ABSTRACT:
In this study, in order to determine the advantages and disadvantages of the most common construction materials, different constructions types for passive houses, such as solid wood, wood-frame, aerated concrete, and brick, were compared with each other. The analytic hierarchy process (AHP) was applied to quantify the comparison. The analysis of different construction types based on quantifying different criteria for passive houses was performed on a case study. The wood construction was considered as one of the most suitable options for passive houses. In the light of the growing importance of energy-efficient building methods, it could be said that wood construction would play an increasingly important role in the future.

KEYWORDS: Passive house; Timber construction; Building criteria; Analytic hierarchy process;

1 INTRODUCTION
Energy efficiency is essential in the efforts to achieve a 20% reduction of primary power consumption by 2020. It is widely recognized that the potential of energy saving in buildings is large. Considering the tendencies of energy production and price, it is becoming urgent to reduce energy consumption in buildings. In Europe, the most comprehensive and widely used concept of ultra-low energy, more precisely, the passive house concept was presented by Dr. Wolfgang Feist of the Passive House Institute. It sets forth the maximum permissible energy consumption for the heating of the building and limits the total primary energy consumption. In its essence, it is an upgrade of the low-energy house standard. The term ‘passive house’ refers to a construction standard that can be met through a variety of technologies, designs and materials such as solid and wood structures. The following considerations are particularly important when choosing the material and the construction type: the construction type should be standardized; the construction system should be based on natural and environmentally friendly materials; the thermal envelope should meet the standards of a passive house; the construction should be wind-tight, airtight and diffusion open. In order to design and implement a high-quality passive house project, attention should be paid to the materials used. The choice depends on personal preferences, in particular on the cost. Over the past few years, the number of passive houses has been seen a continuous increase in Europe. Architects and civil/structural engineers facing with the challenges of climate change have recently focused their efforts on finding environmentally friendly solutions and construction methods that bolster energy efficiency and thus reduce the environmental burden. The choice of a construction material is the most important decision with long-term consequences for the owner of the building. The scale of the external environmental impact depends on the materials used and the energy sources utilized. The theoretical and practical aspects of a passive house’s life cycle and its environment were reported in various research articles and projects. However, based on an extensive literature search, the AHP or another multi-criteria decision model has not been used to rank construction materials for passive houses. The construction of a passive house is a complex and multidisciplinary field.
2 METHODOLOGY

The AHP analysis is a widely used multi-criteria decision model for ranking alternatives or selecting the optimal alternative on the basis of a hierarchical tree structure of goal, criteria, and sub-criteria. The AHP analysis is based on pair-wise comparisons of the elements on the same level of the hierarchy in respect of the parent element on the higher level of hierarchy. Comparisons can combine measurable and non-measurable, tangible and intangible, quantitative and qualitative elements. The objective is to evaluate different types of construction for a passive house. The components of the decision tree are goal, criteria, sub-criteria, and alternatives. We focused on finding the best alternative for a passive house. The answer can be obtained by assessing the criteria that present the core of the decision tree. We decided to choose the most important criteria among the collection of many criteria. The criteria of mechanical resistance and stability, fire safety, and energy efficiency are set forth by construction standards and have therefore been omitted from the ranking. The remaining criteria were combined into tree main criteria groups: the economic aspect, the environment, and well-being. Each group contained five sub-criteria. Based on the decision tree, in the first phase a questionnaire was drafted with paired comparisons of construction criteria in respect of the three criteria groups and the criteria groups with regard to the objective. We sought to establish which criterion is more important for the selection of the construction material for passive houses and to which extent. Eight experts from the field of architecture, wood science and technology, mechanical engineering, and civil engineering, along with eight passive house dwellers-users were selected. The results were obtained from all eight experts and from seven dwellers. The transfer of expert knowledge into the model increased the credibility of the final model. In the second phase, the first six criteria were selected with the highest weight by all the interviewees (Fig. 1). The alternatives were assessed according to the selected criteria.

Figure 1: Analytical model

The estimates for the measurable criteria (end-of-life disposal, emissions of material in their life cycle and functionality) were acquired from the literature whereas the ‘soft criteria’ based on subjective data (health aspect, psychological aspect and aesthetics) were compared using AHP scale by two experts.

3 RESULTS AND DISCUSSION

The results of the evaluation of three criteria groups combined, and experts and dwellers are individually presented in Fig. 2.

Figure 2: The results of evaluation of three criteria groups.

The priorities of each construction material type (alternative) were obtained through the matrix multiplication of weights of alternatives and vector of priorities of the criteria. The final priorities were normalized so that the sum of all priorities equals one (Fig. 3).

Figure 3: The final priority ranking of different construction types for a passive house.

4 CONCLUSIONS

This case study showed the application results of AHP method could be used for analyzing the decision criteria related to a passive house. Based on the findings obtained from the study, it can be said that the AHP analysis is one of the most suitable models for comparing different construction types used in a passive house. The analysis showed that wood as a renewable raw material was one of the best choices for energy-efficient construction. The AHP analysis method can help professionals and future dwellers to make a reasonable choice on further optimizing and developing a particular aspect of the building process by giving them the possibility of comparing different alternatives on a common and comprehensive basis. Moreover, it can identify the weak and strong aspects of using a material for a passive house and thus open up a new dimension to the promotion and marketing of passive wood houses by allowing a better appreciation of the impact of individual parameters on other performance criteria. The findings of AHP analysis can be further integrated into strategies to increase the usage of wood as a construction material. The links between the selected criteria remained unexplored.