Fuzzy evaluation of the technical re-equipment project efficiency

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Abstract. The article describes the computer implementation of an objective assessment and selection of the best project for the technical re-equipment of an industrial enterprise. Based on the opinions of experts, it is established that the efficiency of the technical re-equipment project is an integral indicator consisting of four aggregated characteristics: economic efficiency, technical and technological efficiency, social efficiency and environmental efficiency. Each of these characteristics consists of individual indicators, expressed in different units of measurement. Different perceptions by individuals of the importance of each of these indicators, as well as a wide variation in understanding how an effective technical re-equipment project should look, make the development of such an appraisal model relevant. The model of estimation is based on the ideas of the theory of fuzzy logic and fuzzy sets. The model is developed in the Fuzzy Logic Toolbox package of the MATLAB software environment.

1. Introduction
One of the urgent problems of modern industrial enterprises is the problem of their technical development. The most common direction of technical development is the technical re-equipment of industrial enterprises. This is a very long and costly process, requiring both from the management of the enterprise, and from its employees of high qualification, the ability and skills to make quickly decisions and predict the outcomes of these decisions.

Currently, the market of technical and technological equipment is represented by many kinds of different industrial machines, aggregates, mechanisms of different manufacturing firms, different levels of complexity, productivity, energy intensity and, of course, different costs. The analysis of the market, the choice of suppliers of production equipment, the formulation of terms of delivery and payment, installation, assembly and installation of equipment at the enterprise, commissioning and subsequent technical support are all elements of the process of renewal of fixed assets called technical re-equipment. Before embarking on the technical re-equipment of the industrial facility, a technical re-equipment project is being prepared, which means a system of specific measures, the implementation of which is designed for a certain period. These are measures to develop and implement technologies and equipment to ensure the effective operation of the enterprise, its production activities. The system of indicators for evaluating the effectiveness of technical re-equipment projects includes: economic aspects, interaction with external organizations, internal business processes, staff training and improvement of the business entities [1]. Therefore, the management of the enterprise, where technical re-equipment is planned, is faced with the task of selecting the optimal technical and technical re-equipment in terms of costs and results. As a rule, the technical re-equipment project is presented in

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several variants. In each version, alternatives can also be reflected: by manufacturers of equipment, by types of equipment, by constructive combinations of equipment in the alignment of technological lines, by terms, cost, warranty and post-warranty services, etc. [2]. Therefore, the choice of a technical re-equipment project is an important step on the way to improving the activities of an economic entity, its emergence into an innovative development path. However, when choosing a technical re-equipment project, the management of the enterprise may face significant difficulties, the main one of which is the question: which project is optimal? It is generally accepted that the term “effective project” is synonymous with an optimal project. Efficiency in the general case is understood to be the excess of the magnitude of the effect from the implementation of project activities over the costs of the project. As a rule, the value of efficiency has a monetary expression. Then the efficiency coefficient higher, the project will be better [3]. Prior to the implementation of the technical re-equipment project, only a preliminary effect can be calculated, based on subjective opinions and expert judgments. Therefore, it is advisable to turn to the theory of fuzzy logic and soft calculations, having developed a system of decisive rules, according to which, even on the basis of fuzzy, approximate estimates, one can arrive at a clear solution to the problem of choosing the optimal variant of technical re-equipment.

Thus, the purpose of this work is to demonstrate the possibilities of implementing a fuzzy inference system in modern software using the example of MATLAB for objective evaluation and selection of the optimal project for the technical re-equipment of an industrial enterprise.

2. Preliminary analysis and formation of a system of assessment parameters

Compared with other forms of renewal of fixed assets, technical re-equipment requires significantly less one-time costs and, in a short time of capital investment, allows for a significant improvement in technical and economic indicators. Conducting technical re-equipment does not require the construction of new buildings and facilities, provides for the possibility of using existing fixed assets. Enterprises that are objects of technical re-equipment can also use established channels for the supply of raw materials and materials, as well as sales of products. Capital investments in the technical re-equipment have the most efficient technological structure and relatively short payback period. As a result of technical re-equipment, the company can solve several tasks: from simple replacement of equipment (in connection with the impossibility of its further operation) to the renewal of the assortment and transition to the production of new types of products, improving the quality of products, increasing production volumes, introducing energy-saving technologies, etc. The technical re-equipment is carried out at the operating enterprises, for which the existing production base, organizational structure, branch profile is characteristic, which largely determines the preparation of the technical re-equipment project and its integrated assessment.

The implementation of this project should be preceded by comprehensive pre-investment studies, whose main task is the definition in the current market conditions the internal capacity of enterprises for production of competitive, marketable products.

As a result of a preliminary investment analysis, several alternative variants of a technical re-equipment project should be formed. The choice of the best option can be made only after evaluating the effectiveness of each of them. The system of parameters for the evaluation of technical re-equipment projects and the selection of the best of them is presented in figure 1.

The formation of a larger number of levels of the system of parameters is inexpedient, since it will lead only to a complication of inferences and confusion. For the same reason, do not increase the number of parameters.

3. Setting the task and creating an evaluation model

The problem can be formulated as a problem of decision-making, which is to choose the best project of technical re-equipment of the industrial enterprise. Parameters describing the decision-making situation are shown in figure 1. The decisive rule for choosing an alternative is the integral estimate (Y), obtained on the basis of the convolution of the criteria. Considering the fact that the task is being solved in the conditions of incompleteness and inaccuracy of information on the processes that
constitute technical re-equipment, insufficiency and unreliability of knowledge, subjectivity of assessments is available, it is expedient to use fuzzy logic methods for solving it. Multi-criteria choice of alternatives with application of the rules of fuzzy inference makes it possible to single out the best alternative with the help of the composite rule of aggregating descriptions of alternatives with information on the preferences of the company’s management that are given in the form of fuzzy judgments.

Figure 1. System of parameters for the evaluation of the technical re-equipment project.

When developing a fuzzy model for evaluating a technical re-equipment project for an industrial enterprise, the author of the article was guided by the theoretical positions of fuzzy sets and fuzzy logic [4], [5], [6], and therefore these points are not considered in detail here.

The evaluation of each of the technical re-equipment projects is carried out on the basis of applying a fuzzy conclusion for each level of the hierarchy (figure 1), therefore for each level of parameters fuzzy inference rules are developed. The input and output variables at each hierarchy level in the evaluation model correspond to those shown in figure 1. Each of the input parameters for the output variables $X_I$, $X_{II}$, $X_{III}$, and $X_{IV}$, shown in figure 1, is expressed as a fuzzy set with three levels: low, medium and high. Each of the parameters $X_I$, $X_{II}$, $X_{III}$, and $X_{IV}$, being an input to $Y$, is a fuzzy set with five levels: low, below average, average, above average and high. For example, fuzzy sets of input parameters $x_{I1}$, $x_{I2}$, $x_{I3}$ and output variable $X_I$ (economic efficiency) are given in Table 1.

Scales similar to those shown in Table 1, are compiled for each parameter and in accordance with the levels of their nesting. The fuzzy sets of the output parameter $Y$ correspond to the fuzzy sets of the parameter $X_I$.

Further, in accordance with the theory of fuzzy logic [4], a rule base is created for the parameters $X_I$, $X_{II}$, $X_{III}$, $X_{IV}$ and $Y$. This procedure begins in the reverse order, i.e. with variables of internal nesting. For each block of rules, all possible options are sorted out. After all the parameters are investigated, their definition areas and terms are given, and the rules bases are compiled, the fuzzy evaluation model is implemented in the Fuzzy Logic Toolbox.
Table 1. Fuzzy sets of parameters of the first group.

| x_{I1} – relative preliminary economic effect, % |
|---------------------------------|----------|----------|----------|----------|----------|
| Level                           | 0 – 25   | 26 – 50  | 51 – 75  | 76 – 100 | More than 100 |
| low                             | 1,0      | 0,85     | 0,75     | 0,65     | 0,3       |
| average                        | 0,4      | 0,75     | 1,0      | 0,85     | 0,15      |
| high                           | 0,1      | 0,4      | 0,6      | 0,8      | 1,0       |

| x_{I2} – payback period, years |
|---------------------------------|----------|----------|----------|----------|----------|
| Level                           | Less than 1 year | 1,0 – 2,5 | 2,5 – 4,0 | 4,0 – 5,5 | More than 5,5 |
| low                             | 1,0      | 0,8      | 0,6      | 0,4      | 0,2       |
| average                        | 0,2      | 0,65     | 1,0      | 0,75     | 0,25      |
| high                           | 0,1      | 0,25     | 0,55     | 0,75     | 1,0       |

| x_{I3} – probability of financial risk, % |
|---------------------------------|----------|----------|----------|----------|----------|
| Level                           | Less than 5 | 5 – 8    | 8 – 12   | 12 – 15  | More than 15 |
| low                             | 1,0      | 0,8      | 0,6      | 0,4      | 0,2       |
| average                        | 0,3      | 0,75     | 1,0      | 0,75     | 0,25      |
| high                           | 0,2      | 0,4      | 0,6      | 0,8      | 1,0       |

| X_I – economic efficiency, % |
|---------------------------------|----------|----------|----------|----------|----------|
| Level                           | 0 – 20   | 21 – 40  | 41 – 60  | 61 – 80  | 81 – 100 |
| low                             | 1,0      | 0,8      | 0,6      | 0,4      | 0,2       |
| below average                   | 0,5      | 1,0      | 0,7      | 0,55     | 0,25      |
| average                        | 0,2      | 0,7      | 1,0      | 0,75     | 0,3       |
| above average                   | 0,2      | 0,45     | 0,75     | 1,0      | 0,65      |
| high                           | 0,1      | 0,3      | 0,55     | 0,8      | 1,0       |

4. Implementation of the computer model

Five files are created: EE.fis, TTE.fis, SE.fis, EcolE.fis и EffTReP.fis (abbreviations from names: Economic Efficiency, Technical and Technological Efficiency, Social Efficiency, Ecological Efficiency, Efficiency of the Technical Re-Equipment Project). Previously, the required number of input variables, their names, their action intervals (definition areas), corresponding terms are entered into these files. The FIS editor allows you to describe the basic properties of the fuzzy inference system. So, in this case, the Mamdani algorithm [7] was chosen, the prod method is the method of the algebraic product of the truth degree of the fuzzy sentences being joined, the probor method is the algebraic sum of degrees of truth of connected fuzzy statements, the conclusion method is prod, the probor method is chosen to aggregate the values of the membership function of each of the output linguistic variables of the conclusions of fuzzy rules, the mom method is the mean maximum method and is designed to perform defuzzification. In the rules editor of rules of fuzzy output (Rule Editor) all rules are set according to the principle of exhaustive search. Figure 2 presents a window for entering rules for a variable Y.

With the help of the model realized in this way, it is possible to objectively evaluate the projects of technical re-equipment of an industrial enterprise and choose the most optimal one from them. In particular, the system has proven itself in the implementation of technical re-equipment at some industrial enterprises of the Tver region. Her application has allowed managers of enterprises quickly and with minimal financial costs to find and implement the best option of technical development entrusted to them by the owners of industrial enterprises.
Figure 2. The input window of rules for the variable Y.

Figure 3. The graphical interface of the rule system for the variable Y.
5. Conclusion
When you select a project of technical re-equipment of industrial enterprises it is important to consider not only the technical and economic indicators, but also to take into account the possible negative impact on the environment and humans, the efficiency of the proposed solutions, the need for training and qualification of staff, etc. System of indicators, presented in figure 1, is not static and may be adjusted depending on the preferences of the leadership and the conditions in which the evaluation and selection of the optimal project. However, the proposed system of indicators allows with sufficient reliability to determine the final indicator of the effectiveness of the project of technical re-equipment.

The methodology of fuzzy sets, which used for the creation and implementation of the described evaluation model, has the following advantages:

- when forming a multicriteria assessment, it is possible to use both quantitative and qualitative indicators;
- when forecasting the initial parameters from experts, it is not required to generate point probabilistic estimates, it is sufficient to specify the calculated range of values of the predicted parameters;
- the methodology provides an excellent opportunity to formalize human utterances in a way that is suitable for computer processing, i.e. in the form of schemes, graphs, formulas in modern software environments, for example, such as MATLAB.

Technical re-equipment of enterprises and industrial complexes allows their owners to save significantly in the future due to the use of modern production technologies, by reducing the magnitude of the costs of production and increase of production volume, high demand, allows to obtain a stable income.

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