INTEGRATION OF TWO-SIDED EVALUATION OF A STUDY PROGRAM TOWARDS A SINGLE QUALITATIVE REPORT

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Abstract: Quality assurance in higher education is a complex multifaceted process. Based on the legislative in the European Higher Education Area (EHEA) and worldwide, it is focused on the study program as pillar of the HE system that integrates the influence of all stakeholders regarding the quality in itself. After completion of the study program, graduates are provided with the appropriate qualifications defined with the study program official approval (which is decision for accreditation from the state officials). In order to be as efficient as it is possible, it has to be directly related to two important topics in terms of qualifications delivery: what types of qualifications are delivered (types and their essence) and how are those qualifications delivered (what methods and techniques are used)? The answer of the question what is delivered is related to the substantive (essential) aspect of the study program, referring to the qualifications that are expected to be gained in terms of skills, knowledge and competencies at the very end of the study process. The answer of the question how the qualifications are delivered is related to the teachers themselves and their work during the classes, their engagement, technologies used, methods applied, specific approach etc. The qualifications that are evaluated in this work are part of the elaborate for accreditation of the study program as official document, showing exactly what is to be expected essentially from each graduate in terms of qualifications gained. On the other side, the criteria referring to the methodological part of the study program (how things are done) are part of broader analysis in another research, dealing with qualitative assessment work and model proposals related to the teachers work. There are really many aspects and criteria describing the methodological aspect of the teachers work. Related to this paper, four are evaluated: planning and organization activities, encouraging practical application of the study program during the course, application of new technologies, approaches and tools in teaching (digital per se) and direct support of the student, such as readiness to mentor each student. The idea is to combine these aspects (substantial and methodological aspect of the study program) towards generation of one single quality report. Both aspects are evaluated using optimization MCDM technique Analytic Hierarchy Process (AHP) related to a specific study program, that enables transition from qualitative to quantitative aspect, with objectivity included, thus enabling data processing and generating readable reports. One basic assumption in this paper is that the importance of the substantial and methodological part of the study program conduction is equal, meaning they equally participate in the process of formation of the educated stuff. But, the model itself proposes possibility of different approach towards their importance, depending on the needs and the estimates. At the very end, results are combined in one final report showing the efficiency scale of the courses related to the both aspects evaluated with the AHP method, leading to conclusions about the individual and also, overall efficiency of the study program.
Keywords: AHP – Analytic Hierarchy Process, QA –Quality Assurance, HE – Higher education, EHEA – European Higher Education Area

1. INTRODUCTION

Evaluation in higher education includes broad scope of parameters and stakeholders defining the level of quality, that usually is with pretty general definition. This research is based on proposing a model for evaluation of study program courses with application of Analytic Hierarchy Process (AHP) as Multi Criteria Decision Making (MCDM) technique, used towards determination of two qualitative aspects regarding the courses: substantive aspect and methodological aspect of the study program courses. Substantive (or essential) aspects refers to the question what qualifications in terms of skills, knowledge and competencies are delivered within the study program. Methodological aspect refers to the questions how those qualifications are delivered through the classes, teacher engagement, methods and technologies used, teaching approach applied etc. The model proposed is focused on determination of the level of fulfilment (contribution) of several criteria regarding to the both aspects of evaluation, by each course. The research is conducted as a case study on real study program. Students that are in the final study year or were recently graduated were included in the evaluation questionnaires, as they have the freshest memories about what and how they learned through the study program. By networking contribution levels of the courses regarding the two aspects of evaluation for each course – each aspect with four criteria, with the importance of those criteria, final quality report is generated regarding to both the substantive and methodological aspect of the study program (each course) and final QA courses list, that can be used for further optimization or data processing, if greater modeling is applied.

2. MATERIALS AND METHODS

The multi-criteria programming made through the use of the analytic hierarchy process is a technique for decision making in complex environments in which many variables or criteria are considered in the prioritization and selection of alternatives or projects. AHP is used to transform the comparisons that are usually empirical, into numerical values that can be processed easily in further steps. Given two criteria i and j, decision maker returns a value a_{ij} as a 1-9 value, reflecting the preference of i in relation to j. Responses creates the pair-wise matrix A with $i > j$, if i is preferred to j. Reciprocals are calculated following the positive and reciprocal aspect of the pair-wise matrix: $a_{ij} = a_{ji}^{-1}, a_{ij} > 0$ and $a_{ij} = 1$ for $i = j$. Matrix data are then used in several steps calculations to determine the relative criteria's weights, consistency check and choosing the best alternatives.

AHP hierarchy is consisted of:

- Goal – what is the final aim of the analysis / question to be answered
- Criteria (and sub criteria) – what are the criteria that decisions are depending on, and
- Alternatives – what are the possible alternatives that the best one will be chosen from.

The criteria are compared pair – wise with respect to the set goal. The judgment matrix A – pair-wise $n * n$ matrix is generated with the pairs of each hierarchy level elements' comparisons - criteria or alternatives (reference point of comparison is element that appears higher in hierarchy).

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

Comparison is done using the Saaty's Nine-Point Preference Scale:

Table 1. Saaty's Nine-Point Preference Scale

Scale	**Compare factor between element i and element j of A**
1	Equally important
3	Weakly important
5	Strongly important
7	Very strongly important
9	Extremely important
2,4,6,8	Intermediate values

Source: Gass, S. (2001). The Analytic Hierarchy Process-An Exposition. Operations Research

Using the Saaty method (normalized arithmetic means), normalized matrix $B = [b_{ij}]$ is obtained with elements:

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (2)$$

Calculation of the vector with the criteria's weights $W = [w_i]^T, i = 1, \ldots, n$ from normalized B is performed by calculating the arithmetic mean for each row of the matrix:

$$w_i = \frac{\sum_{j=1}^{n} b_{ij}}{n} \quad (3)$$

Given the fact the decision makers are always inconsistent in their preferences, weights vector must satisfies the following equation:

$$AW = \lambda_{max} W \quad (4)$$

Maximum Eigenvalue $\lambda_{max} \geq n$ ($\lambda_{max} = n$ for ideally consistent matrix) of the pair-wise comparison matrix A can be calculated from the following formulas:

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(Aw)_i}{w_i} \quad (5)$$

Consistency Index (CI) and Consistency Ratio (CR) are calculated as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1}, CR = \frac{CI}{RI} \quad (6)$$

RI denotes the average random index with the value obtained by different orders of the pair – wise comparison matrices are shown in Table 2. If the value of CR ≤ 0.10 (10%), the level of inconsistency is acceptable and the judgements are consistent. If inconsistency is bigger, judgements need to be re-conducted.

Table 2. Random consistency index

N	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0	0,52	0,89	1,11	1,25	1,35	1,40	1,45	1,49

Source: Gass, S. (2001). The Analytic Hierarchy Process-An Exposition. Operations Research

Model synthesis as final step begins with matrix of alternatives and criteria $[ak_{ij}]$ where ak_{ij} refers to the quantification (value) of the alternative i regarding to the criterion j (local preference regarding each alternative is denominated). The final alternative weight $aw_i, i = 1, \dots, m$ is calculated with:

$$aw_i = \sum_{j=1}^{n} ak_{ijNOR} w_j, i = 1, \dots, m \quad (7)$$

Where NOR stands for normalized element related to the preferred value (minimum or maximum) of the alternative's columns' values regarding to each criterion separately.

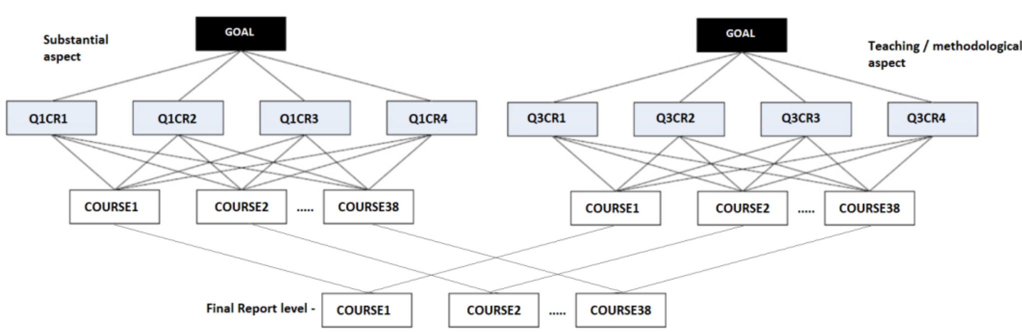
3. RESULTS

The case study was conducted at the study program Computer science and technology at the Faculty of Computer Science, Goce Delcev University in Stip, NMK, enrolled in year 2017 & 2018. 23 out of 47 initially enrolled students from generation 2017 and 38 out of 76 initially enrolled students from generation 2018 studied with no delay and were surveyed and a total of 81 forms were completed. Four questionnaires were conducted:

- Substantive (essential) aspect of the study program:
  - Q1: Importance of the qualifications provided with the study program;
  - Q2: Level of contribution of Q1 criteria by each course;
- Methodological aspect of the study program:
  - Q3: Importance of the teaching/methodological quality criteria;
  - Q4: Level of contribution of Q3 criteria by each course.

AHP model is shown in Figure 1, respecting the goal, criteria and alternatives to be selected (found the best one) from).

Figure 1. AHP evaluation hierarchy / model



Source: Authors research

Q1 is conducted on a representative sample of 19 ICT companies, domestic and foreign (management, CTOs, CEOs, PMs, senior developers), sizes between 20 and >5000, asking to assess the level of importance/need of the provided qualification (Table 3 / Section 1) one in relation to the other, from the labor market perspective, using nine-layer scale for construction of the Pair-wise matrix (Table 4, i=1) where VOI_{ij} refers to the Value of Importance of qualification Q1CRI over Q1CRJ. Q1 enables the feedback from the labour market about the real need market has from the qualifications accredited and delivered with the study program.

Q2 is conducted between the students, enabling the feedback from their perspective about the level of contribution each course (out of 38 analyzed) has achieved within the study process, related to the qualifications provided. The question for each course was constructed (Table 5, i=1) where LOC_i refers to the Level of Contribution of the course analyzed in Q1CRI and

$LOC_i \in \{No\ contribution = 1, Little\ contribution = 2,\ Significant\ contribution = 3, Big\ contribution = 4, Great\ contribution = 5\}$ for $i = 1, \ldots, 4$.

Q3 is conducted between the students, asking to assess the level of importance of the methodological/teaching quality criteria chosen for this research (Table 3 / Section 2) as important criteria defining the quality of teaching and methodological approach during the class, one in relation to the other, using the AHP nine-layer scale for construction of the Pair-wise matrix (Table 4, i=3).

Q4 is conducted between the students, enabling the feedback from their perspective about the level of contribution each course has achieved within the study, related to the teaching/methodological quality criteria. The question for each course was constructed (Table 5, i=3).

Table 3. Generic and specific qualifications

Section 1		**Section 2**	
Type of qualification	**Qualification description**	**Teaching quality criteria**	**Criteria description**
Generic qualification	Q1CR1 - Knowledge and understanding	Planning and organization	Q3CR1 – Teaching activities planning, organization and realization based on the students' needs
Generic qualification	Q1CR2 - Ability for evaluation	Practical work	Q3CR2 – Realization of teaching by encouraging practical application of the course content / working with practical examples
Specific qualification	Q1CR3 - Application of knowledge and understanding	New educational technologies	Q3CR3 - Application of new educational technologies, resources, approaches and tools in teaching (digital and other)
Specific qualification	Q1CR4 - Learning skills	Student support	Q3CR4 – Guiding, supporting and mentoring students / availability for individual work with the teacher

Source: Authors research

Table 4. Pair-wise matrix for the qualifications' criteria (i=1 for Q1 and Q2, i=3 for Q3 and Q4)

	QiCR1	**QiCR2**	**QiCR3**	**QiCR4**
QiCR1	VOI_{11}	VOI_{12}	VOI_{13}	VOI_{14}
QiCR2	VOI_{21}	VOI_{22}	VOI_{23}	VOI_{24}
QiCR3	VOI_{31}	VOI_{32}	VOI_{33}	VOI_{34}
QiCR4	VOI_{41}	VOI_{42}	VOI_{43}	VOI_{44}

Source: Authors research

Table 5. Course contribution level

Contribution level assessment of the course COURSENAME in:	**Level of contribution**
QiCR1	LOC_1
QiCR2	LOC_2
QiCR3	LOC_3
QiCR4	LOC_4

Source: Authors research

Based on Q1 and the questionaries' results, priority vector for the study program qualifications is generated (Table 6). As it is shown, inconsistency is 1,314%, which enthrones the valuables received from the labour market, assessing Q1CR4 = Learning skills as most important and Q1CR2 = Ability for evaluation as least important. Based on Q3 and the questionaries' results, priority vector for the qualitative teaching/methodological criteria is generated (Table 6). As it is shown, inconsistency is even smaller, 1,026%, which proves the results are objectively correct. Q3CR2 – Practical work is assessed as most important criteria and Q3CR1 is assessed as least important criteria from students' perspective.

Table 6. Priority vectors, qualifications and teaching criteria

Q1	**Criteria weights CI = 0,01314**	**Q3**	**Criteria weights CI = 0,01026**
Q1CR1	0,12913	**Q3CR1**	0,12206
Q1CR2	0,10492	**Q3CR2**	0,39905
Q1CR3	0,28972	**Q3CR3**	0,15940
Q1CR4	0,47622	**Q3CR4**	0,31949

Source: Authors research

Table 7 integrates multiple results:

- Q1CR1-4 are the average evaluations of each course contribution regarding the qualification criteria;
- Q3CR1-4 are the average evaluations of each course levels of achievements regarding the teaching/methodological qualitative criteria;
- S1 is synthetized AHP model for the substantial aspect of the study program;
- S2 is the synthetized AHP model for the teaching/methodological aspect of the study program, and
- FR is the final report.

Table 7. Synthesized models S1 and S2, Final Report FR

Course	**Sem**	**Q1CR1**	**Q1CR2**	**Q1CR3**	**Q1CR4**	**Q3CR1**	**Q3CR2**	**Q3CR3**	**Q3CR4**	**S1**	**S2**	**FR**
Introduction in computer science	1	3,29	3,00	3,20	3,20	3,27	3,36	3,05	2,77	0,71	0,69	0,70
Computer elements	1	2,39	2,29	2,18	2,35	2,75	2,61	2,67	2,50	0,51	0,58	0,54
Mathematics 1	1	3,88	3,74	3,87	3,87	4,24	4,04	3,67	4,17	0,86	0,90	0,88
Programming, basics	1	4,33	4,22	4,26	4,26	4,20	4,08	3,63	4,17	0,95	0,90	0,93
Discrete mathematics	1	4,00	3,85	4,10	3,80	4,58	4,35	3,87	4,74	0,87	0,99	0,93
Linear algebra	1	3,39	3,25	3,29	3,35	3,84	3,56	3,22	3,33	0,74	0,77	0,76
Digital logic	2	3,22	3,23	3,23	3,32	3,70	3,64	3,41	3,68	0,73	0,81	0,77
Mathematics 2	2	3,92	3,87	3,91	3,83	4,29	4,17	3,86	4,27	0,86	0,93	0,90
OOP	2	4,38	4,35	4,48	4,36	4,52	4,42	3,92	4,79	0,98	**1,00**	0,99
Algebraic structures	2	4,05	3,95	3,84	3,78	4,35	4,14	3,82	4,73	0,86	0,96	0,91
Informatics	2	3,95	3,95	3,89	3,94	4,10	3,72	3,78	4,00	0,88	0,86	0,87
Computer architecture	3	3,52	3,35	3,45	3,55	4,00	3,47	3,37	4,11	0,78	0,83	0,81
Software engineering	3	3,38	3,33	3,29	3,19	3,83	3,41	3,32	3,41	0,73	0,77	0,75
Data	3	4,22	4,26	4,04	4,17	4,36	4,08	3,88	4,67	0,9	0,9	0,9

structures and algorithms										3	5	4
Probability and statistics	3	3,82	3,71	3,86	3,86	4,26	4,13	3,83	4,43	0,86	0,93	0,90
Graph theory	3	3,59	3,47	3,53	3,53	3,89	3,94	3,44	4,22	0,79	0,88	0,84
Databases	4	4,48	4,50	4,23	4,50	4,28	4,29	3,96	4,67	0,99	0,97	0,98
Visual programming	4	4,04	4,00	4,09	4,18	4,08	4,26	4,04	4,00	0,92	0,92	0,92
Computer networks	4	4,17	4,04	3,96	4,00	4,48	4,42	4,04	4,50	0,90	0,98	0,94
Operating systems	4	3,50	3,52	3,43	3,62	3,72	3,50	3,50	3,83	0,79	0,81	0,80
Graphics and visualization	5	3,90	3,75	3,90	3,90	3,73	3,86	3,90	3,67	0,87	0,84	0,86
Internet programming	5	4,04	3,91	3,96	3,91	4,00	4,13	3,92	3,71	0,88	0,88	0,88
Information theory	5	3,53	3,58	3,53	3,53	4,10	3,90	3,75	4,40	0,79	0,90	0,85
Advanced algorithms	5	3,56	3,59	3,47	3,53	3,80	3,79	3,37	4,32	0,79	0,87	0,83
System software	5	3,46	3,46	3,62	3,62	4,07	3,93	3,93	4,07	0,80	0,89	0,85
Digital signal processing	6	3,73	3,86	3,87	3,87	4,24	4,13	3,80	4,47	0,86	0,93	0,90
Microcomputer systems	6	3,89	3,71	3,65	3,59	4,10	3,95	3,61	4,16	0,82	0,89	0,86
Basics of operational research	6	3,44	3,50	3,38	3,38	4,10	3,75	3,70	4,20	0,76	0,87	0,82
Mobile application development	6	4,31	4,46	4,38	4,46	4,25	4,29	3,85	3,85	0,99	0,91	0,95
Artificial intelligence	7	4,47	4,43	4,50	4,43	4,39	4,29	3,94	4,47	**1,00**	0,96	0,98
E-commerce	7	4,33	4,33	4,27	4,47	4,41	4,24	4,06	4,56	0,98	0,96	0,97
Data management and storage	7	3,77	3,50	3,58	3,83	3,93	3,50	3,58	3,83	0,83	0,82	0,83
Geoinformatics	7	3,91	3,91	3,73	3,75	4,13	4,08	3,83	4,25	0,84	0,91	0,88
Security of computer systems	7	4,25	4,25	4,13	4,13	4,22	4,13	4,07	4,31	0,93	0,93	0,93
Applied software engineering in real environment	7	3,85	3,92	4,00	3,85	4,33	4,08	4,15	4,62	0,87	0,96	0,92

Distributed computer systems	8	3,54	3,79	3,57	3,64	4,07	4,07	3,62	3,79	0,81	0,87	0,84
Information systems	8	3,20	3,21	3,29	3,07	3,78	3,75	3,75	3,73	0,71	0,83	0,77
Machine learning	8	4,33	4,25	4,33	4,42	4,47	4,27	4,07	4,53	0,97	0,97	0,97

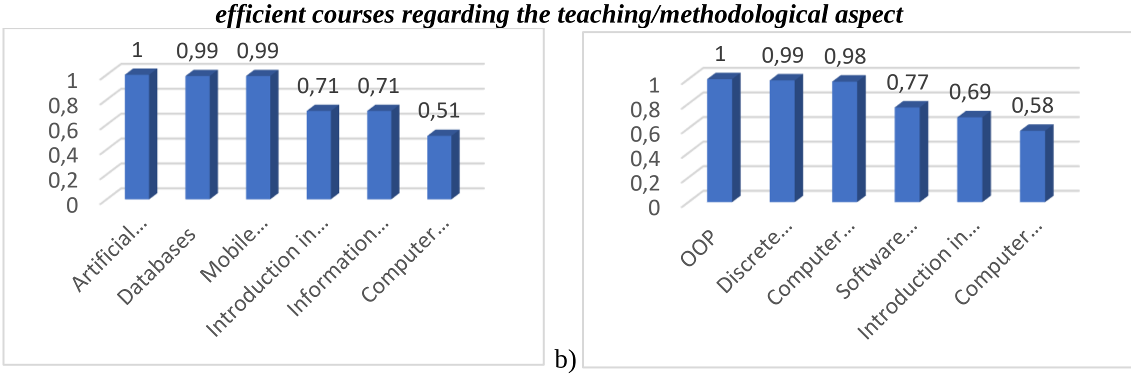
Source: Authors research

4. DISCUSSIONS

Given the results obtained within this research, it can be clearly noted that with the synthesized model S1, the course Artificial intelligence is noted as relatively most efficient and course Computer Elements as least efficient, regarding the contributions courses have in the four qualifications networked with the preferences of the labour market. Additionally, with the synthesized model S2, the course Object oriented programming is noted as relatively most efficient, and course Computer elements is note d as least efficient, regarding the achievements level with respect to the four qualitative criteria in terms of teaching quality and methodology aspects during the classes.
If it is assumed that both aspects of the study program courses evaluation are equally important, than relatively most efficient course is Object oriented programming (0,99), while Computer elements (0,54) is least efficient.

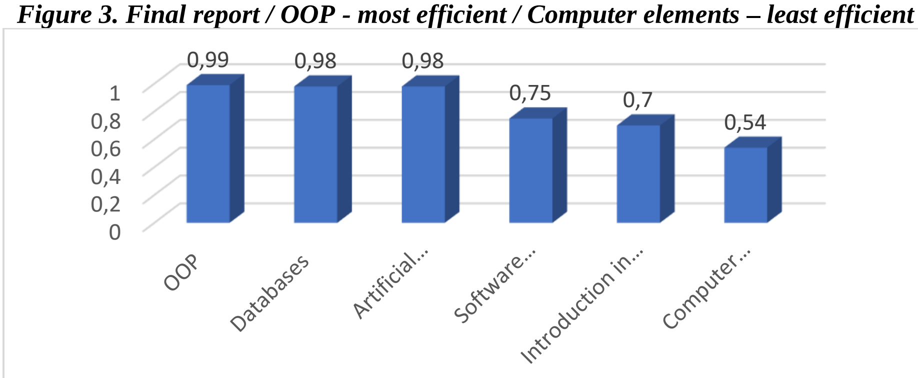
Figure 2. a) Three most and least efficient courses regarding the substantial aspect, b) Three most and least efficient courses regarding the teaching/methodological aspect

a) b)



Source: Authors research

Figure 3. Final report / OOP - most efficient / Computer elements – least efficient



Source: Authors research

5. CONCLUSIONS

Both final reports from the different aspects of the study program – substantive and teaching, as well as the final report can be analyzed to locate the less efficient courses, the difference level with the better courses and to suggest improvement steps, taking the relatively better courses as a reference. We used AHP in collaborative manner, trying to find the strong spots and use them as an example in what to be improved regarding the other courses.

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