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MULTI CRITERIA OPTIMIZATION OF LOW-RISE DETACHED HOUSE HEATING SYSTEMS IN AN ATTEMPT TO MINIMIZE ENVIRONMENTAL DAMAGE AND MAXIMIZE COMFORT OF USE

Abstract: *This paper analyzes the process of multi-criteria optimization in Design Builder software. The analysis is oriented on the process of achieving, analyzing choice of an optimal solution for the specific case of a low-rise detached house project. Presented are, the criteria for optimization and used parameters. This research verifies the assumption that it is possible to minimize price, damaging effects on the environment and discomfort in housing units, which is proven by the results of this research.*

Keywords:*multi-criteria optimization, Design Builder, discomfort, CO_2 emissions*

1.INTRODUCTION

The modern approach to projecting and building of low-rise dethatched housingunits includes predictions of behavior and optimization in realization. With this in mind it is necessary to include the optimization process in developing solutions of these objects. Besides this approach it is necessary to implement new energy sources- renewable resources with a goal to increase all positive effects while at the same time minimizing negative effects. This at the same time represents the analysis thesis of this paper.

Up to date in various optimization methods have been used in research of heating systems as well as other parameters which influence the heating system. In order to achieve the highest possible thermal comfort in a house, the type of heating is very important, [1]. In paper [2] the same authors researched ventilation systems, using COMIS software. With heating efficiency aside from ventilation and heating systems the organization of the floor plan also has a large influence, [3]. The goal of this type of research is to have the house be close to achieving a zero-net energy use as much as is possible under external conditions, [4]. A very important aspect of achieving good results is accommodating the house to its climate region and based on that planning the use of electrical energy, [5,6]. Combining all these parameters into a single-criteria or multi-criteria optimization is possible in Design Builder software, [7]. This software package enables optimization and calculation of costs of building an object, as well as all necessary installation which it may contain.

For the purposes of this research an analysis and calculation of the projected object was performed, as well as a multi-criteria optimization, solar panel systems for producing electric energy and heating water (PV panels and solar collectors) and lastly a comparison of results was performed. Based on this comparison conclusions were drawn with an idea to verify the needs for using renewable energy sources and to build-in the optimization process in the projecting process as an integral step in improving the object's performance and environmental conservation.

2. PROBLEM STATEMENT

2.1 Basic hypothesis

Every building has certain performances. The first step of this research is to determine the projected object's performances. The next step is derived from the hypothesis that it is possible to improve those performances through optimization in the projecting process. The optimization process is performed for the criteria of CO_2 emissions, discomfort and price separately - single-criteria optimization. Also, a Pareto optimization based on most influential criteria has also been performed. Upon the completed optimization the hypothesis is that the use of renewable energy sources can in an even greater capacity improve the object's energy efficiency.

The goal of this approach is discovering steps which achieve better performances during exploitation of low-rise detached houses. Aside from that the contribution of this paper includes determining the implementation of the best systems into the object for the territory of Belgrade, Serbia as location of interest.

2.2 Geometrical characteristics of the housing unit

For the purposes of this paper models have been created in Design Builder software. This software package includes modules for modeling, calculation, visualization of results and optimization.

Geometrical characteristics of the modeled house are shown in figure1.

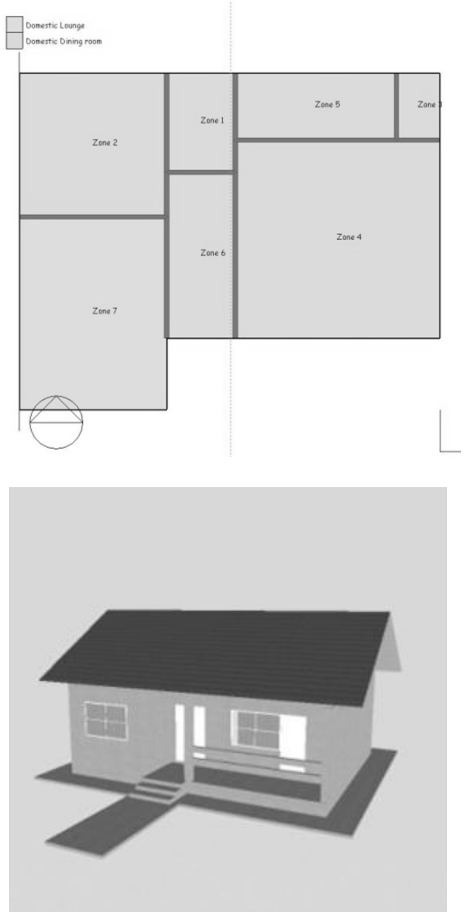


Figure1 -Geometrical characteristics of the analyzed housing unit

The total surface area of the model shown in figure 1 is 58 m^2. The chosen heating system is radiators combined with natural ventilation, heating is on natural gas. Heating systems in the second phase undergo the optimization process in order to determine which system provides the best performances.

Possible solutions of heating systems in Design Builder software are:

- fan coil unit,
- hot water radiator heating, mixed mode with natural ventilation and local comfort cooling,

- hot water radiator heating with natural ventilation,
- storage heaters with natural ventilation and
- under-floor heating system with natural ventilation.

Weather conditions for the simulation are used for the area of Belgrade, Serbia. The number of tenants of the house is two and all appliances are implemented according to suggestions for a two member family. Initial orientation is north-south, where the entrance is oriented towards the south.

3. UTILIZED METHODS

With multi-criteria optimization the most common case is that the quality of the solution which represents the values of the goal function, are not presentable only through one criteria. Through independent determination of the optimal solution for various criteria the final solution leads to mismatching. In actuality, usually the improvement of one criteria directly results in diminishment of another (at least one of the other criteria). An optimal solution represents a harmony of all variable values which are optimized, in order to have all optimized criteria be favorable. While solving optimization problems of multi-criteria optimization an interaction with the user is implied. Pareto optimum, on which the software is based on, can be defined on intuitive hypothesis that the acceptable point X is Pareto optimal if values of no goal function can be improved without diminishing at least one of the other criteria. Based on this theory there is almost always a group of solutions.

For optimization criteria in this software it is possible to chose codependence of two of a total of three possible criteria. Criteria which can be combined are CO_2 emissions, total costs and discomfort, while these values can be minimized or maximized.

Figure 2 shows the view and method of defining criteria for optimization in the software.

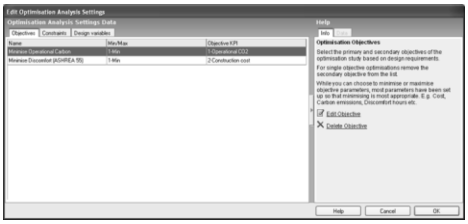


Figure2 -Optimization criteria definition interface

Figure 3 shows the view and way of defining optimization criteria.

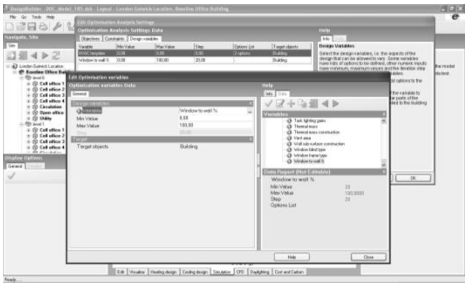


Figure 3 -Interface for defining optimization variables

For single-criteria optimization the only solution is obviously the optimum and a user analysis is not required. An optimal solution in the case of multi-criteria optimization represents a group of values (solutions) for which all goal functions which are included in the optimization - criteria achieve their extreme values. For determining the optimum with a multi-criteria optimization it is necessary to employ professionals in order to choose a valid solution.

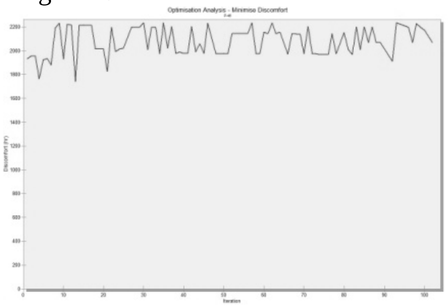
4. RESULTS

The initial model is projected with a thermo cumulative heater system. Values of the previous calculations for the projected object are presented in table 1.

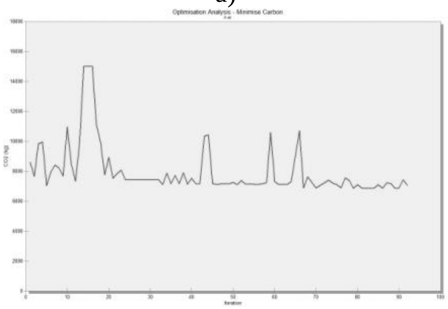
Table 1 – Values of CO_2 emissions, discomfort and building cost

Value name	Value
CO_2 emission	*9998 kg*
Discomfort	*2202 hrs*
Costs	*154070 GBP*

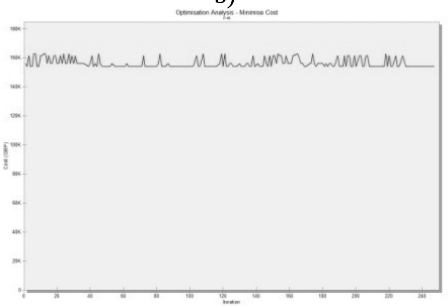
In order to achieve the best possible performances a single-criteria optimization was performed for every criteria separately. Optimization results are shown in figure 4.



a)



b)



c)

Figure 4 -Optimization results for the object based on: a) CO_2 emission, b) Discomfort, c) Costs, criteria

Comparison values, in order to find real improvement in performances, are shown in table 2.

Table 2 –CO_2 emission values,discomfortand price according to the completed single-criteria optimization

Criteria	CO_2	*Discomfort*	Costs
CO_2	*6830*	*2236*	*162972*
Discomfort	*8630*	*1742*	*161503*
Costs	*10241*	*1960*	*154070*

This approach obviously improves one criteria while the other two are noticeably diminished. Because of this a multi-criteria Pareto optimization is performed, and for the criteria the two most influential are chosen from table 2. Results of this optimization are shown in figure 5.

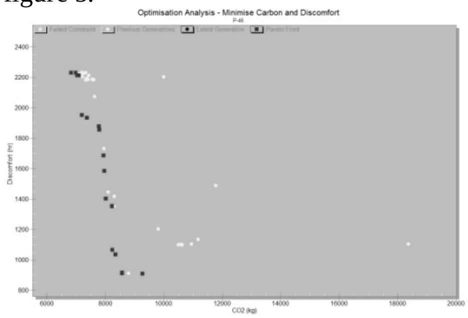


Figure5 -Multi-criteria optimization results

Values attained from optimization are for CO_2 8575 kg, for discomfort 909 hrs and for the costs 161503 GBP. It is noticeable that these values are better than the values achieved through single-criteria optimization.

The final result implies the implementation of a system for exploiting solar energy (PV panels and solar collectors). For proper HVAC system choice in combination with solar energy optimization was done in order to find the most favorable solution for a low-rise dethatched house. For this analysis the placement of solar systems oriented south for efficiency are important. Optimization results for a low-rise detached house with an implemented solar system is presented in figure 6.

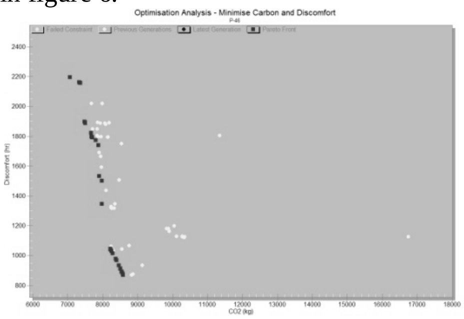


Figure 6 -Optimization results with PV panels and solar collectors

Values attained by this optimization are for CO2 8548 kg, for discomfort 890 hrs and for costs 165116 GBP. It is noticeable that these values are favorable to all previous results. This approach brings out the importance of renewable sources of energy, in this case solar energy, in projecting and exploitation of low-rise detached housing.

Based on optimization results conclusions were drawn and the importance of this process is presented based on specific values.

5. CONCLUSION

This research verifies the necessity to implement optimization in the process of projecting of low-rise detached housing.

In this paper a practical example was projected and calculated for CO2 emission values, discomfort and costs. Aside from that the steps by which significantly better results can be achieved were also presented. Multiple single-criteria optimizations were performed based on which it can be concluded that there is progress, but the there are diminished values of criteria which are not covered logically require a multi-criteria optimization. A Pareto optimization of the most influential criteria was performed. After that an optimization of the object with the use of solar panels was conducted. Upon acquiring these results the firstly projected results were compared to the final solution.

The obvious result is that the optimal solution has a worse CO2 emission value of 14% compared to the initialy projected object, that the discomfort value is improved by 59%, while the price of the object is similar for both solutions and the optimal costs 7% more.

Based on the presented results it can be concluded that the optimization process and use of renewable energy sources enables a significant improvement in object performance.

Further research means determining all processes which improve projecting of the object for the least amount of work results in the most positive effects.

This approach improves comfort of living, energy savings and at the same time conserves the environment

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