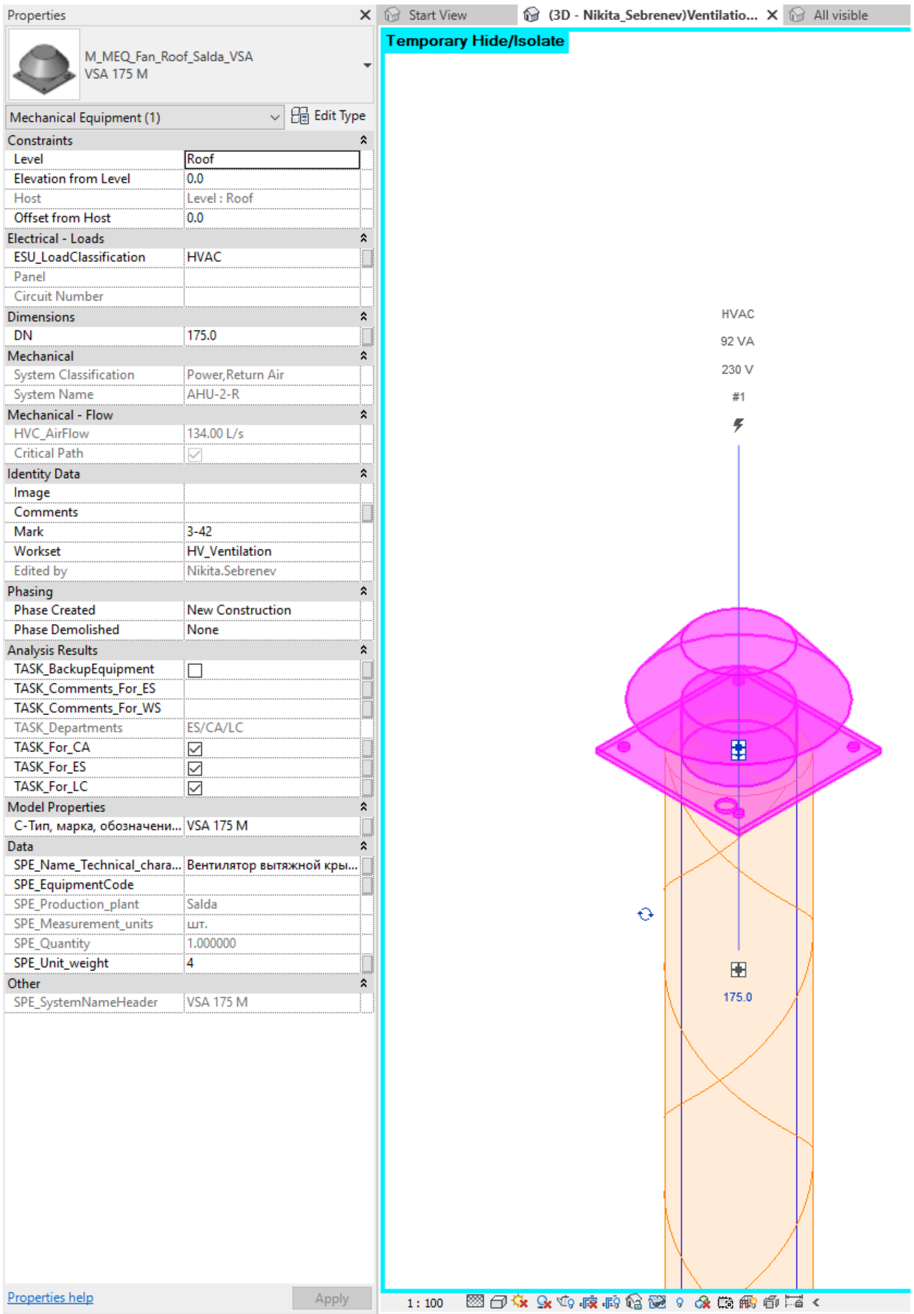

Figure 49. Exhaust unit.

The time taken to design this system is approximately 3 hours. The main advantage of building a model is that it is always possible to see the intersection of the ventilation elements with the building structures and to eliminate unnecessary elements from the view. The finished systems can be seen in the picture below (Figure 50).

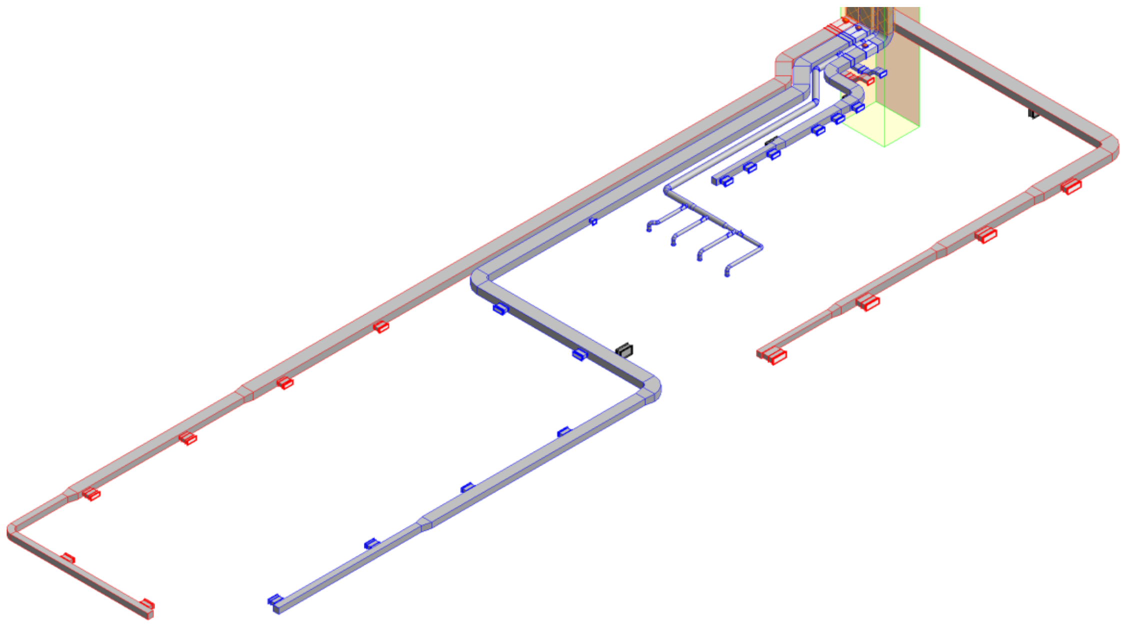

Figure 50. Ventilation systems view.

6.2 CFD simulation

Integrated building design includes all stages of creating a spatial model of the building with optimal envelope characteristics and efficient energy consumption, as well as monitoring the results of operation after construction of the facility, i.e. it covers all stages of the building life cycle. It is the combination of BIM and BEM (Building Energy Modelling) technologies in the design process that makes it possible to think through and implement all processes within the modelled space /10/.

As an example, we will use IES VE software to model the supply and exhaust ventilation system in a single room of the building.

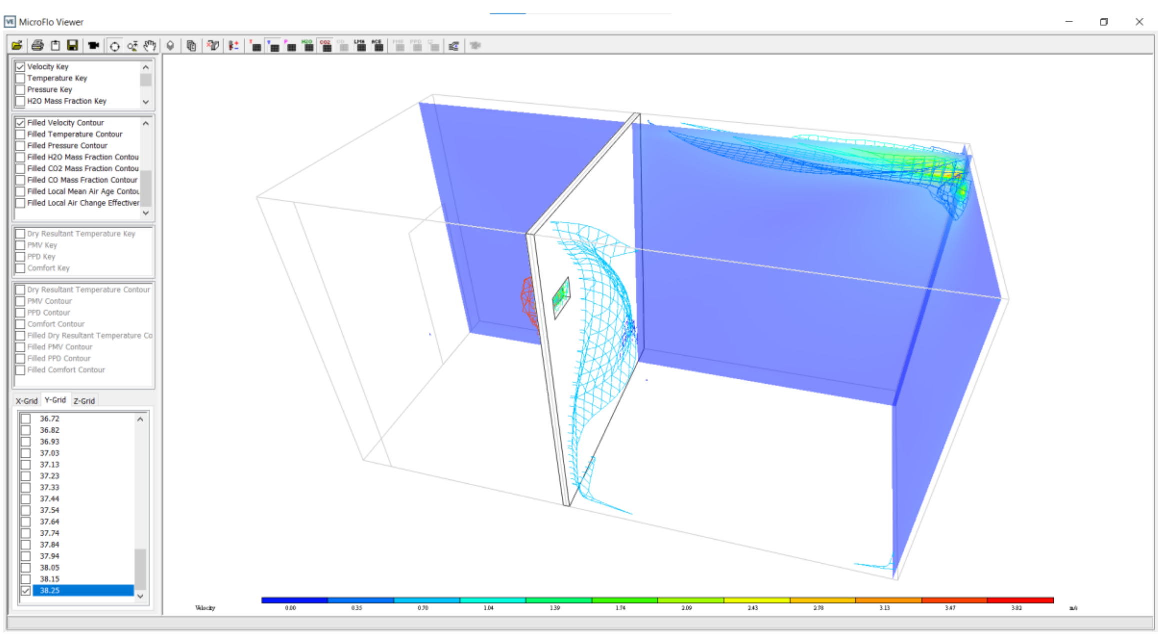

Figure 51. CFD simulation of technical room.

The picture shows how the air flows in the room, which helps to determine the correct position of the supply or exhaust grilles for ventilation (Figure 51).

In addition to CFD modelling, it is possible to calculate temperatures in rooms throughout the building, simulate solar radiation through a window, and so on. Together with BIM, the building design process becomes not only comprehensive, but also fast.

7 CONCLUSION

The main purpose of the thesis was to obtain basic and necessary knowledge and skills in the field of BIM technology. The thesis has also provided a detailed overview of the history and importance of BIM technology, as well as the integration of BIM into companies and the role of BIM departments.

Moreover, the most popular design programs widely used in construction, as well as how to use them, were described in detail. BIM technologies allow to reduce the design time and make the least number of mistakes. The thesis clearly demonstrated how to create and calculate a ventilation system using the Revit program.

In total, BIM technologies are the future, and perhaps someday there will be even more impressive IT solutions that will change the methods of designing buildings and structures and push them to a more advanced level.

BIM technologies have big potential to greatly improve the construction industry and it is important for professionals to stay informed and educated about the latest developments in this field. By embracing these technologies, companies and organizations can improve their performance, increase efficiency, and ultimately deliver better quality projects for their clients.

This is driving us towards the future and undoubtedly it strongly motivates construction enthusiasts from all over the world, which only accelerates the process of innovation.

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