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RESEARCHING THE EFFICIENCY AND FUNCTIONALITY OF BUSINESS SYSTEMS USING STATISTICAL AND DEA ANALYSES

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Abstract: *In this paper, the authors investigated aspects of whether DEA can shed light on relative DMU performance issues with identified, conceptually key input and output parameters and performance measures for representative DMUs of a business system. In this regard, the CCR and BCC models were applied at the level of representative examples. The CCR model is probably the most widely used in DEA analyses. It is also the most famous model based on the assumption of constant returns, which means that every feasible activity (k, i) implies the feasibility of activity (kt, it) for every positive number t. This model measures overall technical efficiency. The BCC model is used, in DEA, in the case of increasing or decreasing returns, when the change in the input variable is proportional (more or less) to the increase in output. This model measures purely technical efficiency (the efficiency* *measure is independent of business volume) by comparing the jth DMU unit only with units of similar size in a technical context.*

The authors were aware that an implicit assumption in DEA is that there necessarily exists some relationship between inputs and outputs.

Companies or subsidiaries (DMUs) can show high input productivity and very successful managerial performance in organizing appropriate inputs in the relevant production processes. The situation is presented in which, when companies operate with constant returns to scale (CRS) throughout the observed period, it can be concluded that the size of the company is optimal.

Specific research, related to surveys and tests, described in this paper, deals with the efficiency of DMU groups (constituent decision-making units within business systems or supply chains). There are aspects of economies of scale, allocative inefficiency and input reengineering in production systems (as well as analysis of changes in productivity, impact of key variables on productivity, efficiency and functionality) according to the adequacy of identified production and business functions of the company.

The research results are presented in tabular and graphical form.

Keywords: *business systems, DEA, DMU, CCR, BCC, CRS, VRS, SE, statistical tests, functionality, efficiency, composite indicators, production, productivity*

INTRODUCTION

In the analysis of the efficiency of the company and its constitutive organizational units, DEA and complementary statistical analyzes are most often used today. Data envelopment analysis (DEA method), sometimes called frontier analysis, was first defined by Charnes, Cooper and Rhodes (1978).

The principles of efficiency and effectiveness are still the most important in measuring and analyzing economic effects with the possibility of maximizing income and/or profit with as little economic investment as possible. DEA as a non-parametric analysis of the efficiency of multiple units (DMU - decision-making unit) of a company or business system (conventionally speaking, DMU can be at the level of one company with operations in different time periods, it can also be at the level of regions, local communities or countries) . Large companies and SMEs can be DMUs e.g. in bus transport, transport-logistics systems, supply chains, tourism organizations or insurance companies, where the economy of scale of service production is important. Large companies, in the economy of scale, have an advantage over SMEs, hence works such as (Ćiraković, Bojović and Milenković, 2014), with the application of DEA, indicated the necessity that SMEs in the transport sector must be reorganized and technologically redesigned. In the business of insurance companies, the authors analyzed works such as (Đurić, Z., Jakšić, M., Krstić, A., 2020), where the situation in Serbia was analyzed using DEA, and (Micajkova, 2015), where the efficiency of Macedonian insurance companies with DEA access was analyzed.

An overview of the research of other authors can be represented at the level of several representative researches and corresponding author's works.

DEA, as a technique for identifying and measuring company performance, is very important in assessing the relative efficiency of decision-making units in parent organizations (DMU - Relative efficiency of decision-making units - DMU's), prema (Radosavljević,M. et al., 2022).

The authors consider the obvious fact that there are many more unpublished studies (eg studies and analysis done internally by companies or by external consultants for the needs of certain firms). More about DEA can be found in the complementary literature (Jiyoung Lee and Gyunghyun Choi, 2019), (Lin eta al., 2015), (Emrouznejad et al., 2018), (Međurečan, 2019),(Micajkova, 2015), (Đurić,Z., Jakšić,M., Krstić,A., 2020) etc.

The flexible structure of DEA, for example, facilitates its application in a wide variety of situations where insufficient information or guidance may preclude the use of parametric methods. The developed statistical tests significantly contribute to the reliability of management and production implications at the level of advanced DEA studies that have an increasing application of DEA in practice.

1. BASIC THEORETICAL RELATIONS

There are many models for analyzing the effectiveness of an entity depending on the available data, environmental conditions or specific management requirements. The basic equations start from the basic formula for calculating efficiency, which boils down to the following,

$$Efikasnost = \frac{Output(izlazniparametri)}{Input(ulazniparametri)}$$

DEA-based results must be valid and correctly interpreted. Definitely, the results must be applicable in real practice, in accordance with the relevant principles and algorithms regarding the application of DEA. The basic principles are given in (Bowlin, 1998). Within each phase of DEA analysis, some basic principles and rules that must be followed can be defined.

The results obtained by solving one of the models will be valid if the model fulfills some basic properties such as homogeneity, positivity, isotonicity, eliminability of Outliers, number of DMUs according to (Jiyoung Lee and Gyunghyun Choi, 2019) and (Savić and Martić, 2019).

The characteristic of positivity. When formulating a DEA model, input/output values are required to be greater than or equal to zero. The relative efficiency, that is, the efficiency index (based on the sum of the products of the weighting coefficients and input or output values) should be as high as possible.[1]

1 https://slidetodoc.com/matematiki-modeli-efikasnosti-dr-gordana-savic-gocafon-bg-2/(pristup:17.06.2022)

Weighted factor control. Weighted factors are determined by resolving DEA models. Each weight is calculated so as to show the observed in the best light relative to the other DMUs of the observed set.

Homogeneity of DMU. Here, with the DEA concept, a relatively homogeneous set of entities is required, in connection with the convenient use of the same inputs for the production of the corresponding outputs (their values must always be positive).

Each DEA software should consist of the following modules:[2]

- Data management;
- Model selection;
- Troubleshooting;
- Generating reports.

According to (Cooper et al., 2000), the primary concept of DMU performance measurement is formalized in the form of a mathematical model at the level of linear programming (Međurečan, 2019). The DEA problem can be illustrated by the following mathematical expressions:

$$\max h_0 = \sum_{j=1}^{n} u_j Y_{jk0} \qquad (1)$$

Where is,

$$\sum_{i=1}^{m} v_i X_{ik0} = 1 \qquad (2)$$

$$\sum_{j=1}^{n} u_j Y_{jk0} \leq \sum_{i=1}^{m} v_i X_{ik0} \qquad (3)$$

Where is:

- k - number of decision making units (DMU;);
- m – number of inputs (inputa;);
- n – number of outputs (output;);
- u – output weighted coefficient;
- v – input weighted coefficient.

In order to understand the essence, basic efficiency models will be presented at the level: CCR and BCC models. These models are named after the initials of their authors (CCR[3],, after Charnes-Cooper-Rhodes; BCC[4], after Banker-Charnes-Cooper). The basic difference between the CCR (total technical efficiency) and BCC (pure technical efficiency) models consists in the assumed transformation of inputs into outputs. [5]

2 Ibid;

3 The model was first promoted by the authors: Charnes, Cooper and Rhodes (1978) in an article published in a journal "European Journal of Operational Research", vol. 2, br. 6, pp.429–444.

4 (Banker, Charnes and Cooper, 1984). Management Science (1984, Vol. 30/9, pp.1078-1092).

5 Bogović,T. (2014). Ocjena učinkovitosti upravljanja hrvatskim gradovima metodom omeđivanja podataka (AOMP), Varaždin, Fakultet organizacije i informatike.

CCR model. This is actually the basic model that is probably the most used in DEA analyses. It is also the best-known model based on the assumption of constant returns, which means that every feasible activity (x,y) entails the feasibility of activity (xt,yt) for every positive number t.

A virtual input and output is created for each DMU. At the start, the weighted coefficients are still unknown (:

$$Virtual\ input = v1X1o+...+VmXmoVirtualoutput = u1Y1o+...+usYso.$$

After determining the input and output, the weight coefficient is determined using linear programming to maximize the value of the ratio:

$$E = \frac{Virtuelniizlaz}{Virtuelniulaz} \quad (4)$$

The optimal weightied ratio varies with DMUs. Therefore, the "weighted coefficients" in DEA analysis are derived from the data, and are not known in advance. The CCR model (Constant return to scale CRS) calculates the total efficiency for each DMU, which includes the sum of pure technical efficiency and business volume efficiency. In the DEA model, the efficiency is maximized for each DMU, so that each variable of the selected indicators is assigned the weighted coefficient that best suits that variable (or the ratio of sizes, e.g. at the level of productivity by programs and employees). When the optimal (most favorable) weighted coefficients for each variable are established and assigned, virtual inputs and outputs are obtained. Now it is possible to apply equation (4).

All weighted coefficients must be non-negative (w_l≥0). There is a limitation, the maximum efficiency of the DMU cannot be greater than 1. Otherwise, there is also a concept of super efficiency (SE-Super efficiency) where the expression virtual output/virtual input can have E>1. The CCR model is therefore applied for each DMU, with the aim of finding the optimum of each DMU, which can be expressed as:

$$\max h_k = \sum_{j=1}^{n} u_j Y_{jk} \, / \sum_{i=1}^{m} v_i X_{ik} \quad (5)$$

Where as,

$$\sum_{j=1}^{n} u_j Y_{jk} \leq \sum_{i=1}^{m} v_i X_{ik} \quad (6)$$

$$\sum_{j=1}^{n} u_j Y_{jk} \, / \sum_{i=1}^{m} v_i X_{ik} \leq 1 \quad (7)$$

Where as:[6]

- h_k – relative effectiveness of kth DMU
- k – number of decision making units

6 Ibid;

- m – number of inputs (X)
- n – number of outputs (Y)
- v – weighted coefficient of input (X)
- u – weighted coefficient of output (Y)
- ε – small positive value (most often it is =10-6)[7]

For *kth* DMU, we search for E_{max} with the condition that the weighted sum of the output is less than the weighted sum of the input, from which it follows, $0 < h_k \leq 1$. The sums can vary:

- for $h_k = 1$, $k - th\ DMU_k$ is relatively efficient;
- for $h_k < 1$, $k - th\ DMU_k$ is relatively non-efficient.

The value of h_k gives an indication of how much it is necessary to relatively rationalize the consumption of resources (including the optimal use of employees) or to increase the overall business results in order to make DMU_k more efficient[8]

Efficient DMUs define the efficiency limit, which is shown as a line in the CCR model due to the assumption of constant returns.

Inefficient units are located below the efficiency frontier (convex line), and their projection onto the efficiency frontier is achieved by reducing inputs or increasing outputs.

BCC model. In DEA, this model measures purely technical efficiency (an efficiency measure that ignores the impact of business volume) by comparing the jth unit of the DMU only with units of similar volume in a technical context. The following equations apply here,

$$\max h_k = \sum_{j=1}^{n} u_j Y_{jk} + u_0 \quad (8)$$

$$\sum_{i=1}^{m} v_i X_{ik} = 1 \quad (9)$$

$$\sum_{j=1}^{n} u_j Y_{jk} - \sum_{i=1}^{m} v_i X_{ik} + u_0 \leq 0; k = 1,2, \dots, n \quad (10)$$

While ,

j≥ε,j=1,2,...,nivi≥ε,i=1,2,...,m

Where as:[9]

- h_k – efficiency result of the kth unit of DMU,
- y_j – represent the jth output of the kth DMU,
- x_i - weighted coefficient of the ith input
- u_j - weighted coefficient of the jth output,
- n – number of outputs

7 Ibid;
8 Ibid;
9 Ibid;

- m – number of inputs
- u_0 - an additional variable that defines the impact of business volume (Međurečan, 2019).

BCC serves to analyze the efficiency of DMUs that achieve variable returns in relation to volume (VRS - Variable return to scale), and the efficiency borderline is then a convex curve (Đurić, Z., Jakšić, M., Krstić, A., 2020), (Međurečan, 2019).

For DMU units that define the efficiency limit, an additional variable defines the nature of the business according to the following (Međurečan, 2019):

- if $u_0 = 0$ then the BCC model is reduced to the CCR model, and the corresponding unit DMUk acts with a constant return on the volume of business;
- if $u_0 \leq 0$, DMUk operates with a non-diminishing return on business volume and
- if $u_0 \geq 0$, DMUk operates with a non-growing return on business volume.

It is noted that, by comparing the networks generated through the DEA application process, information about the actual distribution of effective DMs can be understood. Such research introduces three ways of expressing the relationship of DMUs in a network form:

- impact network (weight network);
- superiority (mreža jaza, gap network);
- domination (weighted-gap network).

In a typical DEA study, the efficiency score and benchmarking results are usually presented in table or text form. By analyzing multi-period trends in competitiveness and positional characteristics of DMUs, it is also possible to measure the sustainability of performance (application of "panel data"). Performance sustainability could become a new feature, alongside superiority and impact.

2. BASIS FOR DEFINING AND EVALUATING CRITERIA FOR ASSESSING THE EFFICIENCY AND EFFECTIVENESS OF DMU

The decision on the selection of criteria for referencing the efficiency and effectiveness of DMU is a complex concept, model and procedure, related to the domain of strategic planning. Solving a series of complex questions in the subject research framework concerns management theory, decision theory, decision support systems, expert systems, and of course, the issue of knowing the basic real system and its interaction with the environment (at the level of DMU and their connection).

Today, there are already tested mathematical-computer tools, as well as program packages and software that (collectively called models or decision support systems). The decision-making method is concerned with the type of problem and the amount of available information that describes it. In order to make a decision on the selection of criteria for the efficiency and effectiveness of DMU, it is necessary to evaluate variant solutions. The widely identified spectrum of criteria, in most cases, very often concerns their mutual conflict. Hence, as a rule, the problem is solved by the multi-criteria decision-making method (eg FAHP). Criteria can be classified into groups such as: resource criteria, financial criteria, operational criteria (functioning criteria), criteria regarding the quality of services and security, etc. Managers, as a rule, follow the partial activities and processes of the DMU and, with the help of the mentioned criteria, get a certain picture of the functioning of the integral business system, but it is necessary to define an integration measure that unites all these criteria. Only with such a measure could a more comprehensive picture of the functioning of the system be obtained, which should serve the purpose of defining appropriate measures (corrective and preventive), plans and business-production actions.

Perhaps it is best to give our determination as authors on this matter at the outset. Efficiency, productivity, functionality and effectiveness are purely functions of representative organizational, production, economic and management parameters that concern the realization of overall quality and the realization of the performance of business systems through the realization of programs, projects, products and services. The permanent task of the company remains in force, regarding the maximization of business performance, which concerns the maximization of income, profit, satisfaction of all stakeholders and the minimization of costs and losses in functioning and business.

In this research, the main hypothesis was set,

Hg: The overall quality of the company is directly reflected through the functionality, efficiency, productivity and effectiveness of the organization.

In the subject sense, it was necessary to prove the functional dependence of the overall quality of the company (not only technical quality, and especially not only through purely technical efficiency - BCC) depending on the representative parameters of both input and output, while considering the correlation of quality and each of the key parameters. Everything, in a very convenient way, is presented below, at the level of the model and the results of the analysis. Great importance was given to these considerations by the statistical processing of results from the field (in accordance with the conducted surveys), where immediate answers were obtained regarding managerial, economic and functional parameters as well as parameters regarding the overall quality of business systems (at the level of QMS and TQM), according to (Šegrt, S., 2022a), (Šegrt, S., 2022b) i (Radosavljević, M. et al., 2022). All the obtained results represent a correct, modest but recognizable contribution to research at the level of complementary non-parametric and parametric analyses, i.e. at the level of combining models based on DEA principles and widely accepted statistical models in connection with applied functions (in these calculations, appropriate Excel functions were used). Subject functional dependencies and obtained results in a good and obviously possible way (with significant simplifications) reflect the algorithmic management of the calculation process and the logical order of the obtained process results, from the input to the final results and appropriate conclusions with recommendations on what and how to proceed.

Auxiliary hypotheses are set as follows,

- H1: There is a direct correlation, regarding quality, between efficiency and productivity.
- H2: There is a direct correlation, regarding quality, between efficiency and functionality.
- H3: There is a direct correlation, regarding quality, between efficiency and effectiveness.

Research into the efficiency and functionality of business systems using statistical and DEA analyses, is focused first on the identification of the most important variables (KBF - key business factors) and their functions at the level of initiating the process and during the implementation of the integrated process with all transformations (that is, at the level of input and output), in accordance with the application of DEA, and then, with the provision of a significant database at the level of recorded real indicators regarding the respective conditions and processes, the application of suitable statistical methods to directly determine the degree of their importance for each DMU, as well as at the level of the business system as a whole. Therefore, in addition to efficiency (DEA), correlations, reliability, risks and weight coefficients should be established through which gradients (or marginal values) of the contribution of each DMU can be viewed, at the level of identified efficiencies (for the considered inputs and outputs in accordance with the included parameters and functions) of interest for improving the overall efficiency of the company's organization and operations.

On the considered examples, the authors will show the high sensitivity of efficiency to changes in inputs and outputs, so that, at the level of a sufficiently large statistical sample, an error in the calculation of certain derived functional values of ratio analysis (e.g., at the level of ratio numbers in regarding profitability, liquidity, profitability of total assets - ROA, rate of return on equity capital - ROE, rate of return on total assets - ROA, return on investment - ROI, etc. At the DEA level, the ratio of capital and total capital can also be explained - leverage, cash flow and productivity, scale efficiency – SE, return to scale (CRS, VRS, DRS, IRS) etc.

There are many different, but complementary, analyzes that serve for an integral overview of the company's business parameters, for example:

1. Ratio analysis of liquidity and financial structure;
2. Ratio analysis of business activity (turnover ratio) and profitability (profitability);
3. Share market value ratio, risk and leverage.

Or there are parameters important at the level of business decision-making cases such as:

1. Pricing policy;
2. Selection of the product range;
3. Special orders, etc.

Financial business management, in itself, requires expansion of tools for data identification, monitoring and processing of business results.[10]

10 Kaplan,R., Norton,D. (1997). Using the Balanced Scorecard as a Strategic Managment System, Harvard Business Review. pp. 75–85.

Therefore, it is clear why there are more indicators that determine the results of the business and management of the company (they directly depend on the management). Based on relevant data from the relevant financial reports, as well as on the basis of other market indicators and non-economic indicators, it is possible to clearly determine the company's performance and make decisions about where and how to proceed, and what to do to achieve realistic plans. The importance of the mentioned indicators is especially emphasized when evaluating the success of management, since they directly affect the creation of conditions for rewarding and earning employees (motivation and stimulation of all employees, including management.

ROI (Return On Investment) provides management, owners and creditors with a convenient performance evaluation tool. [11] So, it's about the relationship between profit and investments that generate profit, it's actually one of the most commonly used business indicators. ROI allows management to determine appropriate valuations for various capital investment opportunities.

Lenders and owners use ROI to do the following:

1. Assess the company's ability to earn an appropriate rate of return. They can benchmark a company's ROI against other companies or against industry norms in developed economies around the world. ROI provides information about the financial health of the company.
2. Provide information on management efficiency.
3. Argumentatively set plans and project future earnings.

Managers use ROI for the following:

1. Performance measurement of organizational units, individual parts of the company as investment centers, or DMU (decision-making unit; in DEA application). At the DMU level, both profit and investment basis (volume, scale) can be controlled. ROI is a fundamental tool used to evaluate both profitability and key performance.
2. Estimates of proposals for capital expenditures (capital budgeting is the process of deciding which long-term investments or projects the company will accept to finance or invest in their development)[12]. Here, capital budgeting based on discounted cash flow should be taken into account.
3. It helps in setting management goals (defining the budget and setting goals more effectively). Most budgeting processes begin and end with a target ROI.

Therefore, in this paper, there will be examples that have as inputs (for each DMU) the number of employees, assets or fixed assets, capital, etc., and as outputs have the number of transactions, number of clients, revenues and profits of the company. However, since in DEA, in order to obtain objective results of efficiency (CCR, BCC), normalized values (reduced to appropriate reference values, maximums or optimums) must be observed,

11 Kaplan,R., Norton,D. (2001). Transforming the Balanced Scorecard from Performance Measurment to Strategic Management. Accounting Horizonts. (2001), pp. 87–104.

12 Ibid;

this will most often be done instead of specific units (number of employees, number of customers, number of processed orders, number of transactions, monetary units or some other physical quantities) in DEA analyses, at the level of input and output, appear dimensionless values (or in the domain 0.00 to 1.00; or at the level of percentages, 0.00% to 100%), and in the case of derived efficiencies (CCR – total technical efficiency or BCC – pure technical efficiency) it is possible that these values will be outside the range [0,1], e.g. in the case of super efficiency they can be $E_{s.eff} > 1,0$.

Due to the nature of the problems under consideration, e.g. at the level of production, very often the relativized values of input or output will be observed, e.g. as an input instead of the number of employees and fixed assets, one derived input can be viewed as a specific asset value (Assets/Average number of employees: ratio of assets and average number of employees in the period based on the balance at the end of the month), then at the level of Assets/Capital: ratio of the total funds and capital of the company, or, at the level of the book value of the share, which is obtained as a quotient of the book value of the capital and the total number of shares of the company, etc. [13] Productivity can be used for output (number of products per employee, number of transactions per employee, revenue per employee, profit per employee, etc.).

And in the case of derived specific indicators (or composite indicators), their normalized amount will be applied. So, if for the derived input, Xi=EUR/employee is obtained, then the normalized form will be derived according to some benchmark or company capacity, e.g. such as,

$$\bar{X_i} = \frac{X_i}{X_{max}} = \frac{\frac{EUR}{br.zap.}}{(\frac{EUR}{br.zap.})_{max}}$$

Determination of composite indicators based on DEA models is a very common case. Composite indicators are used for mutual comparison of areas, i.e. they can be applied in measuring the performance of countries as when comparing complex problems in various fields (environment, economy, society or technological progress). [14] Sometimes these indicators are easier to understand than the trends of several different indicators. They have proven to be suitable for assessing the country's progress, in accordance with the direction in which its respective policies are moving. Composite indicators of course also have drawbacks, and can send a problematic (inadequate) message to the public if they are poorly constructed or misinterpreted.

Composite indicators serve as a tool to initiate discussion and improve public interest. Their relevance would have to be assessed in relation to the units (DMU) that make up the composite index. A composite index is normally formed when individual indicators

13 https://www.blberza.com/pages/DocView.aspx?page=SP34 (Banjalučka berza, 2021).

14 Ibid;

are combined into a single index based on a base model (here, the DEA model). Along with these indicators, it should be possible to measure (specifically in DEA, the measurement of relative efficiency) a multidimensional model that cannot be captured by a single indicator (eg competitiveness, industrialization, sustainability, innovation, etc.). [15]

The analysis can also be performed with the inclusion of "Altman Z-Score", as one of the most well-known summary indicators that can be calculated based on data from financial reports. It is actually "Altman's indicator of financial insecurity" (Financial Distress Ratios), which is a weighted sum of several individual indicators. Based on the weighted sum, the "financial health" of the company is assessed, [16] in accordance with the formula,

$$\sum_{i=1}^{5} Ai\ Xi = 1{,}2X1+1{,}4X2+3{,}3X3+0{,}6X4+1X5$$

- X1= (Total current assets - Total short-term liabilities)/Total assets;
- X2= Retained Earnings/Total Assets;
- X3= Profit from regular operations/Total funds;
- X4= Market capitalization/Total liabilities;
- X5= Total Income/Total Assets.

Based on this weighted sum, the company's financial condition is assessed. A higher sum means greater financial stability of the company. Conversely, a lower sum warns of possible financial difficulties. On the basis of empirical research, it has been established that companies where this sum is greater than 3.00 are very stable (more precisely, there is no risk of bankruptcy for such companies). The size of the sum in the domain [1.81, 2.99] is the so-called "gray zone". When the sum in question is less than 1.81, it means that the company has significant financial difficulties and is very likely going bankrupt.[17] It goes without saying that this sum cannot be a negative number.

Costs can also be monitored through economy (E), as a complex economy or at the level of change in the economy coefficient. such as the ratio of elements that expresses the real level of the economic state of the concrete economic system, measured by the degree of satisfaction of the principle of economy. It represents the content of the complex and is determined by the ratio of produced and consumed values:

$$E = V / T$$

where V is the product value and T is the consumed value. Thus, E concerns the essence of the value produced and the values consumed for that production. Economic referencing can be achieved at the level of the economic coefficient (which is monitored by years of operation) and/or the economic change coefficient as the ratio of the current and previous year's economic efficiency,

15 Ibid;
16 Ibid;
17 Ibid;

$$K_{p.e.} = E_{t.g.} / E_{p.g.}$$

in acccordance with Figure 1.

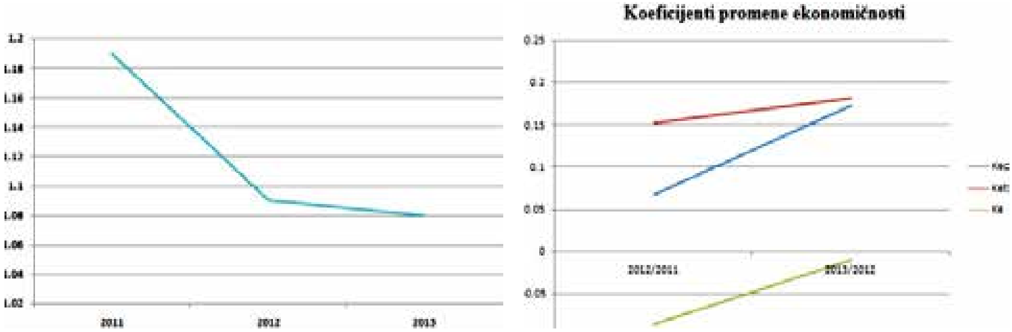

Figure 1. Coefficients of economy and changes in economy

Cost reduction contributes to increased economy. Sources of economy practically explain why some companies are more cost-effective than others.

Therefore, if a task is set with the object of researching the relationship between quality (the overall quality of the company; it can also be based on the concept of TQM) and other parameters of the company's operations (at the level of input and output), then the focus must be directed to the input related to:

- number of employees;
- quality;
- assets;
- capital (primarily intellectual capital);
- as well as to the output regarding the following:
  - productivity;
  - functionality;
  - income;
  - economy (related to cost reduction);
  - profit;
  - profitability;
  - effectiveness and
  - profitability.

To evaluate the efficiency of DMU, using DEA, it will often be quite sufficient for the following to appear at the input level: number of employees, assets and capital (intellectual capital), and for the output level to appear: productivity, income and profit (profit is the difference between income and costs).

The ability to properly manage the enterprise, with the correct market navigation, refers to the activities of the business system to be ahead of all competitors (basically everything leads to the desired profit). Profit (but not only profit) drives the company to improve production, attract investment, expand programs, increase the number of jobs and increase production. This is how the company and the economy of the country as a whole develop.

With arithmetic profit (the difference between income and costs), the return is always considered equal while the costs are different, so the end result is shown in different ways (normal profit, average profit). From an accounting point of view, profit is calculated according to documentation, taking into account all income and expenses. If all implicit costs are subtracted from this category, the net economic income is obtained.[18]

Data envelopment analysis (DEA) is a deterministic method for aggregating multi-dimensional measures and subsequent analysis of efficiency. However, due to its inherent determinism, it reacts sensitively to deviations in data sets. Existing methods for identifying such exceptions have two main drawbacks. First, from a more conceptual point of view, a single definition of an outlier is lacking. Second, there are technical drawbacks to each method. For example, the user must set arbitrarily bounded values, such as the amount of efficiency values beyond which the decision-making unit is considered an outlier. This paper initially presents a definition of outliers, which explicitly takes into account the specificities of DEA. Based on this definition, an approach for identifying outliers in DEA is introduced that explicitly deals with technical deficiencies and takes them into account in the developed algorithm. The credibility of this approach is confirmed on the basis of empirical examples from performance measurement at the university level.

We will further provide a brief overview of DEA, mathematical models of efficiency and the choice of DMU (decision making unit).[19]

Basically, you need to understand the basics of DEA analysis and consider some relevant aspects such as: business analytics; measuring the efficiency of business systems; advanced planning and scheduling; mathematical modeling and optimization; performance analysis and measurement; analysis and efficiency measurement (DEA, SFA, DFA,...); optimization based on DEA models; determination of composite indicators; connecting the DEA method with ConJoint analysis, with game theory and with risk management methods; connecting the DEA method and Petri networks; missing data investigation, etc.

In some situations, finding the status of some variables from an input or output point of view is very difficult; these variables can be treated as both inputs and outputs and are called flexible measures. In this paper, the TOPSIS[20] method is used (TOPSIS - Technique for Order Preference by Similarity to An Ideal Solution, by Hwang and Yoon; 1981). Therefore, it should be seen how changing the input affects the output, that is, how the efficiency changes in such cases. Situations can be represented symbolically with the following expressions:

18 https://sr.puntomarinero.com/revenue-and-profits-of-the/(pristup: 06.07.2022)
19 https://slidetodoc.com/matematiki-modeli-efikasnosti-dr-gordana-savic-gocafon-bg-2/ (pristup:06.07.2022)
20 TOPSIS - Technique for Order Preference by Similarity to An Ideal Solution (by Hwang and Yoon, 1981)

$$Eff_o = \frac{Ouput(Y1, Y2, Y3, \boldsymbol{Axy})}{Input(X1, X2, X3, X4)}$$

ili,

$$Eff_i = \frac{Ouput(Y1, Y2, Y3)}{Input(X1, X2, X3, X4, \boldsymbol{Axy})}$$

It can be concluded that in such parameters with input-output position in the model, they have e.g. and quality or income from research (a well-known example from the literature). According to (Dogan et al, 2016), for example, some authors: (Beasley, 1995) take as input (Research Income, Operating Expenses, Personnel Expenses) and as output (Number of Graduate and Undergraduate Students, Number of Indexed Publications); while (Abbott and Doucouliagos, 2003), as input they take (Operating Expenses, Number of Academic Staff, Number of Administrative Staff, Fixed Assets) and as output they take (Research Quantity, Number of Graduate, Number of Undergraduate Degree, Number of Students) .

Note: VRS (Variable return to scale) efficiency score ³ CRS efficiency score.

$$\text{SC-Scale efficiency} = \frac{\text{Overall Technical Efficiency(CRS)}}{\text{Pure technical efficiency(VRS)}}$$

In an input-oriented DEA model, the goal is to minimize input for the existing level of output. In the output-oriented model, on the other hand, the goal is to maximize output at a given level of input. The solutions provided by the input- and output-oriented CCR models are interconnected..[21]

From the author's research, in accordance with the papers by (Anđelković, M., Anđelković, A., Tomić, R., 2022), (Radosavljević, M. et al., 2022), (Šegrt, S., 2022a), (Šegrt, S., 2022b) and (Šegrt, S., 2022c), it is possible to explicitly download data on the relevant parameters regarding the analysis of the efficiency of business systems using DEA (CCR - total technical efficiency), at the level of: quality, productivity, economy, functionality , purely technical efficiency and effectiveness of the company (directly at the level of supply chains).

The results of DEA and statistical analysis are presented in tabular and graphical form.

21 https://slidetodoc.com/matematiki-modeli-efikasnosti-dr-gordana-savic-gocafon-bg-2/ (pristup: 06.07.2022)

4. EXAMPLES

Examples of DMUs to which the DEA applies are: banks, trading companies, tourism organizations, insurance companies, police stations, hospitals, tax authorities, prisons, defense bases (army, navy, air force), schools and colleges, as well as chains supply (in which data for each partner in the chain must be presented according to the same standard, that is, they must be consolidated and normalized).

Example-1

Of interest for this paper, as announced, is the connection of the DEA method with statistical methods (which will be discussed in more detail later in this paper). With a competent statistical base, there should be no missing data for the formation of functional dependencies, scales or in general a set of missing data for analysis. If there is still a need for missing data, then missingness mechanisms must be activated, with methods for handling missing data.[22] To fill in the missing data, regression, single and multiple, is used (Popović, 2019).

In conventional DEA analysis, the input-output status of each particular performance measure is assumed to be known.

Mathematical modeling-restoration is very often necessary to use. One of the reasons for the easier use of such models lies in the application of the "Excel solver DEA CCR" model, which is also the basic model of DEA analysis. The unknowns are:

- h_k – relative efficiency of the kth of DMU;
- u_r – weighted coefficient for output r;
- v_i – weighted coefficient for input i.

Further examples (1 and 2) follow, where at the beginning the problems or models that are analyzed will only be defined (without additional theorizing, except for what is valid as a general basis given in the previous part of the paper.

This example is given for the comparison of the results based on the DEA model adopted and adapted by the authors (especially with regard to the research of weighting coefficients) with the model that is processed in the complementary literature. [23] For the purpose of efficiency analysis, normalized data were used (Radosavljević,M. et al., 2022).

In both cases, mostly consistent results were obtained in the DEA analysis, with the fact that 7-seven different DMUs were treated in the literature and 4-four DMUs (out of the listed 7) were treated by the authors. It is less important what those parameters were, but in order to preserve the authenticity of the model, it is stated that the input parameters were related to employees (X1-controller's work in [h], X2-banker's work in [h]; -here it is preferable data normalization should be performed in accordance with the total number of employees) and output parameters related to clients and transactions (Y1-number of transactions, Y2-number of clients).

22 Ibid;

23 Ibid;

For relative efficiency, according to the author's model (R2=1 was also achieved), it can be said that it deviates by a maximum of about -16% in relation to Eff from the literature (taken as correct), with the fact that with DMU1 the agreement of the results on level of deviation of -1% (more precisely ε=-0.83%). The main difference relates to different calculations of equivalent inputs and outputs. The authors also look for weighting coefficients in a different way, as will be more closely illustrated in the next example (Radosavljević,M. et al., 2022).

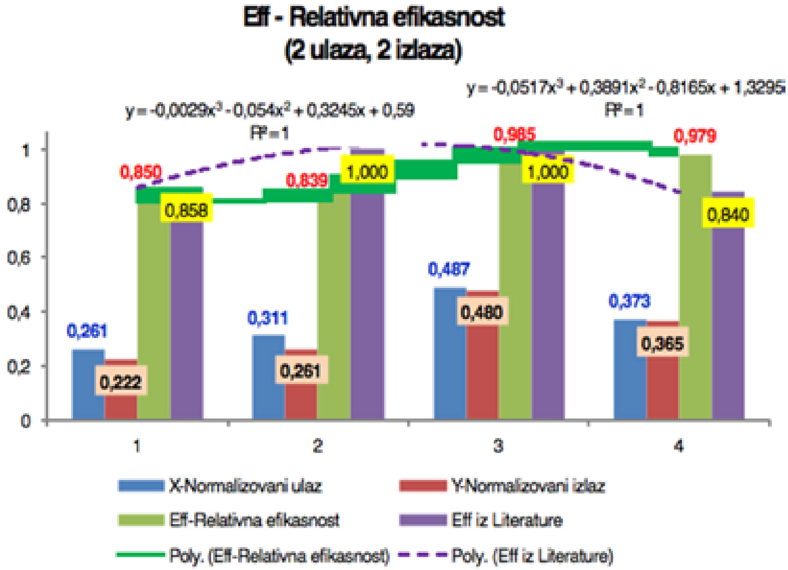

Figure 2. Relative efficiency of 2-input and 3-output DMUs (Source: Authors)

The parameters are well chosen and, according to the weighted coefficients, it can be concluded that they belong to the same category of importance. Specifically, the following values were obtained (herewith stands

$\sum_{i=1}^{4} W_i = 1$): W_1=0.333795165, W_2=0.186429273, W_3=0.136258713, W_4=0.343516848.

In the case that Wi for input and Wo for output are considered separately, a similar result is also obtained, more precisely the ratios of the weighting coefficients. The authors checked it on different models, if instead of $\sum_{i=1}^{n} W_i = 1$, we use $\sum_{i=1}^{m} W_i = 0.5$ i $\sum_{i=m+1}^{m+n} W_i = 0.5$, approximately the same values will be obtained (Radosavljević, M. et al., 2022).

Example-2

In this example, with 3 inputs and 5 outputs, the results of DEA and statistical analysis (at the level of descriptive statistics) will be displayed. The DEA calculation was performed at the level of identification of the most significant input and output parameters (with a clear determination of their mean values and standard deviations; - of course, in the broader report, the authors had insight into all relevant statistical values at the level of parameters and groups of parameters, as well as at the level of correlations of individual group of parameters (with research, when necessary, of appropriate regression functions) in accordance with statistical indicators according to the papers by (Šegrt, S., 2022a), (Šegrt, S., 2022b) i (Radosavljević, M. et al., 2022).

As input parameters (or variables), for each DMU (decision-making unit) the following were taken: number of employees, assets and capital of the company, and for the output, the following parameters were taken: income, profit, economy, quality and functionality (values are at the start normalized).

Table 1: Identification of key parameter values at the DMU level, with a minimum of descriptive statistics

Parameters	INPUT			OUTPUT				
DMU	X1-No of employees	X2-Assets	X3-Capital	Y1-Incomes	Y2-profit	Y3-economy	Y4-Quality	Y5-Function.
P1PK	62	0,903	0,935	0,903	0,822	0,915	0,871	0,907
P1ZK	62	0,954	0,963	0,916	0,849	0,885	0,923	0,901
P2FS	48	0,883	0,874	0,862	0,817	0,788	0,838	0,862
P2ZK	48	0,877	0,862	0,906	0,857	0,869	0,869	0,893
P3ZK	49	0,91	0,94	0,915	0,843	0,892	0,898	0,874
P4PK	61	0,903	1	0,904	0,892	0,899	0,863	0,899
P4ZK	61	0,931	0,849	0,91	0,864	0,863	0,87	0,904
Mean:	55,85714	0,90871	0,91757	0,90228	0,84914	0,873	0,876	0,89143
Variance:	49,80952	0,00071	0,00322	0,00034	0,00065	0,00171	0,00074	0,00029
Standard deviation:	7,057586	0,02671	0,05679	0,01848	0,02558	0,04141	0,02712	0,01694
Note: - only correlation values are emphasized (bold)..								
COR-REL (Xi-Yj, X1)	1	0,68135	0,45014	0,43097	0,33423	0,560659	0,315983	0,83141
COR-REL (Xi-Yj, X2)	0,68134	1	0,31530	0,57848	0,196152	0,341914	0,764685	0,466240
COR-REL (Xi-Yj, X3)	0,45010	0,3153	1	0,33056	0,328115	0,599463	0,764685	0,220405

CORREL (Xi-Yj, Y1)	0,43097	0,57848	0,33056	1	0,497984	0,830476	0,783481	0,650616
CORREL (Xi-Yj, Y2)	0,33423	0,196152	0,328115	0,497984	1	0,378888	0,123431	0,443266
CORREL (Xi-Yj, Y3)	0,560659	0,341914	0,599463	0,830476	0,378888	1	0,556705	0,713832
CORREL (Xi-Yj, Y4)	0,315981	0,764685	0,764685	0,783481	0,123431	0,556705	1	0,334377
CORREL (Xi-Yj, Y5)	0,83141	0,466240	0,220405	0,650616	0,443266	0,713832	0,334377	1

(Source: authors)

The relative efficiency of 7 DMUs was analyzed, and the results were presented in tabular and graphical form. Here, in connection with the reference of efficiency, for the subject models of business systems (field of transport and logistics services), weighted coefficients of different levels appeared, as shown in table 2.

Table 2: Relative efficiency with weighted coefficients of input and output parameters

Parametar	Input/Output	W_i	Note-1 (DEA), in this company model,	Note-2(CORREL), in accordance with TQM
X1-No of employees	Input	0,115160232	The recorded mean value was 55.86 with the highest standard deviation of 7.06	Weak correlation [0.00,0.40)
X2-Assets	Input	0,264311973		Good correlation 0.75,0.85)
X3-Capital	Input	0,12055038	7,057586	Good correlation 0.75,0.85)
W_{ulaz}=		0,5000		
Y1-Income	Output	0,009819439	Very low impact on Eff	Good correlation 0.75,0.85)
Y2-Profit	Output	0,122060212		Weak correlation [0.00,0.40)

Y3-Economy	Output	0,00909439	Very low impact on Eff (Economy. was introduced due to cost participation)	Medium correlation [0.40,0.75)
Y4-Quality (TQM)	Output	0,154292626	TQM comprises economy part ass well	
Y5- Functionality	Output	0,204745122	Eff mostly depends on functionality	
W_{izlaz}=		0,5000	Standard deviations in % for all parameters except for X1 (12.64%), range from 2 to 6%. All positive correlations were obtained!	

(Source: authors)

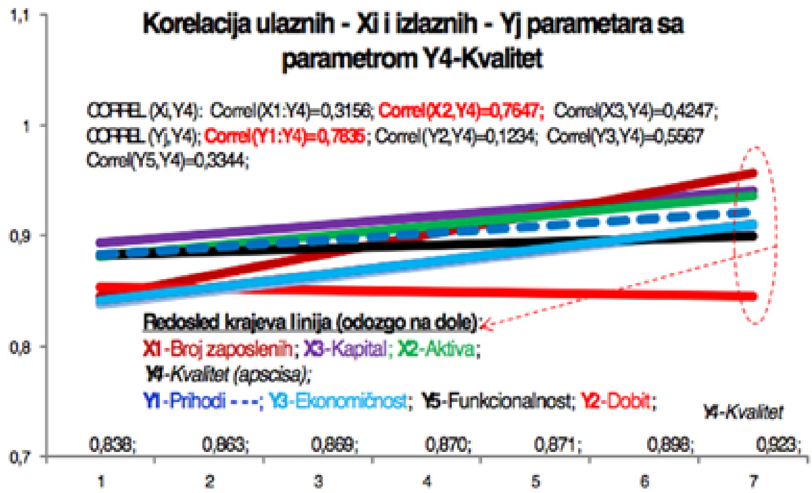

Figure 3. Correlation of input and output parameters with the parameter - Quality
Source: authors

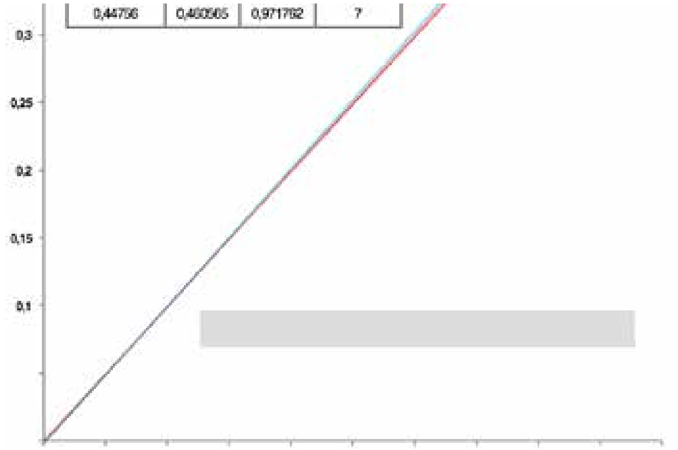

Figure 4. Efficiency of different DMUs with included weighted factors
Source: authors

If we look at a slightly more reduced case, with the same type of input parameters (number of employees, assets, capital) and slightly more modified-reduced output parameters (business income and net profit), where now as a DMU a company is taken in different years of operation, we can get results of Eff - relative efficiency as shown in fig. 5.

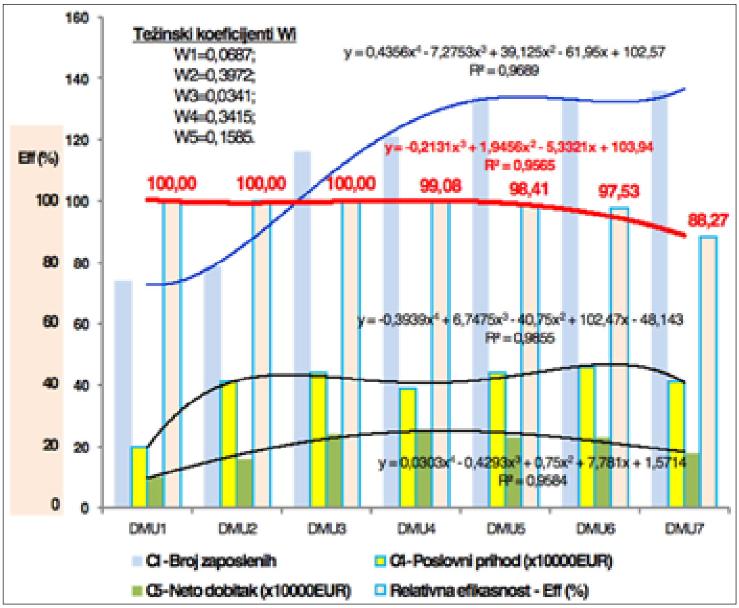

Figure 5. Relative efficiency of the business system for a period of 7 years (2015-2021)
(Source: authors)

From the subject DEA analysis, the results of which are shown in fig. 5, it can be concluded that the weighted coefficients were, on the input side, dominant for Assets (W_2=0.3972), and on the output side that the weighting coefficients were of the same level for income W_2=0.3415) and profit (W_2=0.1585), with the fact that here, for this type of DEA analysis, income is dominant.

The research shows that the business results were the best at the beginning of the fourth year of business, which is particularly related to the number of employees. As long as the number of employees did not significantly increase, the efficiency E_ff was maximum (E_ff≅1.0), the income and profit went on an upward line. The income fell in the 4th and 5th year of operation until the organization got a foothold (modernized and/or accepted new work standards, as well as a reward system on a new basis), with an increased volume of production and placement of goods and services (the company's income started again to grow even in the 6th year of operation until new hires started (obviously, not only for business and market reasons). Profit was very good in the period 2016-2020, at the beginning of the considered period the company had an increase in profit, and at the end of the period In 2020-2021, a drop in profits was recorded (most likely caused by problems in business due to COVID-19; the company probably also received some new people to perform tasks at the e-business level with the maximum activation of contactless work methods, for all this obviously appropriate staff training was needed as well).

Example-3

At the end of this point, as a special example, we can consider the case of detecting wrong data in DEA analyzes (DEA is a very sensitive analysis). If some data are unrealistic (poorly recorded, calculated or estimated), in connection with the recorded "input-output" state, as well as at the level of ratio analysis (ROA, ROE, ROI) they deviate from the larger set of data being analyzed, therefore DEA will show the exact place where attention should be paid or intervention must be done (examine, revise, take corrective measures and definitively eliminate the omission), see fig. [6]

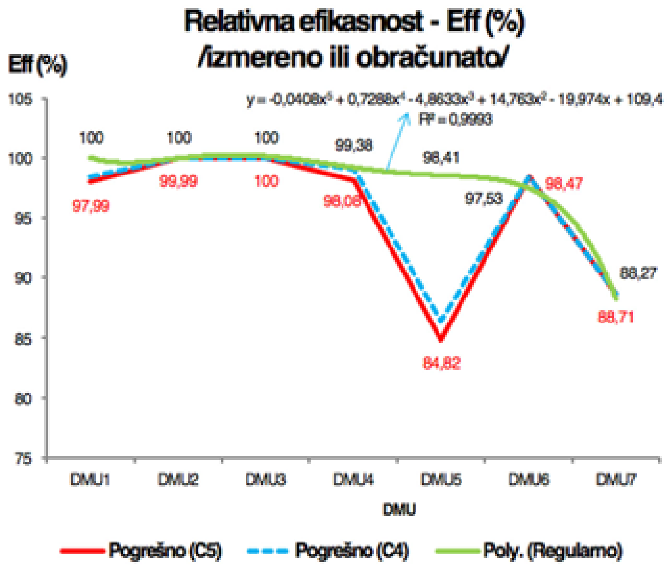

Figure 6. **I**dentification of erroneous data(measured or calculated) through DEA (Source: authors)

Otherwise, ratio analysis is most often used as a powerful analytical instrument for analyzing financial reports (Omerhodžić, 2007; p.152). It is a tool that provides the best information about the company's financial operations and position. Ratio analysis enables monitoring of liquidity, solvency (indebtedness), operational efficiency and profitability of a specific company. The complementarity of ratios with DEA and statistical analyzes is obvious.

The authors analyzed several examples and came to the conclusion that even very small - irregular deviations in parameters can lead to wrong determination of relative efficiency (Eff). The graphic interpretation of the efficiency results was done according to table 3.

Table 3: Relative efficiency in DEA (regular or erroneous data)

DMU	Relative efficiency - Eff (%) /measured or calculated/		
	Regular	Incorrect (C5)	Incorrect (C4)
DMU1	100,0	97,99	98,39
DMU2	100,0	99,99	99,99
DMU3	100,0	100,0	100,0
DMU4	99,38	98,08	99,08
DMU5	98,41	84,82	86,41
DMU6	97,53	98,47	98,47
DMU7	88,27	88,71	88,71

(Source: authors)

If we look more closely, you will notice that the deviations in: - C5, amounted to 1.3 to 13.8%, and in - C4, the deviations were 0.3 to 12.2%. The Eff value varied, even in cases where the deviations were of a lower level (eg, <3%). Therefore, DEA is a good methodology and model used to analyze the sensitivity of functions depending on data changes (Radosavljević, M. et al., 2022).

5. CONCLUSION

The authors presented representative examples of DEA analyzes with two inputs and many outputs, as well as with 3 inputs and 5 outputs. The intermediate variant is made with 3 inputs and 2 outputs. Of course, the analysis with one input and one output would be interesting at the level of educational examples, but the authors draw attention to the fact that this is precisely the most delicate task, i.e. "How to correctly select key inputs and outputs and evaluate the efficiency of such DMUs" or business systems (Radosavljević, M. et al., 2022).

For different types of production systems, the conventional DEA model is modified to include flexible measures. This is where the work of analysts and researchers who can (with extensions of the basic concept) use DEA analysis for statistical evaluation of hypotheses about the characteristics of production capacities, i.e. service potentials, and factors affecting productivity (definitely expressed at the level of relative efficiency) should come to the fore.

In contrast to some characterizations, in certain papers it has been shown that DEA is a complete statistical methodology, based on the characterization of DMU efficiency as a stochastic variable (Banker, 1993). The DEA model of production frontier estimation has desirable statistical properties and provides the basis for the construction of a wide range of formal statistical tests (Banker, 1993) dealing with issues such as: efficiency comparisons of groups of DMUs (correlation), the existence of economies of scale, the existence of allocative inefficiency, separability and substitutability of inputs in production systems, analysis of technical changes and changes in productivity, the influence of contextual variables on productivity and the adequacy of parametric functional forms in the evaluation of monotonic and concave functions (not only those that have maxima, but also functions that have minima, e.g. minimization of energy consumption, materials and production costs), related to the realization and placement of products and services.

On the selection of the minimum of key parameters that describe the efficiency of DMU (including their combination at the level of composite parameters), as well as on how to analyze the DEA model, in case of significant dependence, e.g. one DMU that (by its input efficiency) affects the efficiency of other DMUs etc., the authors intend to publish the following paper in the field of DEA and statistical analysis entitled "Application of a flexible DEA structure in situations where insufficient information may prevent the use of parametric statistical tests in management and production implications."

The application of a flexible DEA structure can be either at the level of a flexible measure (as an input or as an output), or when the efficiency of one DMU enters as an input for another DMU, etc. Flexible structures are obtained when a change is made in the process algorithms or flexible variables or factors are changed. The efficiency of one DMUi can be an input for the performance of indicators of the efficiency of another or other DMUs, which is particularly important for referencing their synergistic impact on the overall behavior of the business system.

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