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The practical use of the QFD method in relation to a passive house project

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Abstract: The aim of the study was to use one of the quality management methods – the QFD method – in a design office offering, among other things, passive house designs. In addition, the effectiveness of the QFD method in the passive house design process was assessed, and the strength of the relationship between customer requirements and technical parameters was analyzed. Achieving these goals was done through the use of respondents' answers regarding the studied issue as well as the creation and analysis of a quality house, the parts of which were related to each stage of the QFD method. The study confirms the effectiveness and versatility of the QFD method in the field of construction services, and also confirms the large number of strong relationships that exist between customer requirements and the technical parameters related to the construction of a passive house.

Keywords: passive house, quality, customer requirements, QFD method

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Introduction

Nowadays, increasing attention is being paid to issues related to the broadly understood protection of the natural environment. In every area of life, solutions are being introduced to minimize the negative effects on the natural environment or to better utilize renewable energy sources. One such solution is the concept of a passive house.

The creator of this idea was the German physicist Dr. Wolfgang Feist, founder of the Institute of Passive Houses in Darmstadt (Lewoc, 2021). The concept of a new energy standard for buildings, is related to optimizing the consumption of renewable heat sources (Kurzak & Bieda, 2012). It is worth mentioning that the idea of a passive house was recognized as one of the goals implemented under the 1997 Kyoto Protocol. This protocol is an international treaty and concerns the reduction of greenhouse gas emissions.

A passive house is defined as a house that processes and retains heat that comes from renewable sources (Bil, 2019; Ionescu, 2017; Kaklauskas et al., 2012, Stasiak-Betlejewska, 2012). This means that no non-renewable fuel (coal, gas, oil) is used within such a house, as energy is supplied from external sources such as light or natural ground heat, and solar energy or by internal sources such as heat generated by household appliances or residents (Karaś, 2020).

In order to reduce heat loss, the form of construction and insulation of a passive house are important (Kovic & Praznik, 2008). There are many factors to consider when building a passive house. One of which is the location in order to maximize the use of insulation. A living room, where a large amount of time is spent, should be located on the south side of the house, while rooms such as the bathroom, kitchen and utility rooms can be located on the north and east side (Płaziak, 2013). The shape is important – a passive house should have a compact body and glass walls. Foundations, walls, roofs and flat roofs should be highly insulated through the use of polystyrene, wool or vapor barrier films (Jura et al., 2014). The window and door joinery should also be highly insulating (Pomada, 2014). A passive house uses cheap energy sources (solar collectors, heat exchangers, mechanical ventilation with heat recovery).

Building a passive house is not cheap, additionally, the entire investment is carried out once, which is why there are not many such houses in Poland yet. An additional factor that may impede the construction of such houses in Poland are the climatic conditions (Schnieders, 2020), which are definitely less favorable than in Western European countries. It is estimated that the investment related to the construction of a passive house is paid off after 10-15 years.

The aim of the study is to implement one of the quality management methods – QFD methods in a design office that offers, among other things passive house designs and evaluate its effectiveness in the passive house design process, as well as analyze the strength of the relationship between customer requirements and technical parameters. These goals were achieved by analyzing the responses of respondents regarding their requirements from the passive house design and a comprehensive analysis of the quality of the house.

1. Theoretical basis of the QFD method

The QFD method (Quality Function Deployment) is one of the available quality management methods in developing products and is also called Quality Function Development or Adjustment or Quality House (Lager, 2020, Wolniak, 2017). The foundations of this method were developed in 1966 by Y. Akao (Akao, 2003) as part of Total Quality Control.

Thanks to the QFD method, it is possible to translate market requirements for a product or service into conditions that must be met by the entity that produces them (Carnevalli & Miguel, 2008; Chan & Ming, 2002; Toruński, 2013). This applies to every stage of its development (design, production, sale, service). This method allows a product or service to be designed in such a way as to take into account not only the technical considerations, but also the requirements of the market and customer expectations (Ćwiklicki, 2017; Ćwiklicki & Obora, 2008a; Ćwiklicki & Obora, 2008b).

The QFD method has many advantages (Wolniak, 2018). One of them is the fact that already in the design phase the voice of a potential customer can be taken into account, so that the end product can be better designed to meet the customer's needs. Additionally, the company can get to know its strengths and weaknesses better when compared to the competition. Also, quality costs can be better planned, product or service planning becomes an element of the quality planning. The duration of the product development cycle is as well shortened. The QFD method is a method that is used because of its simplicity in the analysis and documentation in all industries and services (Jagusiak-Kocik, 2020; Pauliková et al., 2016).

According to Łuczak & Matuszak-Flejszman (2007), the QFD method consists of 8 stages. At work, due to the small number of design offices in the immediate vicinity that deal with the design of passive houses, the QFD method does not include stage VII, i.e. comparing the service with the competition.

2. Application of the QFD method in relation to passive house design

The design office presented in the paper is newly opened and apart from single-family houses built in using the economic system, its offers includes several passive house designs. This office, after recognizing the advantages of the QFD method, decided to implement it in order to better match the technical requirements that are set in the design and construction of a passive house to the growing and constantly changing needs of customers.

The steps taken in the QFD method for the enterprise are presented below. The quality house is presented in Figure 1 (Jagusiak-Kocik, 2019; Jagusiak-Kocik, 2021).

I. Customer requirements and grouping of these requirements according to a relationship diagram

As mentioned, building a passive house is not very popular in Poland. It is influenced by many factors, but the most important is the high cost of construction. You also need to find a suitable contractor, because at the design stage, passive houses must meet a number of criteria. Therefore, the representative group that was to define the requirements for the designed passive house was strictly identified.

Since each construction of a house, and even more so a passive house, is a long-term, costly undertaking that requires many important, long-term decisions, the surveyed population consisted of people who, through contact with a design office, had been interested in the design of such a house for some time. On the basis of an initial analysis consisting of a short electronic questionnaire among 150 interested parties, it was found that the studied population was mainly men, in the age range from 29 to 38 years, with higher education. After the initial identification of the population, collective lists were prepared – it was decided to divide the studied population into 3 groups of 50 people. Then, by drawing lots, 10 people were selected from each of these groups.

In this way, a representative group was created, which was asked the question: *What solutions are you looking for when choosing a passive house project?*
The respondents gave about 30 answers, of which 15 most frequently repeated were selected for further analysis – these solutions (in order to standardize the vocabulary and to fit the terminology to QFD, the word "solutions" will be replaced by the word "requirements") are presented below:

1) attractive price of the project,
2) high air-tightness,
3) large windows on the sunny side,
4) three-layer walls,
5) intelligent building management,
6) winter garden in the project,
7) terrace,
8) the possibility of co-financing the construction,
9) low heat loss,
10) relatively low construction cost,
11) heat recovery from grey water wastewater,
12) electric roller shutters,
13) a fireplace with a distribution system,
14) heaters in the bathroom,
15) infrared heaters

From the analysis of the responses, it can be seen that they concern solutions already currently used in the construction of passive house. These are standard in almost every passive house project, because a passive house must meet strict criteria to be able to be called passive. The requirements chosen by the respondents were placed in the quality house in area I.

After collecting the responses to the customer requirements, they were ranked using one of the new quality management tools – the relationship diagram. Three groups of requirements were specified: technical (high air-tightness, three-layer walls, intelligent building management, low heat loss, heat recovery from grey water wastewater, electric roller shutters, fireplace with distribution system, heaters in the bathroom, infrared heaters), economic (attractive price of the project, the possibility of co-financing the construction, relatively low construction cost) and other requirements (large windows on the sunny side, winter garden in the project, terrace).

II. Determining the importance of customer requirements

In order to implement this stage of the QFD method, a survey was conducted, which includes all customer requirements for the passive house design. Then the representative group was asked to distribute a certain number of points (the study assumed that it would be 50 points) for each requirement. The next step was to add up the points of each requirement thus determining the importance of each of them. The requirement with the highest number of points among the respondents was the requirement with the highest weight, while the requirements with the lowest number of points – had the lowest weight. For the purposes of the study, a scale from 1 to

10 points was used, where 1 is the least important requirement, and 10 – the most important requirement. The most points, and thus the greatest importance, were given to the requirements related to the relatively low construction cost, low heat losses, the possibility of co-financing the construction, and high air-tightness. The requirement covering intelligent building management and three-layer walls turned out to be the second most important. The requirements related to the winter garden in the project and the terrace were of the least importance. This may be due to the fact that, for example, a terrace is not a solution often used in passive house designs, as it is a house element that loses heat. The determination of the importance of customer requirements is presented in area II of the Quality House.

III. Determining the technical parameters of the selected product or service

At this point, the entire passive house design service has been characterized from the designer's point of view, by determining its technical parameters, which are presented below:

1) filling between the panes,
2) sealing windows,
3) heat transfer coefficient for the window,
4) thermal insulation layer,
5) energy demand,
6) roof structure,
7) the shape of the house,
8) building tightness test,
9) mechanical ventilation with heat exchange,
10) the optimal area of the house.

The quality house in area III contains technical parameters.

IV. The relationships between customer requirements and technical parameters

For the purposes of the study, certain symbols were adopted that denote the strength of relationship in the case of its occurrence between customer requirements and technical parameters.

■ – strong relationship (9 points)
◧ – medium relationship (3 points)
□ – weak relationship (1 point)

The relationship between customer requirements and technical parameters is shown in area IV in the middle of the quality house.

V. Assessment of the importance of technical parameters

The importance of technical parameters was calculated on the basis of the formula (Wolniak & Skotnicka, 2011):

$$T_j = \sum_{i=1}^{l} W_i Z_{ij} \tag{1}$$

where: T_j – importance of technical parameters, W_i – importance coefficient of subsequent requirements i, Z_{ij} – coefficient of relationship between customer requirements i and technical parameters j and is shown in area V of the quality house.

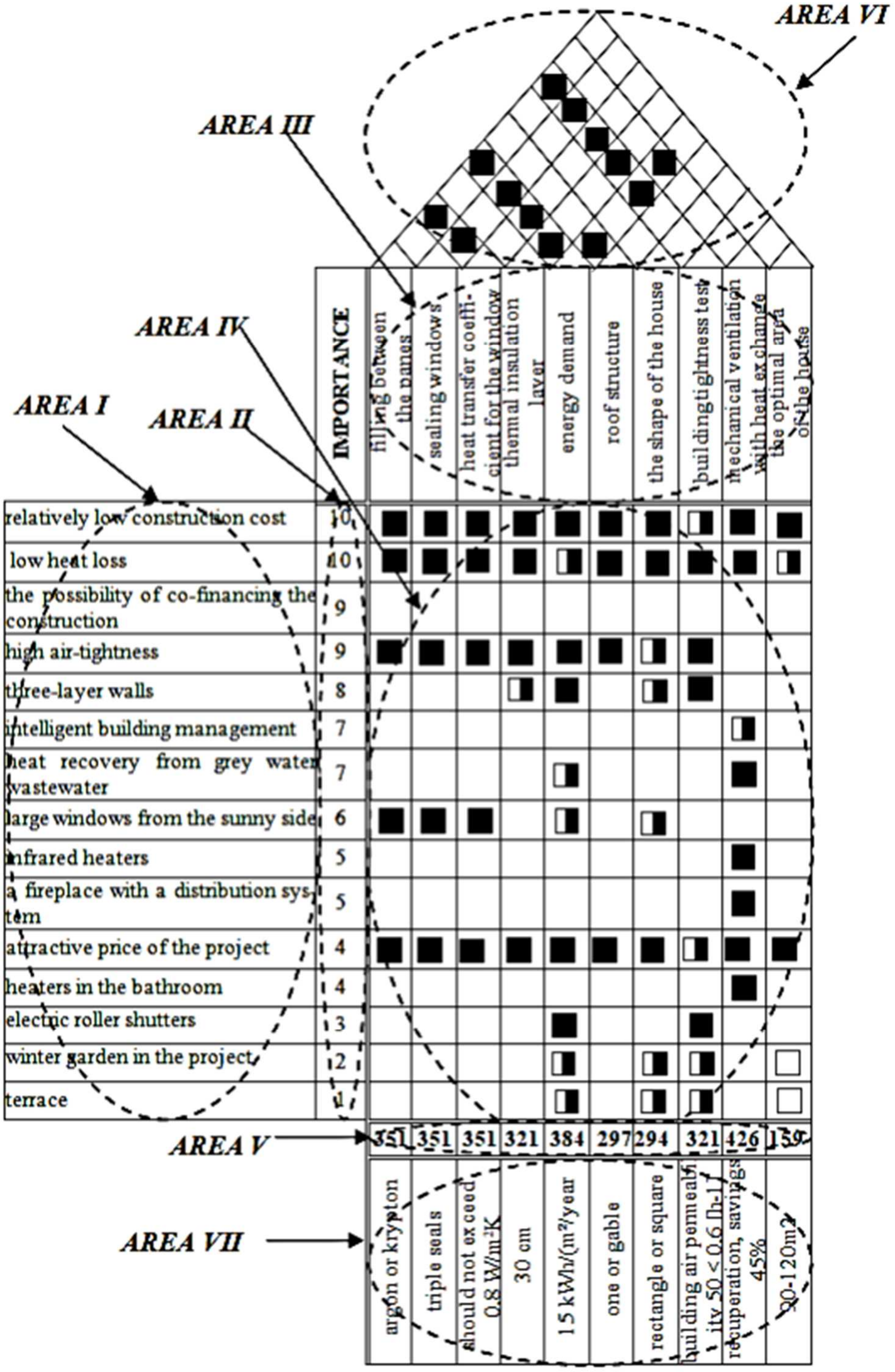

Fig. 1. Quality house for a passive house construction project, source (*own research*)

VI. Determining the relationship between the technical parameters (area VI of the quality house)

The example uses symbols as in the case of the relationship between customer requirements and technical parameters.

■ – strong relationship (9 points)

◨ – medium relationship (3 points)

□ – weak relationship (1 point)

VII. Target values of technical parameters

In the analyzed example, the target values of technical parameters are presented in the Quality House in area VII.

Conclusion

The presented practical use of the QFD method in relation to a passive house design service confirms high efficiency in translating customer requirements into technical language. This is shown by the large number of relationships between customer requirements and technical parameters presented in the middle of the quality house.

It confiems that the largest number of relationships (all technical parameters) occurs with the requirement related to “relatively low construction cost” and “attractive price of the project”. This is due to the fact that a passive house is more expensive to build than traditional single-family houses, and the increased cost of the entire construction is due to the use of certain technical parameters with enhanced properties, presented in area III of the quality house.

“Low heat loss” and “high air-tightness” are other customer requirements, which strongly correlate with almost all technical parameters – to meet these requirements, the use of a specific filling between the panes, special sealing of windows, a specific value of the heat transfer coefficient for windows, a thick thermal insulation layer (about 30 cm for passive houses), a roof structure preventing heat loss or a specific shape without bay windows or dormers must be utilized.

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