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DEVELOPMENT OF AHP BASED MODEL FOR DECISION MAKING ON E-LEARNING IMPLEMENTATION

Nina Begičević, Blaženka Divjak, Tihomir Hunjak
University of Zagreb, Faculty of organization and informatics, Varaždin, Croatia
{nina.begicevic, blazenka.divjak, tihomir.hunjak}@foi.hr

Abstract: *Strategic planning of e-learning implementation includes decision making about the most suitable form of implementing e-learning on different levels. Decision making about e-learning implementation has been covered as consisting of four phases: (1) intelligence, (2) design, (3) choice and (4) implementation. During the Intelligence phase we have precisely identified our central decision problem and have conducted situation analysis. In the Design phase we have developed alternatives and established criteria and subcriteria. Then, we have created the questionnaire about the importance of the advantages and goals of e-learning implementation and about criteria and subcriteria essential for decision making. The survey has been conducted on the sample of 90 e-learning experts in Croatia. Further, we connected these findings with the results of the factor analysis which was performed on the complete survey. The results of the factor analysis have served as input in the multicriteria decision model (AHP) that we have developed in the Choice phase. The AHP model will be presented in the article and qualitative and quantitative evaluation of the model will be indicated.*

Keywords: *e-learning, mathematical modelling, decision making, Analytic hierarchy process.*

1. INTRODUCTION

E-learning has become a catalyst for change in teaching and learning. It supports skills needed in knowledge–based society, such as collecting, analysing and applying information appropriately and comprises different teaching methods, for example information management, creative thinking, critical thinking, problem solving and collaborative learning [2].

Every comprehensive university has a three folded mission: teaching, research and serving the society and therefore e-learning must take an active role in achieving these missions. It must fit in the new system and change the way of learning, teaching, researching and make business.

The universities in Croatia are currently at the stage of strategic planning and bringing decisions about the implementation of e-learning in the existing academic activities. Strategic planning and decision making about the e-learning implementation is one of the aims of Tempus EQIBELT project [11] coordinated by the University of Zagreb which provides useful platform for our research.

Strategic planning of e-learning implementation includes decision making about the most suitable form of implementing e-learning on different levels: state level, university level, faculty level and individual (students' and teachers') level.

There are different options for implementing e-learning in the teaching process. E-learning can be used as a means of support to the already established systems of education i.e. blended – learning model, it can also be partially introduced (for single subject or a group of subjects), or can be implemented as an independent form of teaching, in other words as a separate teaching programme.

Strategic planning and decision making about e-learning implementation has been covered as consisting of four phases: *(1) intelligence, (2) design, (3) choice* and *(4) implementation* [3, 4]. In this article we will consider first three phases and the accent will be put on the second phase. Fourth phase will be just commented and then investigated further in some other article.

2. FOUR PHASES OF DECISION MAKING ON E-LEARNING IMPLEMENTATION

As we mentioned above, there are four phases of strategic planning and decision making on e-learning implementation on the Croatian Universities.

During the Intelligence phase we have precisely identified our central decision problem and have performed situation analysis which has included a review and presentation of key facts and major trends concerning the problem stated. The tools that we have used were: Data Acquisition, Storage and Retrieval and Data analysis.

In the Design phase we have established alternatives, criteria and subcriteria. We have analyzed a lot of relevant sources, but the most important inputs for establishing the criteria and subcriteria and developing the theoretical model were e-learning strategic documents of leading EU universities which are referenced in the paper "Imaginative acquisition of knowledge-strategic planning of e-learning" to be included in the ITI 2006 Conference programme [2]. Based on the established criteria and subcriteria, we have developed a theoretical model for decision making on e-learning implementation. The developed theoretical model (criteria/subcriteria) is presented in Table 2 and details are given in the paper "Imaginative acquisition of knowledge-strategic planning of e-learning" [2]. The alternatives in decision making process on e-learning implementation on different levels are:

- ICT supported face-to-face learning,
- Blended learning and
- Learning that is entirely online.

Thereafter, we have created a questionnaire about the importance of the advantages and goals of e-learning implementation and about criteria and subcriteria essential for decision making about the e-learning implementation. The questionnaire was based on the set theoretical model. The survey has been conducted on the sample of e-learning experts in Croatia. First, the pilot survey was performed on the sample of 33 experts and the results were published in the paper "Imaginative acquisition of knowledge-strategic planning of e-learning" [2]. Then the sample was extended on the almost entire group of experts on e-learning in the higher education in Croatia and 90 questionnaires were collected and analyzed. In this paper the results of pilot study and the complete survey are related and explore.

Further, we connected these with the results of the factor analysis which was performed on the complete survey. The primary purpose of factor analysis was data reduction and summarization of the set theoretical model.

The results of the factor analysis have served as input in the third phase – the Choice phase. In the third phase we have developed multicriteria decision model - Analytic hierarchy process (AHP) which was based on the results of the factor analysis.

The fourth phase of the decision making will be the implementation of e-learning. The action plan and the control system will be included in the fourth phase. The tools that will be used are: Data Acquisition, Storage and Retrieval, Data analysis and Decision analysis.

3. DESIGN PHASE

3.1. QUESTIONNAIRE DESCRIPTION AND RESPONSE

The pilot survey had been conducted at the 1st Policy Workshop on Creating University E-Learning Vision and Strategy, held in March 2006 in Dubrovnik [11]. We have collected 33 questionnaires (explanation of each criteria/subcriteria was attached to the questionnaire). The sample and the results of that pilot survey have been published in the paper "Imaginative acquisition of knowledge-strategic planning of e-learning" [2].

After this pilot survey, we have carried out the complete survey. We have collected a total of 90 questionnaires (including 33 questionnaires collected at the workshop in Dubrovnik). The participants were experts on e-learning and university teaching in Croatia. Therefore, besides the experts from the pilot survey, additionally we have questioned vice-deans for teaching, development or quality improvement of faculties, schools and departments, members of EQIBELT project team and university strategy teams, the university teachers (professors, assistants), coordinators of CARNet reference centres for e-learning, members of the project team for standardization of e-learning materials established by CARNet, project managers of e-learning projects in CARNet [10], tutors in ELA (E - Learning Academy, CARNet) [10] and e-learning specialists in SRCE [12]. The criteria for the selection were expertise in e-learning and familiarity with the HE environment.

THE RESULTS OF THE COMPLETE SURVEY

In this section we present the results of the complete survey on the 90 experts on e-learning in the higher education in Croatia and compare them with the pilot survey.

In all questions the discrete scale for validation of importance was from 1 to 5. Figure 1 shows the ratings of advantages of e-learning implementation. In Figure 2 we can find the results of prioritizing of goals of e-learning implementation and Figure 3 ranks importance of criteria. Details about ranking of the proposed subcriteria are given in the Table 1.

The most important advantages of e-learning implementation are Accessibility of knowledge (average rating is 4,68), Flexibility of learning (4,48) and Preparation of students for lifelong learning (4,28). The lowest ranking advantage is Integration of the media for information dissemination and presentation with rating 3,97. There are slight changes from the pilot survey but the groupings (first three advantages and last three advantages) remain the same.

The highest ranking goals of e-learning are Improving the quality of educational process and learning outcomes (4,49) and Innovation and modernization of the higher education system (4,47). The goals Prepare students for lifelong learning (4,31) and Enable better and broader access to education (4,29) were also recognized as very important. The

lowest ranking goal is Implement European experiences and trends with rating 3,79. Again the groupings remain the same, but the rankings inside the first group are changed. Let us emphasize that the experts consider again, the improving the education quality as the most important goal of the e-learning implementation. It can be recognized as a sign of awareness that introduction of quality culture in Croatian higher education system is very important.

All proposed criteria were accepted as important, but four of them were ranked above the average mark of four. These criteria are Organizational readiness of environment (4,38), Development of human resources (4,28), Availability of human recourses (4,27) and Availability of basic ICT infrastructure (4,24). Legal and formal readiness of environment (3,94) and Availability of specific ICT infrastructure (3,74) are ranked below the average. This last ranking reflects the state of the art of e-learning in Croatia, which is generally below the EU level, and therefore the importance of legal framework and appropriate ICT infrastructure is not recognized. Comparing to the pilot survey, this complete survey respected more the availability and development of human resources and we find it much more in accordance with EU experiences.

In general, the results of the complete survey are very similar to the results of the pilot survey and that fact confirms the consistency of the performed research.

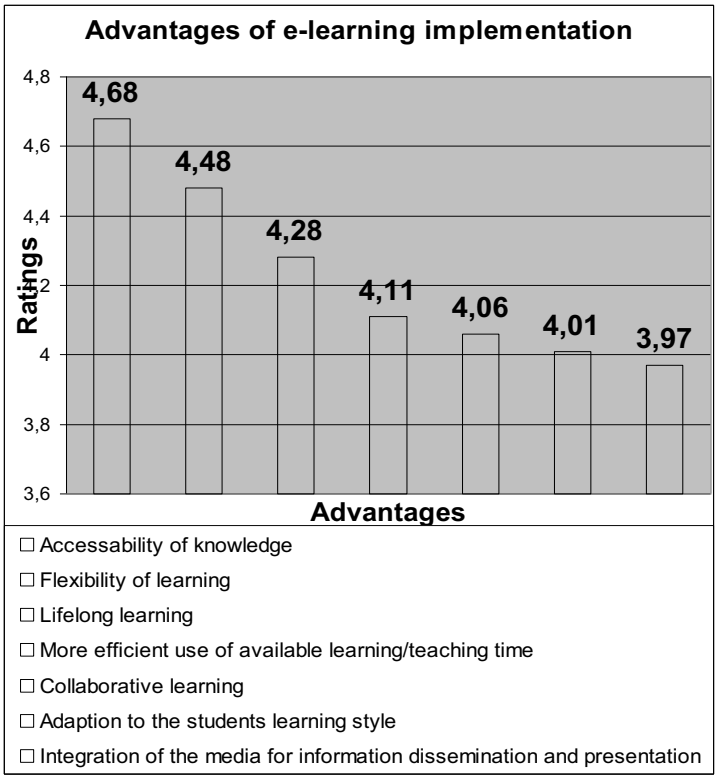

Figure 1. Advantages of e-learning implementation

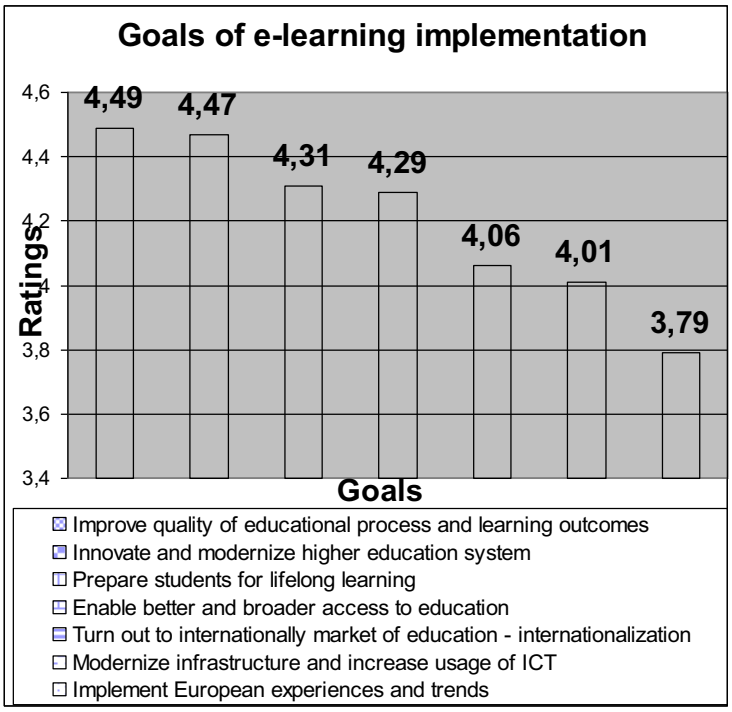

Figure 2. Goals of e-learning implementation

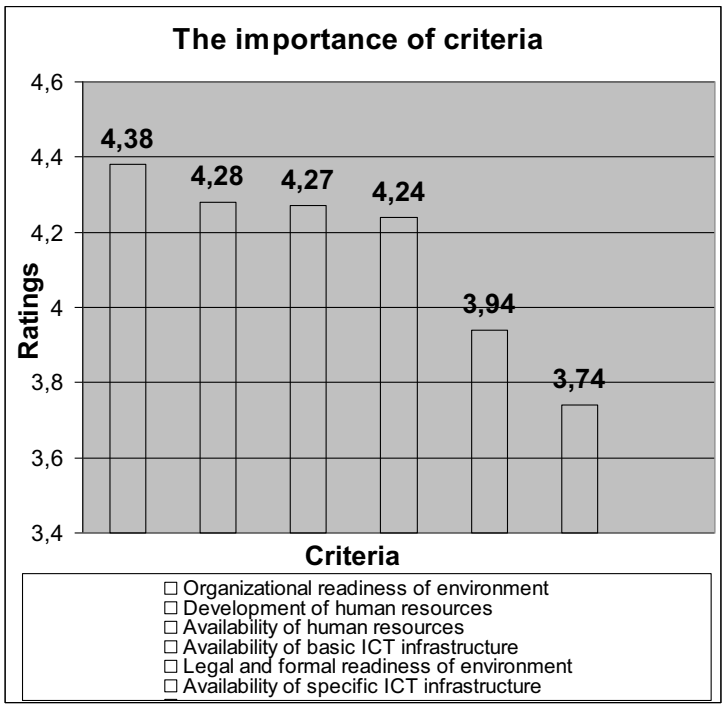

Figure 3. The importance of criteria

Table 1. The importance of subcriteria

ORGANIZATIONAL READINESS OF ENVIRONMENT	
Faculty strategy for development	4,54
Organizational readiness of universities/faculties for e-learning implementation	4,42
University framework for development	4,34
Financial readiness of universities/faculties for e-learning implementation	4,21
AVAILABILITY OF BASIC ICT INFRASTRUCTURE	
Network infrastructure	4,50
Teachers and students equipped with computers	4,43
Classrooms equipped for e-learning	4,17
Integral information system of universities/faculties	3,86
DEVELOPMENT OF HUMAN RESOURCES	
Continuous training of academic staff	4,63
Continuous training of support staff	4,17
Training of students for use of e-learning	4,04
LEGAL AND FORMAL READINESS OF ENVIRONMENT	
Evaluation and quality control at universities/faculties	4,20
System and criteria for academic staff promotion	4,04
Standardization of digital educational materials	4,03
Protecting intellectual property rights on state and academic level	3,49
AVAILABILITY OF HUMAN RESOURCES	
Specialized e-learning centres at universities	4,56
Availability of technical support staff for e-learning	4,36
Availability of support staff for graphical design, animation and video	4,09
Availability of support staff for methodology of e-learning	4,08
AVAILABILITY OF SPECIFIC ICT INFRASTRUCTURE	
Virtual learning environment (CMS, LMS, LCMS…)	4,31
Managed learning environment	4,06
Library management system	3,97
Production of video and audio materials	3,61
Network videoconferencing system	3,60
Exam management system	3,57
Video and audio streaming	3,49
Systems for simulation and virtual environment	3,32

THE RESULTS OF THE FACTOR ANALYSIS

In the design phase, we have also performed the factor analysis. We have connected the results of the complete survey with the factor analysis and the results of the factor analysis have served as input in the multicriteria decision model (AHP) that we have developed in the third phase.

Factor analysis is a generic term for a family of mathematical and statistical techniques that can simultaneously manage over a hundred variables, compensate for random error and invalidity, and disentangle complex interrelationships into their major and distinct regularities [9].

The main applications of factor analysis are: (1) to reduce the number of variables and (2) to detect structure in the relationships between variables.

We have used factor analysis to validate the theoretical model (Table 1), to reduce a large number of variables to a smaller number of factors for modelling purposes (AHP modelling), to specify the strength of the relationship between each factor and each variable and to determine which sets of items should be grouped together in the theoretical model. The complete results of the performed factor analysis are presented in the paper "Validation of theoretical model for decision making about e-learning implementation" [3].

The extraction method which was used in the factor analysis was Principal Component Analysis [6] and the rotation method was the orthogonal Varimax rotation [6] with Kaiser normalization. The number of factors was specified, m=5 (5 factors were recognized in the theoretical model). The factor analysis was performed with the support of the statistical program SPSS [6].

We set the lower boundary for projection of variable variance on the factor on 0.519 and noticed that 6 variables did not correlate above 0.519 with the principal components of the original correlation matrix and therefore we excluded them from the model. Moreover, 5 out of the above mentioned 6 variables relates almost equally to two or three factors. Finally, the new theoretical model was reduced to 21 variables [3]. Variables that are excluded were: Standardization of digital educational materials, Training of students for use of e-learning, Protecting intellectual property rights on state and academic level, Integral information system of universities/faculties, Virtual learning environment (CMS, LMS, LCMS…) and Organizational readiness of universities/faculties for e-learning implementation.

The factor analysis results have also confirmed 5 factors of the theoretical model for decision making about e-learning implementation:

- F 1 - Human resources (the criteria Development of human resources and Availability of human resources can be considered as one factor under the joint title Human resources)
- F 2 - Specific ICT infrastructure for e-learning
- F 3 - Basic ICT infrastructure for e-learning
- F 4 - Strategic readiness for e-learning implementation
- F5-Legal and formal readiness for e-learning implementation

Results of the factor analysis were very close to the structure of the set theoretical model in questionnaire for decision making about e-learning implementation and in that way the set theoretical model was justified. The performed factor analysis has confirmed the major findings of former data acquisition and analysis, but also has refined and better restructured our first theoretical model. The comparison of the theoretical model in the questionnaire (Table 1) and the reduced model, which was a result of the factor analysis, are presented in the paper "Validation of theoretical model for decision making about e-learning implementation" [3].

The reduced and restructured theoretical model (21 variables) has served as input in the multicriteria decision model (AHP) that we have developed in the Choice phase.

4. CHOICE PHASE

4.1. AHP METHOD

The Analytic Hierarchy Process (AHP) (Saaty, 1980) is a powerful and flexible decision making process which is helpful in setting priorities and making the best decision when both qualitative and quantitative aspects of a decision need to be considered [5].

AHP is one of the most widely exploited decision making methods in cases when the decision (the selection of given alternatives and their prioritising) is based on several criteria (sub-criteria). Complex decision problem solving, which this method uses, is based on the problem decomposition into a hierarchy structure which consists of the goal, the criteria, sub-criteria and the alternatives [7]. AHP method is implemented in program tool Expert Choice, in versions for individual and group decision making.

The method application can be explained in four steps [8]:

1. The hierarchy model of the decision problem is developed in such a way that the goal is positioned at the top, with criteria and subcriteria on lower levels and finally alternatives at the bottom of the model.
2. After the hierarchy has been determined, the decision makers begin the procedure of prioritising in order to determine the relative importance of elements on each level. On each hierarchy structure level, the pair-wise comparisons should be done by comparing all possible pairs of the elements of this level, starting with the top of the hierarchy and working this way to the lowest level. A pair-wise comparison in Expert Choice is the process of comparing the relative importance, preference or likelihood of two elements with respect to another element (the goal) in the level above.
3. On the basis of the pair-wise comparisons, relative significance (weights) of elements of the hierarchy structure is calculated. The calculation of relative priorities for each decision making element through a number of numerical calculations are made. Finally, these results are eventually synthesised into an overall priority list of alternatives. Decision maker is allowed to change preferences and to test the results if the inconsistency level is considered high.
4. Results are priorities of the alternatives in the form of priority list of alternatives and hierarchy tree with objectives' relative significance. The sensitivity analysis is also carried out. Sensitivity analysis is used to determine the sensitivity of the alternatives to changes in the objectives' priorities.

We will explain the second step using the mathematical induction. Let n be the number of criteria (or alternatives), which weights (priorities) w_i have to be determined on the basis of estimated values of their ratios $a_{ij}= w_i/w_j$. These ratios form the matrix A. In case of consistent estimates, i.e. where $a_{ij} = a_{ik}\ a_{kj}$ holds, the matrix A satisfies the equation $Aw=nw$. The matrix A has specific properties such as all its rows are proportional to the first row, all elements are positive and $a_{ij} = 1/a_{ji}$ holds. Therefore, only one of all its eigenvalues differs from zero and it is equal to n. If the matrix A contains inconsistent estimates, and it is so in all real cases, vector of weights w can be obtained by solving the equation $A-\lambda_{max}I\ w=0$ under the condition $\Sigma w_i = 1$, where λ_{max} is the biggest eigenvalue of the matrix A. Since $\lambda_{max} \geq n$, the difference $\lambda_{max} - n$ is used as measure of consistency of estimates. Using the consistency $CI = (\lambda_{max} - n)/(n-1)$ we calculate the consistency $CR=CI/RI$, where RI is random index i.e. consistency index of matrix of order n, randomly generated pair-wise comparisons.

If for the matrix A we have $CR \leq 0.10$, then the estimates of relative importance of criteria, and therefore prioritizing alternatives, are considered acceptable. In other case it have to be investigated why inconsistency of estimates is unacceptably high.

4.2. AHP BASED MODEL FOR DECISION MAKING ON E-LEARNING IMPLEMENTATION

In the Choice phase, we have developed AHP based model for decision making on e-learning implementation based on the reduced and restructured theoretical model (21 variables).

We have built the AHP model in TeamEC2000 software which is specially designed for making group decisions. TeamEC2000 software is based on the Analytic Hierarchy Process (AHP) and it helps groups to structure decisions into objectives and alternatives, prioritise using pair-wise comparisons, and justify decisions using graphical reports and sensitivity analyses.

The hierarchy tree and alternatives for our problem are shown in Figure 4.

The evaluation of set AHP model will be carried out in two ways. First approach is based on the qualitative analysis of similarity of the obtained results with implementation strategies of comparable European universities. The problem in this analysis is that the Croatian universities did not define their benchmark universities. Benchmark universities are a group of universities which we would like to compare ourselves. These comparable universities have to be identified on the university level as a result of serious institutional research and therefore this can not be obtained as the output of some individual research.

The second one is quantitative one in which as a sample, the group of the vice-deans/deans of faculties, schools and departments and the members of university bodies responsible for teaching, quality improvement or university development, will be used. These professionals have a responsibility to initiate and implement strategic decisions about the most suitable option for e-learning implementation at Departments/Faculties/Universities in Croatia.

The results of the group decision making incorporates knowledge of all the stakeholders in process of group decision making and will conclude with the recommendation for applying the most suitable option for implementing e-learning. This evaluation will be reported on in another paper.

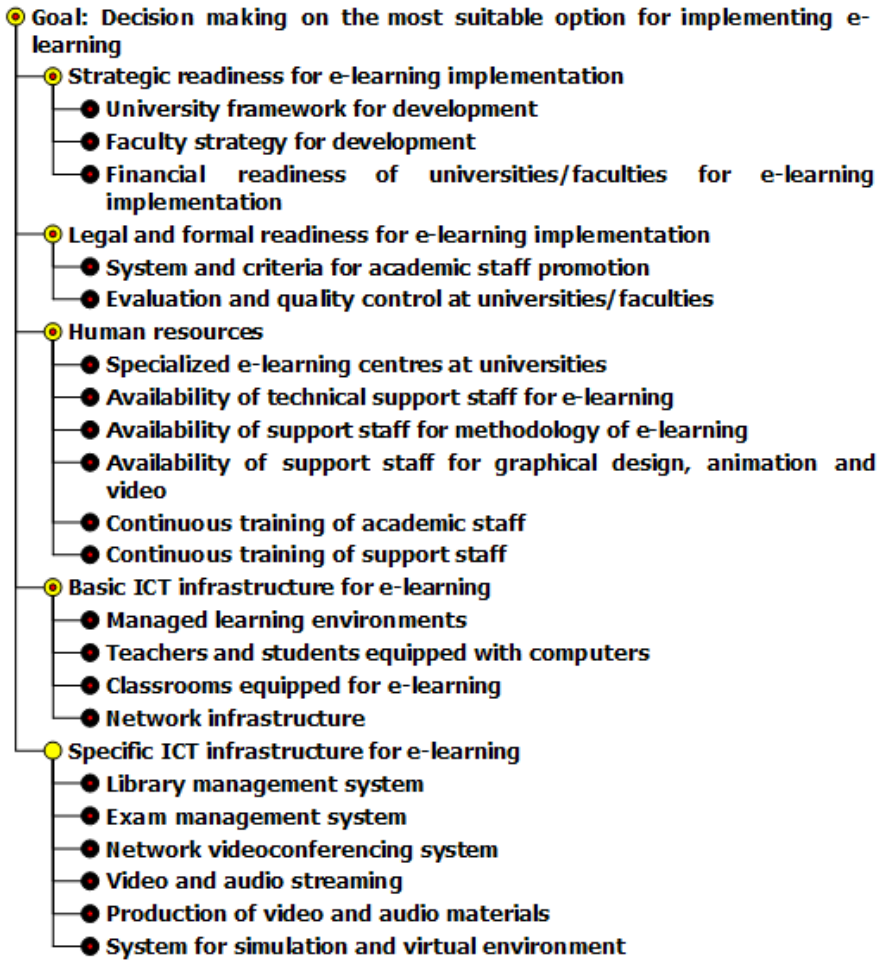

Figure 4. AHP based model for decision making on e-learning implementation

5. FURTHER RESEARCH

Next step of this research is evaluation of AHP model in quantitative and qualitative way. In process of quantitative evaluation, the results of evaluation, i.e. objective's relative significance, will be compared with the results of the ratings of criteria and subcriteria, obtained from the questionnaire.

Further, we intend to develop the ANP (Analytic Network Process) model for decision making about e-learning implementation in the higher education. The ANP method is an upgrade of AHP method and it is the most comprehensive framework for the analysis of societal, governmental and corporate decisions that is available today to decision-makers.

Finally, we have to record and analyze the final – the implementation phase and evaluate achieving of the implementation.

6. CONCLUSION

On the basis of 90 survey results and performed factor analysis we construct AHP based model for decision making on e-learning implementation. Organizational readiness, that includes university framework and faculty strategy for development, as well as financial readiness, was recognized as the most influential criterion for e-learning implementation. At the same time it can be identified as a weakness of most Croatian universities and faculties, since the strategic planning of university and faculty development has been systematically neglecting.

Furthermore, the criterion human resources was highly ranked as well. This criterion covers continuous training of academic staff, support staff and students. In the AHP model based on the factor analysis, the training of students for use of e-learning was excluded, and in our opinion it happened because of discrepancy between ratings given to those criteria by students and by teaching staff. The teachers have prejudice that students have grown up staying connected 24-hours 7 days a week and dismiss the fact that we have students with different students' background. The students' orientation sessions are important for widening access to HE.

Survey participants placed the basic ICT infrastructure much higher than specific ICT infrastructure and the factor analysis discovered that the managed learning environment inclined more to the basic than specific ICT infrastructure. But it also reveals the fact that Croatian universities still starve for basic ICT infrastructure.

Legal and formal readiness is in the AHP model but reduced to just two subcriteria (academic staff promotion and quality control), since the standardization of e-learning materials and intellectual property rights were not uniformly recognized as significant or insignificant.

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