# Application of the Data Envelopment Analysis method for estimation the performance of enterprises in the fuel and energy complex

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**Abstract.** The article proposes the DEA method for solving the problem of estimation the efficiency of the heat supply system in Krasnoyarsk, various enterprises providing heat supply services. The architecture of the universal DSS has been modified into the architecture using the DEA method.The application of DSS with such an architecture made it possible to make more informed decisions regarding the estimation of the enterprise's safety with respect to the environment. The article also shows theefficiency of the DEA method in solving the problem of estimation the efficiency of the heating system in Krasnoyarsk. The features of using this method in decision support systems are given.

## 1. Introduction

It is very important to estimate its efficiency to manage an organization of any type. This is due to the fact that efficiency characterizes the quality of the organization's activities, and, consequently, its viability. This concept depends on the degree of the goal achievement, taking into account the costs (resources, time) and the scope of its application. On this basis, the efficiency of functioning will have a certain sense depending on the goal and the model of estimation.

In solving practical problems of management, the analysis of the efficiency of complex systems is widespread because the study of the operation efficiency allows increasing the efficiency of planning and management in various fields of human activity. Data Envelopment Analysis (DEA) is one of such methods.

## 2. Materials and methods

The Data Envelopment Analysis (DEA) method is a rather popular tool for the estimation the efficiency of complex systems. This method appeared in 1978 and it was developed by American scientists A. Charnes, W. W. Cooper, E. Rhodes [1]. The DEA is based on a non-parametric methodology, because no any forms of production function are defined. DEA refers to boundary methods.This is due to the fact that the method is based on the development of the efficiency boundary and the analysis of objects located relative to this boundary [1]. This method is, in fact, a way to estimate the production function, that is unknown in practical reality. The DEA method is based on the development of the so-called efficiency boundary. It is an analogue of the production function for the case when an output is not scalar, but vector.This boundary has the form of a convex hull or a convex cone in the space of input and output variables that describe each object in the studied population. The efficiency limit is used as a reference for obtaining the numerical value of the efficiency indicator of each of the evaluated objects. The degree of the object's efficiency is determined by the degree of their proximity to the efficiency boundary in the multidimensional space of inputs / outputs. The method of developing the efficiency boundary is a multiple solution to the linear programming problem [1].

The DEA model is divided into 2 types depending on the orientation [2]:

1. The input-oriented model

At the output we have a product - y, and it is necessary to use two types of resources for the manufacturing of this product, i.e., inputs $x_1$ and $x_2$.

2. The output-oriented model.

At the output we have two products -inputsy$_1$ and $y_2$, and it is necessary to use one input resource – x for the manufacturing these products.

The efficiency value of the DEA model is calculated by the formula [2]:

$$0 \leq \text{Efficiency}_Z = \frac{0Z1}{0Z} \leq 1$$

Its value is always in the range from 0 to 1.

## 3. The efficiency of the enterprise study based on the DEA method

Consider a decision support system (DSS) to develop an effective performance estimation model. DSS is a set of data processing procedures and statements that help a manager in decision making based on the application of models [3].

DSS solves two main tasks:

1. Optimization is a choice of the best solution from a variety of possible solutions.
2. Ranking is streamlining possible solutions by preference.

The important point here is a choice of alternatives, that is, a set of specific criteria according to which the decisions will be estimated and compared.

DSS focuses on individual problems of decision-making and in most cases it is based on the individual work.

Consider the standard DSS diagram. A diagram of a typical DSS is presented in Figure 1.

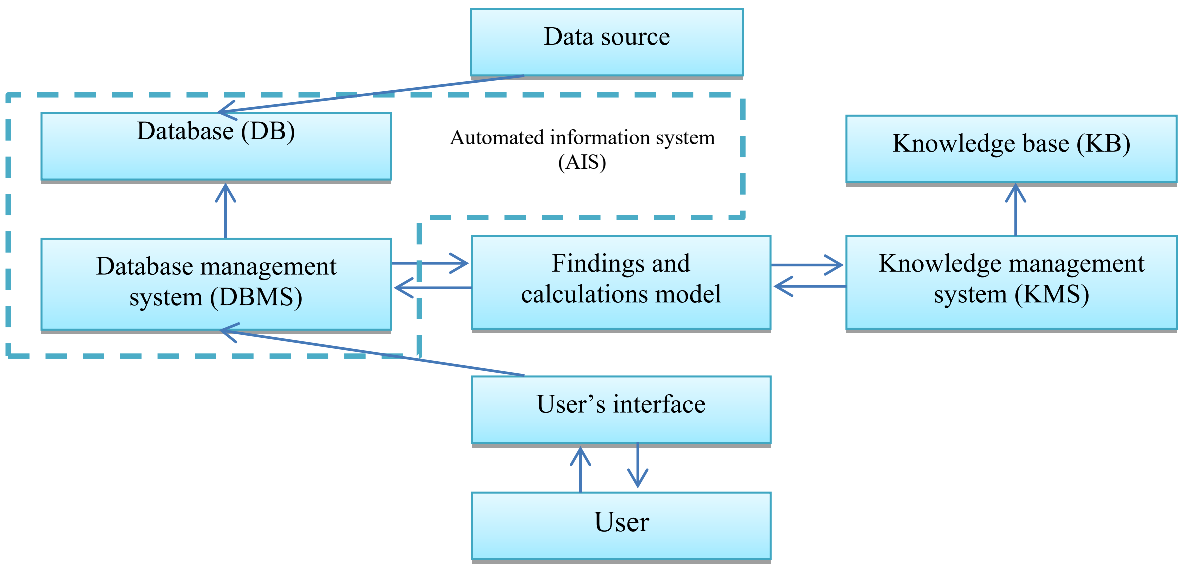

**Figure 1.**Diagram of a typical DSS.

First it is necessary to formulate the functions of the DSS architecture before its development. The main functions of the DSS in our case, for the sake of which is being created, will be [4]:

- estimation of the current state of a complex system;
- recommendations to achieve certain values of indicators describing the state of the system and its subsystems.

DSS should perform some auxiliary functions, including [4]:

- assisting linear programming (LP) in selecting input and output variables for DEA models;
- preliminary processing and preparation of the initial data;
- visualization of the results of the DSS operation in the visual form;
- organization of data exchange with other systems (conversion of source data presented in other formats, i.e., export and import of data).

In designing a DSS according to the given function, we modify the diagram of a typical DSS and use the DEA method as the main operating tool. The DSS will consist of several functional subsystems shown in Figure 1 [5].

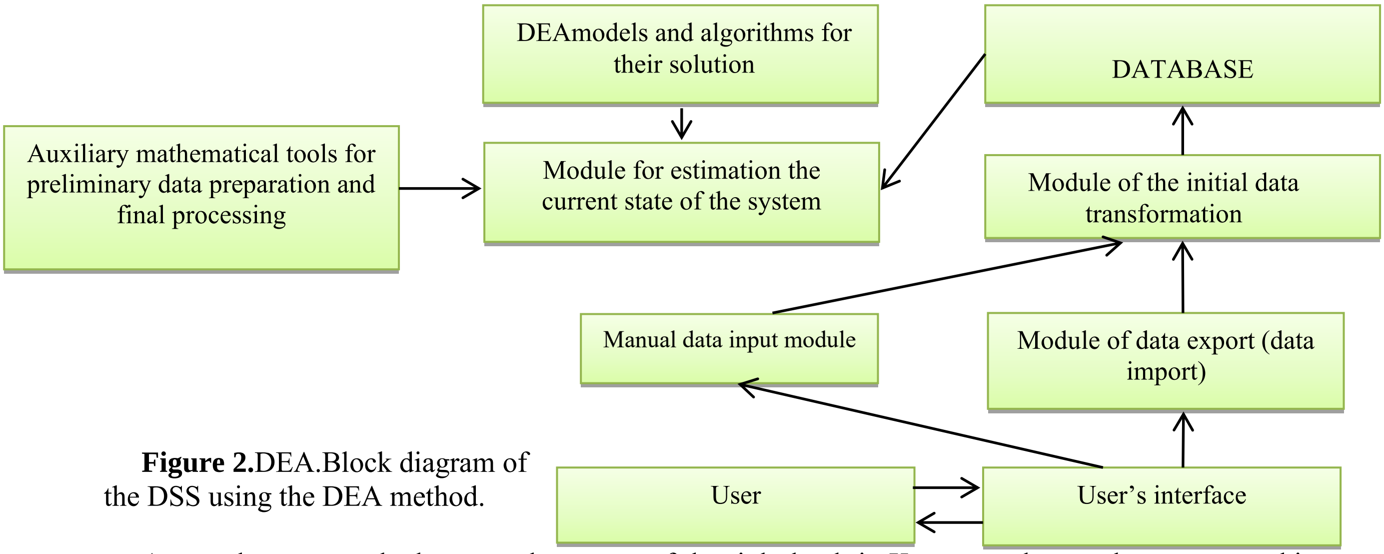


**Figure 2.**DEA.Block diagram of the DSS using the DEA method.

A complex system the heat supply system of the right bank in Krasnoyarsk was chosen to test this method.

The concept of a complex system does not have a strict specific definition. But in general terms, one can say that a complex system is a system that includes some components (subsystems) interacting with each other [6].

Here are some features, but not formal signs of a complex system:

1. The absence of a mathematical description and the need for it.
2. Stochastic behavior or “Noisy”. This feature is due both to the presence of random noise generators and to a large number of secondary processes.

3. “Intolerance” to management. The system has its own goal, and management has its owngoal.

4. The non-stationarity of a complex system is manifested in the drift of its characteristics, change of parameters, evolution over time.

5. Irreproducibility of experiments with it.

The Data Envelopment Analysis Program (DEAP) software developed at the University of New England in Australia by Professor T. Coelli was applied to obtain results [1].

On the basis of the project [7] "The scheme of heat supply of the Krasnoyarsk city until 2033" four boiler-house heating systems of the right bank of the city were selected. Also, indicators for boiler houses for 2018 were highlighted; a sample was formed necessary to solve the problem of estimating the efficiency of the system based on the DEA methodology [8].

In this study we will use the DEA model, focused on the output of the problem with one input and two outputs.

Table 1 given below contains the information about the source data, i.e., Decision Making Unit (DMU) with one input and two outputs. The last column of the Table 1 contains the deviation of the output indicator from the threshold value. For the threshold we take the value equal to 22000.0 thousand tons per year.

**Table 1.**Initialdata - DMU List, inputs and outputs

| № DMU | Name of DMU | INPUT (x) | OUTPUT (y) | | |
|---|---|---|---|---|---|
| | | Available thermal power, Gcal / hour | Heat supply to the grid, thousand Gcal per year | Mass of emission, thous. Tons per year | Mass of emission (deviation from the threshold) |
| 1 | Object №1 | 1464,00 | 3531,00 | 21165,6953 | 834,3047 |
| 2 | Object №2 | 1405,00 | 3470,00 | 18218,3039 | 3781,696 |
| 3 | Object №3 | 153,20 | 423,39 | 6789,9520 | 15210,05 |
| 4 | Object №4 | 339,85 | 795,6 | 6431,6010 | 15568,4 |

We have a goal to increase the output without increasing the input, i.e., with a certain power of equipment of each DMU, we need to increase the amount of energy supplied to the network, as well as reduce the emissions.

In accordance with the goal we will solve the exit-oriented problem.

The projection of an inefficient object on the border of efficiency is a hypothetical object. A hypothetical object is formed as a linear combination of one or more efficient objects; these objects are otherwise called reference ones. Each object has its own weighting factor and it is a component of a linear combination [9].

According to the results of this study, we will organize Table 2. It will contain the values of the recommended values of indicators for all the enterprises under consideration. If the performance indicator is equal to one, then this value coincides with the recommended. Paying attention to the last column of Table 2, one can notify that the change in indicators for different inputs or outputs for the same DMU will not be the same. This is explained by the fact that sometimes there is a need for not only a proportional increase in values, but also an additional increase not in the same proportions [10,11].

**Table2.**Initial and recommended values of indicators

| № | Devision(DMU) | Efficiency indicators |
|---|---|---|

| | Inputs and outputs | Iitial values | Recommended values | Difference between values | Difference in % |
|---|---|---|---|---|---|
| 1 | Object №1 | 1 | - | - | - |
| | Availablecapacity of the equipment | 1464 | 1464 | 0 | 0% |
| | Heat supply to the grid | 3531 | 3531 | 0 | 0% |
| | Mass of emission | 834,3047 | 834,3047 | 0 | 0% |
| 2 | Object №2 | 1 | - | - | - |
| | Availablecapacity of the equipment | 1405 | 1405 | 0 | 0% |
| | Heat supply to the grid | 3470 | 3470 | 0 | 0% |
| | Mass of emission | 3781,696 | 3781,696 | 0 | 0% |
| 3 | Object №3 | 0,948 | - | - | - |
| | Availablecapacity of the equipment | 153,2 | 153,2 | 0 | 0% |
| | Heat supply to the grid | 423,39 | 446,387 | 22,997 | 5,4% |
| | Mass of emission | 15210,05 | 19400,232 | 4190,182 | 27,5% |
| 4 | Object №4 | 0,902 | - | - | - |
| | Availablecapacity of the equipment | 339,85 | 339,85 | 0 | 0% |
| | Heat supply to the grid | 795,6 | 881,735 | 86,135 | 11% |
| | Mass of emission | 15568,4 | 17253,905 | 1685,505 | 10,8% |

It can be concluded that object No. 1 and object No. 2 of the heat supply system in Krasnoyarsk operate most effectively based on the research data presented in Table 2. Their performance indicator is the maximum of the possible values and is equal to 1. Object No. 3 has a performance indicator of 0.948. And object No. 4 has the lowest performance efficiency; it is 0.902, and, accordingly, is the least efficient object of the heat supply system in Krasnoyarsk.

## 4. Conclusion

The given article proposes the setting up the DEA method to solve the problem of estimating the efficiency of the heating supply system in Krasnoyarsk, in particular, to estimate the level of harmful substances released into the environment from various enterprises providing heat supply services.

The architecture of the universal DSS has been modified into the architecture using the DEA method. It reflects the structure of the object interconnections. The use of DSS with such an architecture will make it possible to make more informed decisions regarding the estimation of the enterprise's safety with respect to the environment, and, in general, regarding the performance of the enterprise.

The efficiency of the DEA method in solving problems is given. The features of using this method in decision support systems are shown.

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