Optimizing parameters of a technical system using quality function deployment method

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Abstract. The article shows the practical use of Quality Function Deployment (QFD) on the example of a mechanized mining support. Firstly it gives a short description of this method and shows how the designing process, from the constructor point of view, looks like. The proposed method allows optimizing construction parameters and comparing them as well as adapting to customer requirements. QFD helps to determine the full set of crucial construction parameters and then their importance and difficulty of their execution. Secondly it shows chosen technical system and presents its construction with figures of the existing and future optimized model. The construction parameters were selected from the designer point of view. The method helps to specify a complete set of construction parameters, from the point of view, of the designed technical system and customer requirements. The QFD matrix can be adjusted depending on designing needs and not every part of it has to be considered. Designers can choose which parts are the most important. Due to this QFD can be a very flexible tool. The most important is to define relationships occurring between parameters and that part cannot be eliminated from the analysis.

1. Introduction
Nowadays the problem of optimizing parameters of technical systems is a common issue for many companies. The final product has to fulfill customer requirements which are becoming more and more complicated to translate into measurable technical requirements. The most important ones are called critical technical requirements and without them the final product cannot be completed. Critical requirements are the most difficult to implement. Quality Function Deployment (figure 1) can help with that problem by evaluating complete set of assumptions to determine the proper design parameters [1, 2].

QFD method was invented in the Mitsubishi Heavy Industry Ltd by two experts Shigeru Mizuno and Yoji Akao for better understanding and improvement the design processes. QDF was successfully used by Toyota which helped to reduce costs of introducing a new car into the market by 60% and shortening product development time by 1/3. This method allows increasing the customer satisfaction and improving the quality of every final product. A summary of the method is to create a QFD diagram often called the House of Quality. In essences basic general diagram shows (figure 1) customer requirements and answers how those needs are translated into design requirements. It also gives a view on how customers and design requirements correspond with each other, assigns weights and evaluate their relationships.
The first step in the proposed method would be to select main groups of design parameters and define customer. The customer is understood not only as a person buying final product but also as a designer. In the article customers are represented by marketing department and designers by engineering department. Each department has different needs and the task of QFD is to combine both and choose their appropriate measured values. Most common requirements from customer point of view are: effective and practical use, appearance, easy operating, availability, physical proprieties (such as weight, temperature, type of material, etc.), reliability, environmental friendliness. The engineering department will have measurable requirements such as: dimensions, materials characterization, assembly features, power and energy consumption, ergonomic parameters, physical and chemical properties, gravity, cross-sectional shapes, cross-sectional dimensions and others depending on the type of the product.

![Quality Function Deployment diagram](image)

**Figure 1.** Quality Function Deployment diagram [1].

2. Optimization of a mining support

The mining mechanized support is the most important part of mining complexes (figure 2). It is utilized in hard coal mine for deep mining. The problems considered with this technical mean, results from the designed systems and adopted work parameters.

The role of a support is to protect the mining area against the rock falls what causes destruction of mining equipment, covering up a heading and, what is the most dangerous, jeopardizing human life. This is why this device should be proper designed and optimized. Moreover it should be prepared to assembly and disassembly under difficult mining conditions.

This analysis of parameters of a support could be realized according to the general model of the structure of a technical mean [3]. It consists of three main component systems: a “material” one, an “energetic” one and an “information” one (figure 3). The sequence of the component systems responds to their hierarchy. The material system includes such elements like: canopy, shields, lemniscate system, and foot piece. The energetic system includes main hydraulic props, hydraulic cylinder for canopy correction and hydraulic cylinder of a front shield. Finally the information system includes elements of a hydraulic system with control valves.

The presented structure, used as a decomposition tool, could be utilized to distinguished features that could be optimized using the QFD method.
Figure 2. Virtual model of a mining mechanized support.

Figure 3. Model of the structure of a technical mean [3].
3. Quality Function Deployment methodology
The first step in determine construction parameters is to know how the test object is built. Traditional mechanized mining support has 9 main parts: front shield, props, base, lemniscate connectors, rear shield, correction prop, shield, side shields and canopy. Based on that, design requirements (construction requirements) and their weights are: compliance of direction of the load and support (0.06), compliance of direction of the load and canopy trajectory (0.06), the vulnerability of structures (0.14), versatility (0.12), continuous roof support (0.08), cover of workplace (0.07), standard components (0.11), simplicity (0.11), reuse of elements (0.15), workflow automation (0.09).

Then the requirements from the client point of view (marketing requirements) and also their weights are established such as:
- the use of the most accessible materials (0.13);
- costs (0.25);
- durability (0.21);
- prevention of destruction of the roof (0.42).

The second step is creating a QFD quality matrix (figure 2), were all the above requirements are put in, as well as theirs weights. All requirements are compared with each other and the assessment of existing relationships between them is made [4, 5]. Because there is not any relevant competition in the mining industry manufacturing mechanized mining support, analysis of the competition was omitted. Weights were analyzed and selected by experts (table 1).

|                           | 1  | 2  | 0.13 | 0  | 0  | 1  | 2  | 0  | 0  | 3  | 2  | 2  | 0  |
|---------------------------|----|----|------|----|----|----|----|----|----|----|----|----|----|
| the use of the most       |    |    |      |    |    |    |    |    |    |    |    |    |    |
| accessible materials      |    |    |      |    |    |    |    |    |    |    |    |    |    |
| costs                     | 4  | 1  |      | 3  | 3  | 2  | 1  | 2  | 0  | 1  | 3  | 2  | 2  |
| durability                | 2  | 3  | 0.12 | 3  | 3  | 2  | 1  | 2  | 0  | 1  | 3  | 2  | 2  |
| prevention of destruction | 3  | 4  | 0.42 | 2  | 3  | 1  | 0  | 3  | 1  | 0  | 0  | 0  | 1  |

The gray area in the QFD matrix means future project goals and the correlation matrix is done using weights and establishment of the validity of marketing parameters [6, 7]. QFD diagram does not
have to look like a typical house of quality. In some cases, as in this example it is easier to create a typical table and adjusted it, accordingly to a chosen technical system.

Figure 4. Model of exemplar support construction including optimized parameters.

4. Conclusions
The presented QFD approach helped to elaborate the set of constructional requirements that allowed designing the mechanized mining support that fulfil the most complex technical requirements indicated by the QFD analysis. The virtual model of this support is presented in figure 4. The model was used to conduct analysis considered with the assessment process of a new design [8]. The next analysis should be considered with material analysis [9,10] to select the most appropriate one taking into account the conditions in a hard coal wall.

The second direction of work is to consider with preparation the production scheme that allows decreasing manufacturing costs. To help with that it would be a good idea to use application of new intelligent tools [11,12] to realize this task as a multi-enterprise project.

The presented approach of the QFD technique to technical project realization shows that this multidisciplinary approach could bring synergetic effect in the designing process. Application of the QFD approach allows confronting customers’ requirements (representatives of hard coal mines) and designers’ problems. In comparison to other approaches, the QFD technique allows analyzing problem aspects not only in qualitative terms but also in quantitative ones. The last could be called as the main advantage of this engineering tool.

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