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Editor in Cheaf - President of OC ITRO 2017:
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Lecturer:
Erika Tobolka, Ph. D, Professor

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УНИВЕРЗИТЕТ
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ШТИП

THE SCIENCE COMMITTEE:

With this publication, the CD with all papers from the International Conference on Information Technology and Development of Education, ITRO 2017 is also published.

INTRODUCTION

The Technical Faculty "Mihajlo Pupin", Zrenjanin, of the University of Novi Sad, the Republic of Serbia organizes VIIIth International Scientific Professional Conference "Information Technologies and Development of Education 2017" (ITRO 2017). The Conference will be held on 22nd June 2017 at the Technical Faculty "Mihajlo Pupin" in Zrenjanin, Serbia.

The Conference "Information Technologies and Development of Education 2017" (ITRO 2017) is organized due to the needs to connect science, profession and education through topics and content concept, first of all concerning the teaching process as base of information society. The tendencies of developed countries are in accordance with the efforts of UNESCO to improve this area related to the needs of life and work in the XXIst century. It is necessary to assess the state, detect the problems and perspectives of the development of education by competent professionals and teachers as well as the influence of the development of education on the development of the society as a whole.

The central topic of the meeting is the model of dual education as base for creating good base for the development of industry. Thus, our aim is to gather the representative entities who are able constructively contribute to establishing link between the educational system and industry as follows: Chamber of Commerce of Serbia – Centre for Dual Education, Ministry of Education, Science and Technological Development, Union of Employers of Serbia, ZREPOK – Business Organization of Zrenjanin and Companies that run their business in the region, directors of grammar schools and secondary vocational school, members of the academic communities and other participants who are interested in the topics.

The main topics of the scientific professional conference are:

- Model of dual education
- Teaching based on the concept of entrepreneurship

Other thematic areas of the Conference:

- Theoretical and methodological questions of contemporary Pedagogy
- Digital didactics media
- Contemporary communication in teaching
- Curriculum of contemporary teaching
- Developing teaching
- E-learning
- Management in Education
- Teaching methods of natural and technical subjects
- Information-communication technologies

The Chairman of the Organizing Committee of the ITRO 2017 Prof. Dragana Glušac opened the Conference. The participants were addressed by the vice dean of the Technical Faculty »Mihajlo Pupin«, Prof. Dijana Karuović; provincial secretary for science, higher education and scientific Research prof. Zoran Milošević, and the vice-major of Zrenjanin Mr. Dusko Radisic.

There were total of 143 authors that took part at the Conference from 12 countries, 2 continents: 82 from the Republic of Serbia and 61 from foreign countries such as: Macedonia, Bulgaria, Slovakia, Austria, Cyprus, Albania, Hungary, Spain, Bosnia and Herzegovina, USA, Portugal.

The Proceedings of papers contains 60 papers and it has been published in the English language.

President of the Organizing Committee
Prof. dr Dragana Glusac

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CONTENTS

Two-layer Quality Analysis of University Study Program Subjects Using DEA and AHP

T. Atanasova-Pachemska*, R. Timovski*, M. Lapevski* and A. Rushiti**
*Goce Delcev University, Stip, Macedonia
** Ministry of Education and Science of the Republic of Macedonia, Skopje, Macedonia
tatjana.pacemska@ugd.edu.mk

Abstract; One of the most important pillars in the society (every possible state in the world) is the education system, especially the higher education. It is known as the basic generator of knowledge and starter of all future progress and system development. Thus, it is very important to put guarantees as much as it is possible that the products from the educational processes will ensure quality future in every aspect of our living. Having this in mind, it is necessary to have permanent approach of measuring the performances of the education system, find all pros and cons and locate the efficient and inefficient parts of the mosaic, so it is possible to suggest steps for improvement in order to have better graduates and future academic citizens and overall, better skills and knowledge delivery during the studies.

Of course, conduction of the education (and having knowledge as output) requires certain investments of resources (teachers, equipment, conditions), that can be treated as input. In such manner, we build a system / model for measuring the output/input ratio using specific LP technique known as Data Envelopment Analysis (DEA) that can give good perspective of efficiency of the study process. Furthermore, in the pool of the efficient parts of the model we examined, we do another more analysis using Analytical Hierarchical Process (AHP) method in order to find "the best of the best" parts. More specific, our system is the specific university study program. The constituent elements that we do our examination over are the study program courses.

I. INTRODUCTION

Optimization is mathematical approach that can often give good answer to the question how to find the best of the offered / possible alternatives to solve a speciffic problem. In other words, it gives an answer to the question which option is the most efficient, among all of the options available. Thus, in terms of linear programming (LP), it is necessary to build a precise mathematical model that will reflect the real problem in a best way. If a particular problem that is being analyzed is presented as a mathematical model reflecting certain real production (objective) function, the problem boils down to determining the optimum (minimum or maximum) value of the same. It must describes the reality as an input/output system, with inputs and outputs - real values (variables) with their own characteristics and limitations, used to mathematically sketch the objective function. 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. In this analysis, we examine the courses of a specific university study program as input/output systems and use DEA to find the efficient ones. Furthermore, AHP is applied to the efficient courses to find their internal efficiency scaling and thus to deepen the research and double the weigth of the results. It is important to note that the justification for the use of both DEA and AHP methods on practically the same problem, lies in the fact that they successfully deal with patterns and problems involving heterogeneous and quite different in nature parameters and criteria to decide, as in this study.

A. DEA Mathematics

Modeling of the real word in DEA terms means having:

- Set of production units – input/output systems – known as DMUs (Decision Making Units), in this examination – university study program courses;
- Input parameters (same for all DMUs), in this examination investments for each course;
- Output parameters (same for all DMUs), in this examination the results of study program conduction in terms of knowledge and skills gathered from the students;
- Technical efficiency (the goal of the examination) of a single DMU is defined as:

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

It is called ***Pareto*** efficiency in case of best resources allocation (usually inputs) in the examined set of DMUs. The DMU with Pareto efficiency is called **efficient** DMU (in this paper – efficient course). The other DMUs are relatively inefficient (only in the observed set of DMUs). It is not possible for the efficient DMUs to change something in order to achieve better performances to the efficient DMUs (it is impossible to improve the output without worsening the input).

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

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

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

- 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:

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

$$\dots$$

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

$$\dots$$

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

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

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

The result are weights that maximizes each DMU's efficiency in respect of all the 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:

- Find $min\theta$
- Having limitations:

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

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

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

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 (shows possible ways for improvement). The composite DMU for each inefficient real DMU is consisted as sum of the ERS (efficiency reference set – efficient DMUs) multiplied with its lambda coefficients. If 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' can be calculated as:

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

B. AHP Mathematic

AHP is an approach for decision making that involves structuring multiple choice criteria into a hierarchy, assessing the relative importance of these criteria, comparing alternatives for each criterion and determining an overall ranking of the alternatives. AHP helps to capture both subjective and objective evaluation measures, proving a useful mechanism for checking the consistency of the evaluation measures and alternatives suggested by the team, thus reducing bias in decision making. In the following text we show the base AHP step methodology.

Step 1: Perform Pair – wise Comparison according Saaty nine – point preference scale.

Table 1. Saaty's Nine – Point Preference Scale

Scale	Compare factor of I and j
1	Equally Important
3	Weakly Important
5	Strongly Important
7	Very Strongly Important
9	Extremely Important
2,4,6,8	Intermediate value between adjacent scales

Let A represents $n \times n$ pair – wise comparison matrix:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix}$$

Step 2: Normalize the raw score by Arithmetic Mean as given below:

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, \qquad j = 1,2, \cdots, n$$

Step 3: Perform Consistency check.
Step 3a: Let C denotes a n – dimensional column vector describing the sum of the weighted values for the importance degrees of the attributes, then

$$C = [C_i]_{nx1} = AW^T, \qquad i = 1,2, \cdots, n$$

Step 3b: To avoid inconsistency in the pair – wise comparison matrix, Saaty suggested the use of the maximum Eigen value $\lambda_{\max}$ to calculate the effectiveness of judgement. The maximum Eigen value $\lambda_{\max}$ can be determined as follows:

$$\lambda_{max} = \frac{\sum_{i=1}^{n} c \cdot v_i}{n}, \qquad i = 1,2,\cdots,n$$

Step 3c: With $\lambda_{\max}$ value, a consistency index (CI) can then be estimated by

$$CI = \frac{\lambda_{max} - n}{n-1}$$

Step 3d: Consistency ratio (CR) can be used as a guide to check the consistency

$$CR = \frac{CI}{RI}$$

Where RI denotes the average random index with the value obtained by different orders of the pair – wise comparison matrices are shown in Table 1. The value of $CR \le 0.10$ is the consistent criteria.

II. Problem, model, goal

The starting approach and modeling of the real world is based on forming the input of parameters whose increase will reduce the DMU's efficiency and output of parameters whose increase will increase the DMU's efficiency (in natured of the input oriented DEA CCR CRS). The modeling concentrates on the university study course that aggregates investments of the resources as input parameters (teachers' costs, equipment costs and number of classes held) and produces types of skills and knowledge as output parameters. Model can be pictured as:

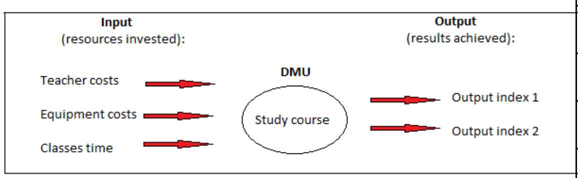


Figure 1. Model for DEA appliance

A. *Input/output definition*

The model is applied on study program of informatics (Faculty of Informatics, Goce Delcev University in Stip, RM, generation 2007), at 24 courses from all the semesters.

Input is consisted of:

- Number of classes held - classes load is often very important issue in terms of study program structuring, forming groups of students and organizing the real implementation of the course – **time component of the model**.
- Expenses that University had with equipment and inventory used for this study program. This is done by calculation of the degree of utilization in accordance with their gross purchase price and the legislation and considering the percentage of load / utilization in terms of number of students of the observed course and all students that used the same equipment – **material component of the model.**
- Expenses that University had of hiring professors and assistants, calculated in terms of gross salaries with consideration of the semester length (period of knowledge delivery) and the percentage of load in terms of number of students of the observed course and all students that the concrete teacher covered – **material component of the model.**

Output is consisted of:

- Index of the level of contribution of each course in skills, competencies and knowledge delivery, prescribed with the accreditation elaborate of the study program (**Index 1**). It is done through a massive survey and based on the official documents.
- Index of the quality of skills, competencies and knowledge delivered (**Index 2**) through the study program. This parameter, represented by the average grade of each course is calculated using the powerful e-index platform of Goce Delcev University, fully automated for students' e-administration.

B. *Total numbers and final DEA model*

The numerical DEA model is represented with table 2:

Table2. DEA model

(1)	(2)	(3)	DMUs / Courses	Index 1	Index 2
24	28737,71	83066,86	English language 1	3,5714285715	9,0227
168	31190,88	122253,1	Electrical engineering	3,910742855	7,8181
252	28737,71	87609,05	Math 1	3,928571429	7,1705
168	31190,88	105634,6	Programing	4,267857143	6,8522
24	25154,8	79832,87	English language 2	3,571428572	8,8160
252	24766,98	101473,2	Linear algebra	3,875	7,5568
252	27093,87	101473,2	Math 2	3,982171427	7,0795
168	27093,87	107276,6	Objective programing	4,267857143	7
108	31979,06	36434,47	Probability and statistics	3,785714286	6,943181
96	31979,06	78218,35	Digital logic	4,285714286	7,1136
60	218481,7	51455,4	Operational systems	3,875	7,7045
96	218481,7	131314	Software processes	3,964285714	7,2954
96	218481,7	117407,6	Data structures and algorithms	4,25	6,9545
96	154104,2	187273,8	Computer architecture	3,678571429	7,1477
96	227342,5	62070,34	Data bases	4,321428572	7,318181

72	118954,8	65492	Internet programing	4,339285715	7,2386
72	12381,86	62527,75	Microprocessors	3,571428572	6,7954
72	13413,68	64872,67	Software analysis and modeling	3,928571429	7,125
48	128867,7	65273,13	Graphics and visualization	4,160714286	8,1704
72	128867,7	95668,31	Multimedia	3,982142857	7,6931
72	87132,91	64428,28	Visual programing	4,339285715	7,0568
72	7203,188	90306,62	Intelligent systems	4,142857143	7,6931
72	7536,731	67004,76	Distant learning systems	3,196428572	7,60227
72	7536,731	57935,99	Software projects management	3,821428571	7,0113

III. DEA RESULTS

With processing of the input and output parameters in DEA software solution (there are many available open source applications that can be used for this purpose), results give picture of efficient and inefficient courses:

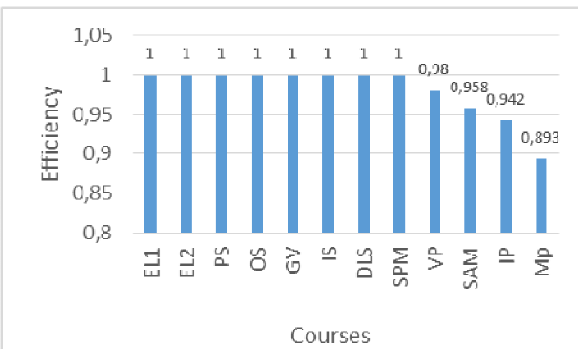


Figure 2. Efficiency of courses (part 1)

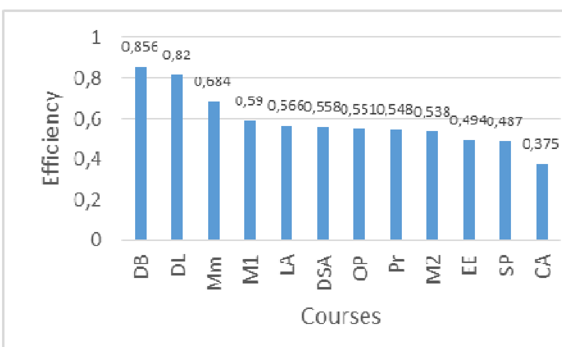


Figure 3. Efficiency of courses (part 2)

Courses with efficiency = 1 are noted as relativly efficient courses and are set of representative courses for the courses with efficiency bellow 1, noted as inefficient courses. Most efficient courses are used in most of the cases of composite courses. Table 3 shows number of use of every efficient course (consisting Efficiency Reference Set – ERS) in creating composite courses.

Table3 . ERS Courses (DMUs)

ERS Courses	Number of times used
English language 1	0
English language 2	6
Probability and statistics	**12**
Operating systems	2
Graphics and visualization	**10**
Intelligent systems	0
Distance learning management	0
Software projects management	**16**

Three courses are used most often in creating composite units: Software projects management, Probability and statistics and Graphics and visualization. This means that they form the "best" part of the frontier, or that they have the best resource allocation in this conditions and constellations. It is very interesting that it gives the **first "best from the best"** picture.

IV. AHP RESULTS

Having the first pool of efficient courses located with DEA at the first layer, we additionally applied AHP in order to sketch scaling of those courses (summary, eight courses) hand find the most efficient one (DEA treats all the efficient courses at same level). In this approach, both inputs (three) and outputs (two) are used as decision criteria in AHP application: Number of classes held (time component) (K1), Inventory and equipment expenses (K2), Teachers and assistants engagement expenses (K3), Level (index) of skills and knowledge achieved (K4) and Average study success (grades) (K5). The AHP alternatives are pictured in the eight DEA located efficient courses: English language 1 (A1), English language 2 (A2), Probability and statistics (A3), Operational systems (A4), Graphics and visualization (A5), Intelligent systems (A6), Distant learning systems (A7) and Software projects management (A8). Results from the expert analysis conducted are given in following. Abbreviations are used in the following text, respectively K1 to K5 for the criteria and A1 to A8 for the alternatives.

Table 4 shows estimates (judgments) and weights of criteria for selection with respect to the goal. Since, it can be seen that best ranked criteria with respect to the goal is the first criterion Number of classes held (lectures and exercises). Maximal eigenvalue λ_{max} is 5,065, consistency index CI is 0,016, consistency ratio

CR is 1,47%, because is lower than 10% level of inconsistency is accepted.

Table 4.Pairwise comparison matrix of the main criteria and weights with respect to the goal.

	K1	K2	K3	K4	K5	Weights
K1	1	3	2	4	2	0,3758
K2	1/3	1	1/2	1	1/2	0,106
K3	1/2	2	1	2	1/2	0,1759
K4	1/4	1	1/2	1	1/3	0,0918
K5	1/2	2	2	3	1	0,2505
Sum	2,58333	9	6	11	4,333333	

Table 5 shows estimates (judgments) and weights of alternatives for selection with respect to the first criterion Number of classes held (lectures and exercises). Since, it can be seen that best ranked alternative with respect to the first criterion is A1 (English language 1). Maximal eigenvalue λ_{max} is 8,649, consistency index CI is 0,092, consistency ratio CR is 6,62%, because is lower than 10% level of inconsistency is accepted.

Table 5. Pairwise comparison matrix for the alternatives and weights with respect to the first criterion.

	A1	A2	A3	A4	A5	A6	A7	A8	Weights
A1	1	3	6	5	5	7	4	7	0,3956619
A2	1/3	1	1	1	1	2	2	1	0,1002597
A3	1/6	1	1	2	1	2	2	3	0,1149405
A4	1/5	1	1/2	1	1	3	2	5	0,118669
A5	1/5	1	1	1	1	1	2	1	0,0862056
A6	1/7	1/2	1/2	1/3	1	1	3	1	0,0705822
A7	1/4	1/2	1/2	1/2	1/2	1/3	1	2	0,0585274
A8	1/7	1	1/3	1/5	1	1	1/2	1	0,0551536
Sum	2,43571	9	10,833	11,033	11,5	17,33	16,5	21	

Table 6 shows estimates (judgments) and weights of alternatives for selection with respect to the second criterion Inventory and equipment expenses. Since, it can be seen that best ranked alternative with respect to the second criterion is A1 (English language 1). Maximal eigenvalue λ_{max} is 8,833, consistency index CI is 0,119, consistency ratio CR is 8,51%, because is lower than 10% level of inconsistency is accepted.

Table 6. Pairwise comparison matrix for the alternatives and weights with respect to the second criterion.

	A1	A2	A3	A4	A5	A6	A7	A8	Weights
A1	1	3	3	5	5	3	2	5	0,3120172
A2	1/3	1	1	1	2	2	3	1	0,1212842
A3	1/3	1	1	2	3	4	2	3	0,1624815
A4	1/5	1	1/2	1	3	3	2	3	0,128012
A5	1/5	1/2	1/3	1/3	1	1	2	3	0,0774697
A6	1/3	1/2	1/4	1/3	1	1	3	1	0,0762466
A7	1/2	1/3	1/2	1/2	1/2	1/3	1	2	0,068037
A8	1/5	1	1/3	1/3	1/3	1	1/2	1	0,0544518
Sum	3,1	8,33333	6,9167	10,5	15,83333	15,33	15,5	19	

Table 7 shows estimates (judgments) and weights of alternatives for selection with respect to the third criterion Teachers and assistants engagement expenses. Since it can be seen that best ranked alternative with respect to the third criterion is A1 (English language 1). Maximal eigenvalue λ_{max} is 8,756, consistency index CI is 0,108, consistency ratio CR is 7,72%, because is lower than 10% level of inconsistency is accepted.

Table 7. Pairwise comparison matrix for the alternatives and weights with respect to the third criterion.

	A1	A2	A3	A4	A5	A6	A7	A8	Weights
A1	1	3	1	2	5	3	2	7	0,2520387
A2	1/3	1	2	1	2	4	3	5	0,1814465
A3	1	1/2	1	2	4	1	2	3	0,1613851
A4	1/2	1	1/2	1	3	3	2	6	0,1537709
A5	1/5	1/2	1/4	1/3	1	1	2	1	0,0623664
A6	1/3	1/4	1	1/3	1	1	3	1	0,0839693
A7	1/2	1/3	1/2	1/2	1/2	1/3	1	1	0,0590377
A8	1/7	1/5	1/3	1/6	1	1	1	1	0,0459855
Sum	4,00952	6,78333	6,5833	7,3333	17,5	14,33	16	25	

Table 8 shows estimates (judgments) and weights of alternatives for selection with respect to the fourth criterion Level (index) of skills and knowledge achieved. Since it can be seen that best ranked alternative with respect to the fourth criterion is A1 (English language 1). Maximal eigenvalue λ_{max} is 8,740, consistency index CI is 0,105, consistency ratio CR is 7,55%, because is lower than 10% level of inconsistency is accepted.

Table 8. Pairwise comparison matrix for the alternatives and weights with respect to the fourth criterion.

	A1	A2	A3	A4	A5	A6	A7	A8	Weights
A1	1	3	1	1	5	5	4	7	0,2473579
A2	1/3	1	2	1	4	4	5	5	0,1934338
A3	1	1/2	1	3	4	1	4	7	0,1937946
A4	1	1	1/3	1	3	3	2	6	0,1498853
A5	1/5	1/4	1/4	1/3	1	1	2	3	0,0583908
A6	1/5	1/4	1	1/3	1	1	3	5	0,0866942
A7	1/4	1/5	1/4	1/2	1/2	1/3	1	3	0,0472271
A8	1/7	1/5	1/7	1/6	1/3	1/5	1/3	1	0,0232163
Sum	4,12619	6,4	5,9762	7,3333	18,83333	15,53	21,333	37	

Table 9 shows estimates (judgments) and weights of alternatives for selection with respect to the fifth criterion Average study success (grades). Since it can be seen that best ranked alternative with respect to the fifth criterion is A1 (English language 1). Maximal eigenvalue λ_{max} is 8,580, consistency index CI is 0,0,82, consistency ratio CR is 5,93%, because is lower than 10% level of inconsistency is accepted.

Table 9. Pairwise comparison matrix for the alternatives and weights with respect to the fifth criterion.

	A1	A2	A3	A4	A5	A6	A7	A8	Weights
A1	1	2	1	1	3	2	4	5	0,2002668
A2	1/2	1	2	1	2	2	5	7	0,1865907
A3	1	1/2	1	3	1	2	4	7	0,1840198
A4	1	1	1/3	1	3	1	3	6	0,1511288
A5	1/3	1/2	1	1/3	1	2	2	5	0,1065591
A6	1/2	1/2	1/2	1	1/2	1	3	5	0,0996851
A7	1/4	1/5	1/4	1/3	1/2	1/3	1	4	0,0488041
A8	1/5	1/7	1/7	1/6	1/5	1/5	1/4	1	0,0229454
Sum	4,78333	5,84286	6,2262	7,8333	11,2	10,53	22,25	40	

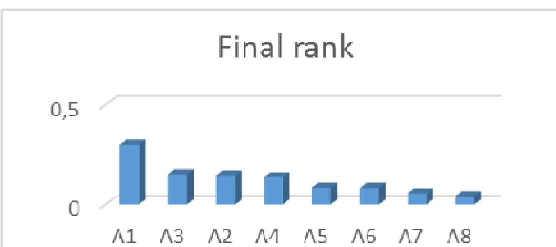
Table 10 summarizes the calculations for obtaining the final order which of the subjects is the most efficient and which is least efficient.

TABLE 10. Summing to obtain the final result

		A1	A1 x K	A2	A2 x K	A3	A3 x K	A4	A4 x K	A5	A5 x K	A6	A6 x K	A7	A7 x K	A8	A8 x K
K1	0,4	0,4	0,1487	0,10026	0,038	0,11	0,0432	0,1	0,0446	0,1	0,03239	0,1	0,02652	0,06	0,022	0,055154	0,021
K2	0,1	0,3	0,0331	0,12128	0,013	0,16	0,0172	0,1	0,0136	0,1	0,00821	0,1	0,00808	0,07	0,0072	0,054452	0,006
K3	0,2	0,3	0,0443	0,18145	0,032	0,16	0,0284	0,2	0,0271	0,1	0,01097	0,1	0,01477	0,06	0,0104	0,045985	0,008
K4	0,1	0,2	0,0227	0,19343	0,018	0,19	0,0178	0,1	0,0138	0,1	0,00536	0,1	0,00796	0,05	0,0043	0,023216	0,002
K5	0,3	0,2	0,0502	0,18659	0,047	0,18	0,0461	0,2	0,0379	0,1	0,0267	0,1	0,02497	0,05	0,0122	0,022945	0,006
Sum			0,299		0,147		0,153		0,137		0,0836		0,0823		0,056		0,042

Following the analysis and calculations using AHP method, it can be concluded that the most efficient course is English language 1 and less efficient one is Software projects management. The final ranking of the courses is show in figure 4.

Figure 4. Final rank for the most efficient subject



This combined application of both AHP and DEA methods allow obtaining clear ranking of courses and addressing the lack of equally effective courses that appeared after obtaining to the results of the application of the DEA technique.

V. CONCLUSION AND DISCUSSION

In this paper we developed integrated approach based on DEA and AHP methodologies. The purpose of the application of these two techniques was to determine the most efficient courses of study program in Informatics. For this goal, DEA technique is initially applied, using resources invested in terms of material and time component as input. Furthermore, output is consisted of the outcome of study program conduction, such as knowledge and its quality gained. The DEA results gives clear picture of summary eight equally efficient courses. To overcome this condition of equally effective courses and getting a more accurate ranking of courses, AHP method was applied. As selection criteria, AHP used inputs and outputs from DEA DMU's. Alternatives which the election was conducted over were those eight equally efficient courses. After corresponding calculation, we obtained final ranking that shows the inequality between equals. In the final order the most efficient course was English language 1 and the least efficient was Architecture of computers.

REFERENCES

Charnes, A., Cooper, W.W., Lewin, L. A., Seiford, M. L., "Data Envelopment Analysis, Theory, Methodology and Applications", Kluwer Academic Publishers, Norwell, Massachusetts, 1994

Taha, Hamdi A., "Operational research, Introduction", Pearson Education, Inc., 2007

Cooper, W. W., Seiford, M. L., Zhu, J., "Data Envelopment Analysis: History, Models and Interpretations", Springer, NY, USA, 2011

Charnes, A., Cooper, W.W., Rhodes, E., "Measuring the Efficiency of Decision Making Units", North-Holland Publishing Company, 1978

Wang, Y., Liu, J. and Elhag, T.M. (2008) 'An integrated AHP-DEA methodology for bridge risk assessment', Computers & Industrial Engineering, Vol. 54, No. 3, pp.513–525.

Yang, T. and Kuo, C. (2003) 'A hierarchical AHP/DEA methodology for the facilities layout design problem', European Journal of Operational Research, Vol. 147, No. 1, pp.128–136.

Satty, T. L. (1980). The Analytic Hierarchy Process. McGraw-Hill International Book Company.

Sinuany-Stern, Z., Mehrez, A. and Hadad, Y. (2000), An AHP/DEA methodology for ranking decisionmaking units. International Transactions in Operational Research, 7, pp.109-124.

Vaidya, O.S. and Kumar, S. (2006), Analytic hierarchy process: An overview of applications, European Journal Of Operational Research, 169 (1), 1-29.

Saaty, T.L. (1986), 'Axiomatic foundation of the analytic hierarchy process' Management Sciences 32 7 841 855.