Implementation of noise data into building information model (BIM) to reduce noise in the environment and at workplace

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Abstract. Noise mapping is the best way to present information on the acoustic pollution. To design noise protection measures, authors use modern software package SoundPLAN, which is based on the up-to-date normative documentation and scientific researches. The program allows importing the results of calculations to Autodesk tools. Improving the efficiency of the noise protection design process is executed through the implementation of building information modeling (BIM). Data exchange between SoundPLAN, AutoCAD 3D or Revit and Navisworks is used in the development of building information model. In the article we present a new approach to noise reduction through implementation of noise data into the overall information model of the infrastructure or building project. BIM helps to track the collision of calculated noise levels with residential buildings, protected premises and workplaces. It lays a basis for the sound proof allocation of workplaces and development of protection measures. BIM also serves as a support tool for the design process of sound protection barriers, since it helps to avoid interconnection of noise barriers basement with engineering networks or paste a barrier in the proper place to provide its efficiency.

1. Introduction
Noise is the main source of pollution in cities. It comes from automobile and rail transport and industrial sources. The results of noise mapping in Europe show that 33% of European population suffer from increased environmental noise levels. About 56 millions of people are affected by increased noise levels coming from roads, 9 million suffer of railroad noise and about 1 million is exposed to the noise of industrial sources [1].

Industrial noise is a cause of professional diseases that affect workers at the workplace during the production process. About 7% of workers suffer from work related hearing difficulties [2].

So, at the design of infrastructure projects, such as roads or railroads, and design of industrial buildings the noise factor should be evaluated. Noise levels should be decreased to the limits to avoid noise caused diseases.

Evaluation of the noise impact is executed using up-to-date calculation methods that take into account all main parameters of traffic and buildings. At the calculation of noise propagation one should also consider distance, atmospheric attenuation, sound absorption and screening [3]. On the basis of the
calculation results, the noise protection measures should be developed. The most effective way to design noise protection measures is to use specialized software [4].

At the environmental impact assessment, development of noise maps and noise protection measures the researches and practitioners use modern software systems based on updated methods established according to [5] in Europe and according to [6] in Russia. All these methods are implemented in SoundPLAN noise calculation program that we use at the design process. SoundPLAN imports the data necessary for the calculation, and exports the results to formats that allow data exchange between SoundPLAN and other programs intended for design [7].

Increasing the effectiveness of noise design is implemented through the introduction of building information model or BIM technology. The essence of this concept is that in the design process, we use the information model that acts as a general source of data on the object, providing optimal decisions at all stages of its life cycle. The fundamental difference between BIM and the traditional approach based on the preparation of project drawings is that BIM creates, processes and uses computable information about the object, which can be automatically reconciled, matched and internally regulated. BIM contains geometry, spatial relationships, geographic information, the amount and characteristics of building elements, cost estimates, inventories and project lead times. BIM provides close interaction in the design, involving and integrating the various parties involved in the project development. The joint work of the project team allows to identify potential problems before they occur during the construction process [8, 9, 10].

In the process of implementation of noise data into BIM we use data exchange between Geo-Information System (GIS), SoundPLAN, AutoCAD 3D or Revit and Autodesk Navisworks.

2. Algorithm of development of information model on noise pollution

The algorithm for entering data on noise pollution into BIM is executed with following steps:

1. Import of layouts and information on heights and elevation lines from Geo-Information Systems or Civil 3D as *.dx/$/*.dbf files into SoundPLAN.

2. Creation of digital ground model in SoundPlan software (Figure 1). Using information on the heights and elevations the digital ground model of the terrain is automatically calculated in SoundPLAN.

   Figure 1. 3D visualization of the terrain and buildings in SoundPLAN.

3. Entering of parameters of noise sources and buildings in SoundPLAN. For infrastructure linear project such as road or railroad the necessary information include data on intensity and speed of traffic, percentage of different types of vehicles or trains, type of road pavement or rails, bridges, overpasses, slope of road and other parameters that should be taken into account according to the calculation method. For the recipient buildings we should enter their shapes, height – either in meters or amount of floors, usage and address if necessary.
The same approach is used to implement noise information into the BIM of any production plant. For the industrial building we should also enter the layout of premises at each level of building, allocation of noise sources and their power levels, thickness and material or sound isolation of walls, allocation of workplaces, sound absorption surfaces, etc. [11,12,13]. These data are used for the calculation of noise maps inside the building. On Figure 2 a model of the industrial building with calculated noise levels is presented.

![3D model of industrial building combined with noise maps](image)

**Figure 2.** 3D model of industrial building combined with noise maps.

4. **Calculation of noise levels and creation of a noise map.**

With the purpose to implement the results of calculation into building information model we should develop a noise map. The noise map is the most visible way of presenting information on the acoustic situation. Noise maps are also an effective tool in the design and implementation of noise protection measures.

To calculate noise propagation, the calculated area is divided on a grid with a certain step, that is the most appropriate to the purposes of mapping, i.e. 5 m, 10 m but not more than 30 m. After determining the noise levels at the grid points, the points with equal sound levels are connected by isolines, resulting in equal-sound lines. The most convenient step for presentation of sound levels is 5 dBA, which corresponds to the sanitary noise limits [14].

On Figure 3 the noise map for the territory adjoined the rail road is presented. The noise levels at the territory are presented as the isolines and the areas between them are marked according to the provided color scale. The buildings with different usage are marked out with different colors to assign noise limits.

![Noise map of the territory adjoined the rail road](image)

**Figure 3.** Noise map of the territory adjoined the rail road.

5. **Export of isolines of equal noise levels from SoundPLAN to Civil 3D.** The most spread format of data *.dxf is used to allow exchange of data between different programs.
6. **Creation of surfaces of equal noise levels in Civil 3D at different heights.**Normally, a plain surface at every floor of building as it is shown on Figure 4 is enough to evaluate a necessity of implementation of noise measures.

7. **Creation of 3D models of buildings with use of Civil 3D, Revit and Navisworks.** SoundPLAN does not allow to evaluate the amount of premises (or windows) that are exposed to the increased noise levels. Civil 3D allows to make different layers with windows of different usage within the same building. Navisworks includes a useful tool that helps to stretch a real photo of the existing building on its virtual model that helps to understand the usage of premises.

8. **Export of equal noise levels’ surfaces and models of buildings from Civil 3D into Navisworks using *.nwc files.** The result of import is shown on Figure 4. The exported noise levels’ surfaces and models of buildings with different premises (or windows) are used to trace the collisions, i.e. the intersection of the surface of sound level of 55 dBA (the limit noise level) with premises intended for residential use. In Figure 4 the surface with a sound level of 55 dBA crosses a number of rooms that have a residential purpose. Therefore, it is necessary to develop a complex of noise protection measures.

![Figure 4. Imported limit noise level surface and a model of building [15].](image)

3. **Results of noise information model development and protection measures**

3.1 **Analysis of BIM for infrastructure project**
The most spread measures to reduce road noise are installation of noise barriers and usage of noise-proof glazing [14, 16]. For the case presented on Figure 4 the use of a noise barrier was proposed. The barriers are installed with account of guidance provided in [17,18]. The noise levels after installation of the barrier were calculated using SoundPLAN. The results are shown on Figure 5.
The calculated noise levels after the barrier installation were imported into the Navisworks program using the algorithm described above. In the Navisworks program, collisions were tracked again. It was found that the excess of the noise levels is observed at heights of more than 10 m, therefore, additional use of noise-proof glazing is recommended for residential premises located above the third floor.

BIM is also useful when developing working documentation for noise barriers. It contains a digital terrain model which helps to determine the exact location of the screen to provide its efficiency. By tracking collisions in the Navisworks, it is possible to assess whether the pile foundation of a barrier or a barrier itself crosses the engineering networks or other road construction elements, such as lighting supports or road fencing, that are also parts of BIM of a road construction project (Figure 6).

3.2 Analysis of BIM for building project

The same procedure of creation of noise information model is used for industrial premises to reduce noise levels at workplaces. On Figure 7 a) the noise map for the production plant of the industrial building presented on Figure 2 is shown. In the result of calculation, we have obtained that the noise levels are exceeded by 10-15 dBA at the majority of workplaces.

For the reduction of noise levels inside the production plant the sound absorption with baffles installed at the ceiling and noise curtains are proposed according provisions of [19-26]. The results of calculations of noise levels with sound absorption (Figure 7 b) show that the noise levels are decreased by 2-14 dBA at the workplaces No. 5, 6 and 7. For the workplaces No. 1 and 4 a rational planning should be used, i.e. the permanent workplaces should be shifted from the zone with excess levels to the quieter zones. Workers No. 2 and 3 should use personal protection measures such as earphones.

The limit noise line should be pasted into the BIM of the plant to redevelop the workplaces [27-32]. The noise protection constructions should be imported into BIM to avoid collision with ceiling constructions and to allow the cost of sound absorption in the project budget documentation.
Thus, the use of BIM is an effective tool of noise protection measures’ design. BIM allows designers to take into account the results obtained at the development of related sections, promptly eliminate emerging problems and allow protection measures in the budget documentation. The joint work of the project team allows to identify potential problems before they occur at the construction or even at the exploitation of the object designed.

4. Conclusions

1. Noise is one of the main factors affecting population and workers. It can be minimized with proper evaluation and introduction of protection measures.
2. The design of noise protection measures is performed using specialized software calculation tools.
3. At the implementation of noise information to BIM, data is exchanged between SoundPLAN, AutoCAD 3D and Navisworks software.
4. Using BIM, it is possible to track the excess of noise levels in residential premises and at workplaces, the models of which are developed in Civil 3D or Revit.
5. BIM allows designers to take into account the results of noise evaluation, eliminate problems and allow protection measures in the budget documentation.

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