BIM cost analysis of transport infrastructure projects

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Abstract. The article describes the method of analysis of the energy costs of transport infrastructure objects using BIM software. The paper considers several options of orientation of a building using SketchUp and IES VE software programs. These options allow to choose the best direction of the building facades. Particular attention is given to a distribution of a temperature field in a cross-section of the wall according to the calculation made in the ELCUT software. The issues related to calculation of solar radiation penetration into a building and selection of translucent structures are considered in the paper. The article presents data on building codes relating to the transport sector, on the basis of which the calculations were made. The author emphasizes that BIM-programs should be implemented and used in order to optimize a thermal behavior of a building and increase its energy efficiency using climatic data.

1. Introduction

Further development of railroad network needs to resolve issues of quality and reliability of infrastructure facilities. Today, such issues can be addressed by using the Building Information Modeling (BIM) technologies [1-4]. This paper examines an example of power optimization for a standard-design railroad terminal building in the climate zone of the Baikal-Amur Mainline (BAM) Railroad.

2. Construction Siting Simulation

Selecting the building’s orientation respective to sunlight is a basic factor for construction design [5-13]. Solar radiation can be direct or dissipated, with beneficial and noxious effects. The effective construction project design regulations set forth the guidelines for light panes to fit the respective climate zone. Because insolation time remains unregulated for such public buildings as railroad terminals, we have scrutinized a number of siting options based on the need to subject main passenger waiting areas for 3 to 4 hours of continuous daily sunlight radiation as means of general sanitation, creating bactericidal effects, etc.

The time of insolation throughout the period was calculated for the first or last day of the respective season, because the insolation achieves its maximum and minimum level on such days. In the central zone of our project, the first and last days of the season are March 22 and September 22. The railroad terminal is to be built in the city of Irkutsk.

Let us now consider the inputs for preliminary selection of the construction site. In our case, the facade should be preferably facing either south or west as this ensures maximized insolation in the rooms. Southwestern or southeastern orientations are undesirable options since they give inferior sunlight penetration. IES VE software solution was used for this calculation; we used the SketchUp...
solution to build the model. To illustrate the selected surfaces and season, here is graphic representation of the quantity of sunlight received:

![Figure 1. Insolation dial diagram](image)

Imaging of directly sunlit indoors zones for specific rooms (Figure 2).

![Figure 2. Sunlit areas](image)

Now consider the simulation result of Earth orbiting around the Sun to site the railroad terminal’s main entry gate.

![Figure 3. a) Facing west (left view) b) Facing south (right view)](image)
Based on conducted consistent simulation of a number of options we have to conclude that the best scenario is with the facade facing south.

3. Simulating Different Insulating Materials’ Options
The main designed purpose of any transport terminal is to organize safe, quick and convenient passenger services with document processing on departure, between transit trains, boarding and discharge, and also transient services to arriving passengers and escorting individuals.

The terminal in question is a 2-story building designed to serve 500 passengers. So, under SNiP II-85-80 “Railroad Terminals. Construction Design Standards”, this is a ‘small and medium’ category building that must be built of at least Class 2 fire resistant materials. All construction materials and structures of the main rooms and escape ways must meet the required fire resistance limit of 2.5 hours. They must also be relatively inexpensive, environmentally friendly, and frost-resistant as the project location is in Siberia. To select finishing materials one needs to consider the architectural style and layout of other buildings and structures near the terminal and in the square (premises) in front of it. The terminal should be made architecturally expressive using artistically true but low-budget means in line with current trends of architecture, focusing on issues of engineering esthetics and optimization of premises. In regions with low ambient temperatures, three-layer slabs with high-efficiency thermal insulation are most expedient. Resistance to vapors in the internal layer should be at least 20% higher than in the external layer. The supporting structure is to be built mainly of ceramic perforated bricks, covered with 3D plaster of pigmented cement-sand mix to emphasize the plastic of the facade. The timberwork of all windows and doors are to receive two coats of varnish. Floors are made of reinforced-concrete slabs, types PK 60-12 and PK 60-15, each 220 mm thick. In between the slabs, there will be a layer of vapor and thermal insulation, made of silicate wool: though relatively inexpensive, this material is non-combustible, possessing good thermal and acoustic insulation properties, resistance to heat deformation, and biological and chemical stability.

As an illustration, we have created a 2D model used the ELCUT engineering modeling software pack. The model clearly represents distribution of temperature over the mass of the wall. The inputs were based on the above information on outdoors and indoors air temperatures.

![Figure 4. Building enclosure heat exchange model](image)
The color scale shows the color-temperature dependences. The heat flow is always from indoors to the outside.
4. Simulating Different Options of Window Design

The following options were selected for comparison:  
- Glass and 2 insulated chambers, size 1,500 x 1,200 mm  
- 2 insulated chambers, 12-12-12 mm, size 1,500 x 1,200 mm  

The parameters of window openings used as inputs by the software application:

Computer estimate of heat loss for option one: 110 KW  
Heat loss for option two: 142 KW  

| No | Design option                    | Size, HxW, mm | Heat loss, W |
|----|----------------------------------|---------------|--------------|
| 1  | Glass + 2 insulated chambers     | 1.500 x 1.200 | 110          |
| 2  | Two insulated chambers           | 1.500 x 1.200 | 142          |

The first option is thus preferable.

5. Conclusion

Using comprehensive computer simulation, we were able to select the siting option that considered both sunlight penetration and architectural layout. Based on the region’s climate characteristics, we chose construction materials and calculated the thickness of heat insulation layer, ensuring that the building’s enclosure meets the requirements to the building’s thermal protection, then based on the heat loss estimate we decided the type of window design.

Therefore, used to assist construction design for transportation infrastructure facilities, BIM technologies help to optimize building operation expenses and reduce the costs of ownership.

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References

[1] Peng C 2016 *Journal of Cleaner Production* *112* pp 453-465  
[2] Xu Z, Zhang H, Hu C, Mei L, Xuan J, Choo K-K R, Sugumaran V and Zhu Y 2016 *Concurrency Computation* *28* (15) pp 4038-4052  
[3] Yang J, Santamouris M and Lee S E 2016 *Energy and Buildings* *121* pp 344-349  
[4] Volkov A, Chelyshkov P and Lysenko D 2016 *Procedia Engineering* *153* pp 828-832  
[5] Bulgakov A, Volkov A and Sayfeddin D 2016 *ISARC 2016 - 33rd International Symposium on Automation and Robotics in Construction* pp 98-104  
[6] Volkov A, Chelyshkov P and Lysenko D 2016 *Procedia Engineering* *153* pp 833-837  
[7] Volkov A A and Batov E I 2015 *Procedia Engineering* *111* pp 849-852  
[8] Volkov A 2014 *Advanced Materials Research* *838-841* pp 2973-2976  
[9] Volkov A 2014 *Advanced Materials Research* *838-841* pp 2969-2972  
[10] Ginzburg A 2016 *MATEC Web of Conferences* *73* art no 02018  
[11] Ginzburg A, Shilova L, Adamtsevich A and Shilov L 2016 *Journal of Applied Engineering Science* *14*(4) pp 457-460  
[12] Anatol’Evich V A, Vladimirovich S A, Dmitrievich C P, Andreevich D L and Valer’Evna D A 2015 *International Journal of Applied Engineering Research* *10* (22) pp 43269-43272  
[13] Volkov A, Sedov A, Chelyshkov P and Doroshenko A 2014 *Applied Mechanics and Materials* *580-583* pp 3231-3233