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TECHNICAL FACULTY "MIHAJLO PUPIN"
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**Milan Pavlovic, Ph. D, Professor, Dean of the Technical faculty „Mihajlo Pupin”, Zrenjanin**

Technical treatment and design:
**Ivan Tasic, Ph. D, Professor**
**Dijana  Karuovic, Ph. D, Professor**
**Marjana Pardanjac, Ph. D, Assistant Professor**
**Erika Eleven, M.Sc, Assistant**
**Dusanka Milanov MSc, Assistant**

Lecturer:
**Erika Tobolka, Ph. D, Professor**

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*With this publication, the CD with all papers from the International Conference on Information Technology and Development of Education, ITRO 2015 is also published.*

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# INTRODUCTION

This Proceedings comprises papers from the **International conference on Information technology and development of education** that is held at TECHNICAL FACULTY ”MIHAJLO PUPIN”, ZRENJANIN, on June 26th 2015.

**The International conference on Information technology and development of education** has had a goal to contribute to the development of education in Serbia and in the region, as well as, to gather experts in natural and technical sciences’ teaching fields.

The expected scientific-skilled analysis of the accomplishment in the field of the contemporary information and communication technologies, as well as analysis of state, needs and tendencies in education all around the world and in our country have been realized.

The authors and the participans of the Conference have dealt with the following thematic areas:

- Theoretical and methodological questions of contemporary pedagogy
- Personalization and learning styles
- Social networks and their influence on education
- Children security and safety on the Internet
- Curriculum of contemporary teaching
- Methodical questions of natural and technical sciences subject teaching
- Lifelong learning and teachers’ professional training
- E-learning
- Education management
- Development and influence of IT on teaching
- Information communication infrastructure in teaching proces

All submitted papers have been reviewed by at least two independent members of the Science Committee.

The papers presented on the Conference and published in this Proceedings can be useful for teacher while learning and teaching in the fields of informatics, technics and other teaching subjects and activities. Contribution to science and teaching development in this region and wider has been achieved in this way.

***The Organizing Committee of the Conference***

# CONTENTS

# SEVERAL ASPECTS OF MEASURING PERFORMANCE OF UNIVERSITY STUDY CYCLES USING DEA

R. Timovski[*], T. Atanasova-Pacemska[**], A. Rusiti[***] V. Sarac[****]
[*]Head of E-Index department, Goce Delcev University in Stip, Republic of Macedonia
[**]Faculty of Computer Sciences, Goce Delcev University in Stip, Republic of Macedonia
[***]Pedagogical Faculty St. Kliment Ohridski, Ss. Cyril and Methodius University in Skopje, Republic of Macedonia
[****]Faculty of Electrical Engineering, Goce Delcev University in Stip, Republic of Macedonia
riste.timovski@ugd.edu.mk, tatjana.pacemska@ugd.edu.mk, agim_rushiti@yahoo.com, vasilija.sarac@ugd.edu.mk

**Abstract - Higher education presents main engine of society's overall progress and development. In this context, Universities are meant to be generators of knowledge and academic force, which can be treated as output of their functioning. It is important to achieve high level of educated and qualified students/future employees that will be able to fit in the real sector and contribute to the collective/personal live. On the other side, it is necessary to invest some specific resources in order of efficient productivity of knowledge – input in the process. Having this in mind, we can always learn from the past, in meaning what is invested as input and what is the result, as output. This paper treats different study programs / cycles at a specific University as entities, that use specific kind of resources as input and produce knowledge as output. Linear programming technique application called DEA (Data Envelopment Analysis) is applied, in order to show several aspects of efficiency measurement of the study cycles and their comparison.**

## I. INTRODUCTION

Optimization in mathematical terms usually means how to find the best of the offered / possible alternatives to solve a speciffic problem or give answer to the question which option is the most efficient, among all of the options available. In terms of linear programming (LP), the approach means that it is necessary to build a precise mathematical model that reflects the real problem in a best way, so that it is possible to project the process being observed as a production function of the system. In this manner, the "mathematical" goal is to find the minimum / maximum (dependds on the approach) value of that production function. The LP modeling of the system means to sketch the real problem as an input/output system. The inputs and outputs represent real values (variables) with their own characteristics and limitations and are used to mathematically sketch the objective function, which is actually the subject of optimization (optimization of linear equitation). The objective function should give real picture of the interdependence of the parameters of the system. DEA represents LP tool that pictures the problem as an input/output system, composed of a specific number of production units, that threats the inputs and produce the outputs. The goal is to find the best production (best allocation of inputs for best output) and to give a clear picture what shoud be changed to the other production units, in order to improve them.

### *A. DEA mathematics*

In order of correct application of DEA, modeling of the real world should include:

- Set of production units – entities from the real world that will use specific set of input parameters to produce specific set of output parameters – known as DMUs (Decision Making Units);
- Input parameters (same for all DMUs);
- Output parameters (same for all DMUs);
- Technical efficiency (the goal of the examination) of a single DMU is defined as:

$$\theta = \frac{Output}{Input}$$

We call it ***Pareto*** efficiency in case of best allocation of the resources (usually inputs) in the observed set of DMUs. The DMU with Pareto efficiency is an efficient DMU. The other DMUs are relatively inefficient (only in the observed set of DMUs). It is impossible in the case of efficient

DMUs (and the observed set of DMUs) to change something and thus to achieve better performances to the efficient DMUs (it is impossible to improve the output without worsening the input).

With n DMUs, m inputs and s outputs, the efficiency of k-th DMU is:

$$\theta_k = \frac{u_1 y_{1k} + u_2 y_{2k} + \cdots + u_s y_{sk}}{v_1 x_{1k} + v_2 x_{2k} + \cdots + v_m x_{mk}}$$

where $x_{1k}, x_{2k}, \ldots, x_{mk}$ are the inputs of the k-th DMU, $y_{1k}, y_{2k}, \ldots, y_{sk}$ are the outputs of the k-th DMU, $v_1, v_2, \ldots, v_m$ are inputs' weight coefficients and $u_1, u_2, \ldots, u_s$ are outputs' weight coefficients, with mathematical limitation (in connotation of the reality):

$$v_1, \ldots, v_m \geq 0, u_1, \ldots, u_s \geq 0,$$

In this paper, we use DEA CCR CRS input oriented model [1]:

- Goal:

$$max\ (\theta_k = \frac{u_1 y_{1k} + u_2 y_{2k} + \cdots + u_s y_{sk}}{v_1 x_{1k} + v_2 x_{2k} + \cdots + v_m x_{mk}}),$$

- Limitations:

$$\frac{u_1 y_{11} + u_2 y_{21} + \cdots + u_s y_{s1}}{v_1 x_{11} + v_2 x_{21} + \cdots + v_m x_{m1}} = \frac{\sum_{i=1}^{s} u_i y_{i1}}{\sum_{j=1}^{m} v_j x_{j1}} \leq 1$$

...

$$\frac{u_1 y_{1k} + u_2 y_{2k} + \cdots + u_s y_{sk}}{v_1 x_{1k} + v_2 x_{2k} + \cdots + v_m x_{mk}} = \frac{\sum_{i=1}^{s} u_i y_{ik}}{\sum_{j=1}^{m} v_j x_{jk}} \leq 1$$

...

$$\frac{u_1 y_{1n} + u_2 y_{2n} + \cdots + u_s y_{sn}}{v_1 x_{1n} + v_2 x_{2n} + \cdots + v_m x_{mn}} = \frac{\sum_{i=1}^{s} u_i y_{in}}{\sum_{j=1}^{m} v_j x_{jn}} \leq 1$$

$$v_1, \ldots, v_m \geq 0, u_1, \ldots, u_s \geq 0;$$

$$x_{ij} \geq 0, y_{rj} \geq 0; i = 1, \ldots, m; r = 1, \ldots, s; j = 1, \ldots, n.$$

The result are weights that maximizes each DMU's efficiency in correlation of all other DMUs, forming frontier line consisted of best DMUs with efficiency = 1 (**efficient DMUs**). All inefficient DMUs have efficiency below 1 and are called inefficient.

Often, as in this paper, the dual DEA CCR model is used. It is represented with following equations:

- Find $min\theta$
- Having limitations:

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{i0}, \qquad i = 1, \ldots, m$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r0}, \qquad r = 1, \ldots, s$$

$$\lambda_j \geq 0, \qquad j = 1, \ldots, n$$

index 0 is for each DMU that equitations are solved for separately (in order to maximize its efficiency); lambdas represent weighted coefficients that build the composite DMUs for each inefficient DMU. The composite DMU for each inefficient real DMU is consisted as sum of the ERS (efficiency reference set – efficient DMUs used for interpretation of the composite DMU for the observed real DMU) multiplied with its lambda coefficients. As an example, A and B are efficient DMUs (m inputs, s outputs) and belong to the ERS set of observed inefficient C DMU. The composite DMU C' is given with:

$$\lambda_A \begin{bmatrix} y_{1A} \\ \ldots \\ y_{sA} \\ x_{1A} \\ \ldots \\ x_{mA} \end{bmatrix} + \lambda_B \begin{bmatrix} y_{1B} \\ \ldots \\ y_{sB} \\ x_{1B} \\ \ldots \\ x_{mB} \end{bmatrix} = \begin{bmatrix} y_{Composite} \\ \ldots \\ y_{Composite} \\ x_{Composite} \\ \ldots \\ x_{Composite} \end{bmatrix}$$

In DEA world, we speak about "good enough" solution and real enough models [2].

## II. Problem, Goal and Modeling

It is very difficult to measure the quality of the educational processes, especially in terms of high education. In order to be able to give assessment of a specific process in high education / whether it is efficient or not, there are numerous factors that need to be considered and also, their mutual links, dependencies and correlations. The approach that is used in this paper (and furthermore as base of the model that DEA is applied on) is based on following:

- Study cycles, in terms of study course + generation of students is the main producer of knowledge (Data ;
- Resources are invested in each study cycle (input parameters);
- Each study cycle produce specific categories of knowledge (output parameters), and
- How to structure this data in a DEA model, in order to find the best study cycle.

Details for the approach:

- Consider the inputs as parameters whose increase will reduce the DMU's efficiency, and

- Consider the output of parameters whose increase will increase the DMU's efficiency.
- Each study cycle (course + generation) delivers skills and knowledge structured and provided in the study programs accreditation documents. They form the output set. For this goal are used specific resources in terms of finances and other (usually) material issues. They form the input set. For building more than one model, bigger set of input and output parameters are gathered and used (DEA applied) in specific combinations. Having this, the model can be pictured as:

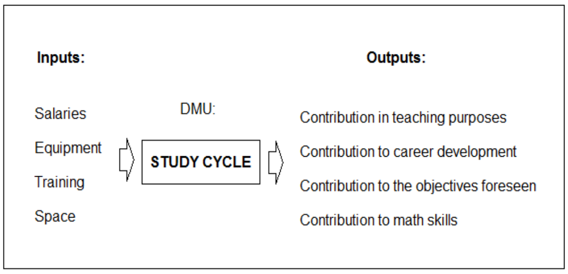


Figure 1. Study cycle DMU DEA model

## A. *Input and output parameters*

Input parameters are:

- Expenses of the University for hiring teachers (professors and assistants) during the regular study cycle (three study years for each study cycle). Expenses are calculated as gross salaries. The factor of load / utilization in terms of teaching on more parallel study years from different study cycles is taken into account;
- Expenses of the University for the equipment (computers, projectors etc.) for the specific study cycle. The degree of utilization, i.e. the ratio of annual depreciation of computer equipment and inventory used is taken into account, as well as the percentage of load / utilization in terms of number of students of the observed course and all students that used the same equipment (parallel study years from different study cycles);
- Space used for each study cycles realization, in terms of square meters. Load / utilization factor is taken into account also, and
- Expenses of the University for realization of employed professors and assistants trainings, conferences and every activity for their professional improvement, in the country and abroad.

Output parameters are (strictly defined in accreditation documents of the study programs, in terms of average indexes from 1 to 5):

- Contribution in teaching purposes;
- Contribution to career development;
- Contribution to the objectives foreseen, and
- Contribution to math skills.

## B. *Model tables*

For displaying several aspects of measuring efficiency and performance of the study cycles, DEA was applied to these three derived models from the general table (2 inputs and 1 output each):

TABLE I. NUMERICAL DEA MODEL 1

| DMUs | Teachers expenses (EUR) | Space (squared meters) | DMUs explicit | Contribution to career develop. |
|---|---|---|---|---|
| DMU1 | 124.080 | 180 | Generation 2008-2011, Business informatics | 3,5 |
| DMU2 | 124.080 | 90 | Generation 2009-2012, Business informatics | 4,5 |
| DMU3 | 112.800 | 180 | Generation 2010-2013, Business informatics | 3,75 |
| DMU4 | 319.200 | 640 | Generation 2006-2009, Computer sciences | 4 |
| DMU5 | 324.900 | 640 | Generation 2007-2010, Computer sciences | 3,5 |
| DMU6 | 285.000 | 640 | Generation 2008-2011, Computer sciences | 4 |
| DMU7 | 285.000 | 640 | Generation 2009-2012, Computer sciences | 3,33 |
| DMU8 | 250.800 | 640 | Generation 2010-2013, Computer sciences | 4,33 |
| DMU9 | 50.160 | 90 | Generation 2009-2011, ICT-Computer engineering | 4 |

TABLE II. NUMERICAL DEA MODEL 2

| DMUs | Teachers and training expenses (EUR) | Equipment expenses (EUR) | DMUs explicit | Contribution to math skills |
|---|---|---|---|---|
| DMU1 | 124.080 | 0 | Generation 2008-2011, Business informatics | 4,33 |
| DMU2 | 124.080 | 0 | Generation 2009-2012, Business informatics | 4,8 |
| DMU3 | 112.800 | 0 | Generation 2010-2013, Business | 4,75 |

| | | | | |
|---|---|---|---|---|
| | | | informatics | |
| DMU4 | 330.966, 67 | 106.366, 67 | Generation 2006-2009, Computer sciences | 3,13 |
| DMU5 | 336.366, 67 | 67.366,6 7 | Generation 2007-2010, Computer sciences | 2 |
| DMU6 | 297.326, 67 | 52.354,6 7 | Generation 2008-2011, Computer sciences | 4,5 |
| DMU7 | 298.410, 00 | 34.248 | Generation 2009-2012, Computer sciences | 3,33 |
| DMU8 | 265.843, 33 | 21.128 | Generation 2010-2013, Computer sciences | 3,33 |
| DMU9 | 50.160 | 3.000 | Generation 2009-2011, ICT-Computer engineering | 2,75 |

TABLE III. CUMULATIVE NUMERICAL DEA MODEL

| DMUs | All expenses (EUR) | Space (Squared meters) | DMUs explicit | Cumulative con. index |
|---|---|---|---|---|
| DMU1 | 124080 | 180 | Generation 2008-2011, Business informatics | 4.04 |
| DMU2 | 124080 | 90 | Generation 2009-2012, Business informatics | 4.225 |
| DMU3 | 112800 | 180 | Generation 2010-2013, Business informatics | 4.0625 |
| DMU4 | 437333 | 640 | Generation 2006-2009, Computer sciences | 3.6425 |
| DMU5 | 403733 | 640 | Generation 2007-2010, Computer sciences | 3.125 |
| DMU6 | 349681 | 640 | Generation 2008-2011, Computer sciences | 3.875 |
| DMU7 | 332658 | 640 | Generation 2009-2012, Computer sciences | 3.5825 |
| DMU8 | 286971 | 640 | Generation 2010-2013, Computer sciences | 4.08 |
| DMU9 | 53160 | 90 | Generation 2009-2011, ICT-Computer engineering | 3.875 |

The first two models have taken specific aspects of the impact of the financial resources and square on concrete outputs and offers possibility to measure the efficiency in such an enviroment. The third model integrates all input and output parameters. The output parameter takes into account all real output parameters as equally signifficant and represents the average value for each study cycle.

## III. RESULTS, DISCUSSION

The three models from the same environment are processed with specific software solution to generate the clear picture of efficient and inefficient production units (three pictures).

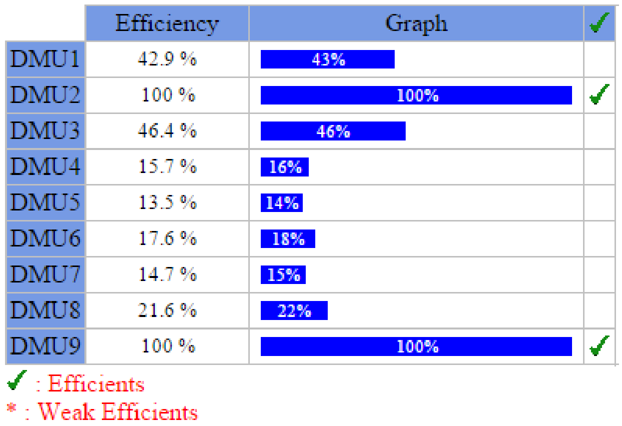


Figure 2. Efficiency graph DEA model 1

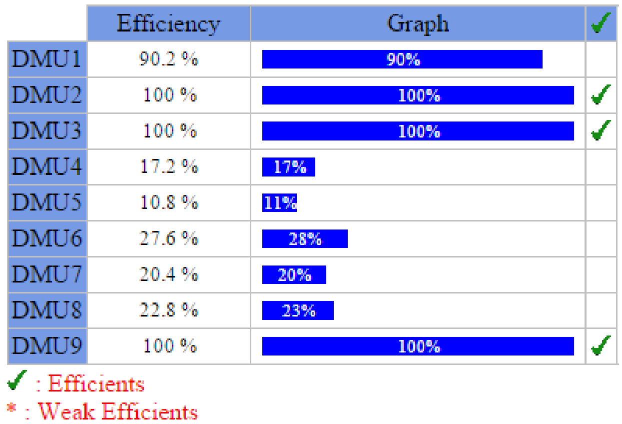


Figure 3. Efficiency graph DEA model 2

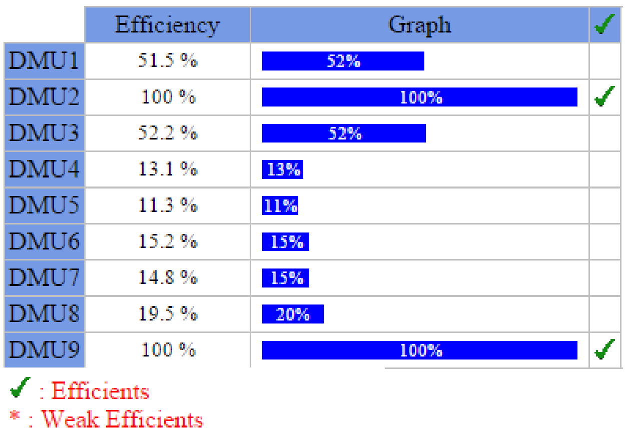


Figure 4. Efficiency graph DEA model 2 (All parameters included)

Study cycles with efficiency = 1 (100%) are noted as relatively efficient and represent the set of ERS cycles for the cycles with efficiency bellow 1, noted as inefficient cycles. Most efficient cycles are used in most of the cases of composite cycles. Looking in figure 2, 3 and 4, it easily can be noted that DMU 5 is the most inefficient DMU in all cases, even in the case of All Integrated DEA model (Figure 4). This study cycle consumed enormous resources to produce worst results (in terms of educated students / students with worst results) in the observed set. From the other side, DMU2 and DMU9 are noted as efficient study cycles with best input resource allocation and should be example (ERS) for all the other DMUs, noted as inefficient.

Because the cumulative DEA model (figure 4) integrates all the input and output parameters, it can be noted as most important model that gives clear picture where to make an intervention in order to improve the study cycle in general. Figure 5 shows ERS set and frequency of their use, building the composite units for inefficient DMUs:

| | Peer Group | Frequencies | ✓ |
|---|---|---|---|
| DMU1 | DMU2,DMU9 | 0 | |
| DMU2 | DMU2 | 5 | ✓ |
| DMU3 | DMU2,DMU9 | 0 | |
| DMU4 | DMU2,DMU9 | 0 | |
| DMU5 | DMU2,DMU9 | 0 | |
| DMU6 | DMU9 | 0 | |
| DMU7 | DMU9 | 0 | |
| DMU8 | DMU9 | 0 | |
| DMU9 | DMU9 | 8 | ✓ |

✓ : Referenced

Figure 5. ERS set for cumulative DEA model

Figure 6 gives the information about the composite units for each inefficient study cycle. DEA propagates that, in order to make inefficient DMUs efficient, changes have to be made that will cause for each inefficient course to became as closer it is possible as its composite DMU / study cycle, that lays on the frontier (set of best possible courses, virtual or real). For constant output, every composite entity is consisted as sum of the multiplications of **lambdas** and inputs of the ERS entities, qualified as efficient.

| | DMU2 | DMU9 |
|---|---|---|
| DMU1 | 0.129 | 0.902 |
| DMU2 | 1 | 0 |
| DMU3 | 0.048 | 0.996 |
| DMU4 | 0.109 | 0.821 |
| DMU5 | 0.041 | 0.762 |
| DMU6 | 0 | 1 |
| DMU7 | 0 | 0.925 |
| DMU8 | 0 | 1.053 |
| DMU9 | 0 | 1 |

Figure 6. ERS set for cumulative DEA model

Figure 7 shows probably the most important ratio diagram – Expenses / Efficiency:

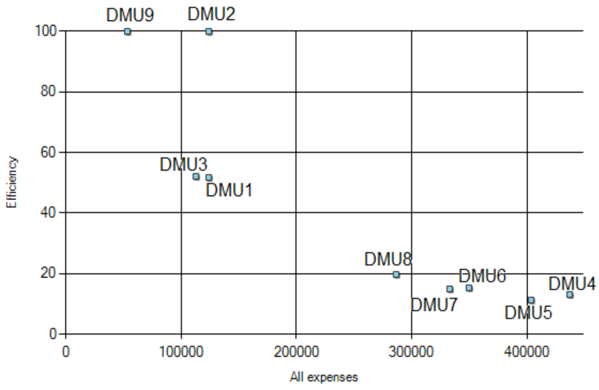


Figure 7. Efficiency / Expenses ratio

## IV. Conclusion, Possible Optimisations

This paper makes one clear approach of measuring the study cycle efficiency in high education. We applied DEA on a set of 9 study cycles, with respect to the 4 inputs and 4 outputs. In the first two aspects are taken certain parameters (several of them) to build a specific image of mutual dependence on each other. In the third embodiment, all parameters are included to generate the all picture. In all the cases, the dependence of each input resource can easily be noted. It is understandable that the reduction of each can improve the specific study cycle. Using this results and the information that is specific for each study cycle (which professors and assistants were engaged, their professional experience, the types of trainings conducted, the effects of them etc.) can be a good guideline for improvement steps taken from the management of the institution. The model that is used (input oriented CCR CRS) allows intervention at the input side, for bigger efficiency [3]:

- Reduction of expenses for professors, assistants and associate staff:
  - By engagement of the teachers and assistants for bigger number of students (increase the effectiveness);
  - By reducing the amount of gross financial structure / salaries;
  - By realizing training and additional activities for lower prices.
- Reduce costs for equipment:
  - Purchase cheaper equipment;
  - Usage of the same equipment by bugger number of students.
- Better use of the space:
  - Use smaller rooms;

- Use same rooms for bigger number of students.

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