ISAHP 2007, Viña Del Mar, Chile, August- 3-8, 2007

COMPARISON BETWEEN AHP AND ANP: CASE STUDY OF STRATEGIC PLANNING OF E-LEARNING IMPLEMENTATION

Nina Begičević
nina.begicevic@foi.hr

Blaženka Divjak
blazenka.divjak@foi.hr

Tihomir Hunjak
tihomir.hunjak@foi.hr

University of Zagreb
Faculty of Organization and Informatics
Pavlinska 2, 42 000 Varaždin

Keywords: e-learning, AHP, ANP, factor analysis

Summary*:*
The specific objectives of the paper are: validation of the theoretical model for strategic planning of e-learning implementation by means of factor analysis, presentation of the structure of AHP and ANP models for decision making about e-learning implementation, comparison between developed AHP and ANP models, analysis of the results of group decision making supported by sw TeamEC2000 based on AHP model and the results of decision making supported by sw Super Decisions 1.6.0. based on ANP model.
The models can be applied at the course level, for the group of courses (department level) or at the study program (faculty level). At the same time the proposed models are useful for structuring discussion on strategic decisions on e-learning implementation at the university level. Our aim is to analyze and identify advantages and disadvantages of using different models and tools in the process of decision making about e-learning at different organizational levels.

1. Introduction

E-learning is usually defined as a type of learning supported by information and communication technology (ICT) that improves quality of teaching and learning. Implementation of e-learning contributes to the advancement of higher education (HE). E-learning system is a powerful tool for achieving strategic objectives of the university (teaching, research and serving the society) and it contributes to the progress on the institutional level as well as the personal level, including both teaching staff and students (Divjak and Begicevic, 2006). It supports collecting, analyzing and applying information appropriately and comprises different teaching methods, for example information management, creative thinking, critical thinking, problem solving and collaborative learning (Bates, 2005).
Generally speaking, universities in Croatia and some other European universities are currently at the stage of strategic planning and deciding about the systematic 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 (EQIBELT, 2006) coordinated by the University of Zagreb, which provides useful platform for our research.
In our paper we will present the possibility of using AHP and ANP models and statistical techniques in strategic planning and decision making about e-learning.

2. Objectives and research methodology

The overall objectives of the research are:

- to provide basis for decision making for members of EQIBELT project team and university strategy teams in the process of creation of e-learning vision and strategic documents
- to develop the general model for decision making about e-learning implementation in the HE based on theoretical findings and surveys results
- to complete the factor analysis, validate the theoretical model and reduce a large number of variables to a smaller number of factors, i.e. designing the improved theoretical model for modeling purposes
- to develop the AHP and ANP model for decision making about e-learning implementation in HE
- to compare decision models for e-learning implementation in HE based on some other research methods or built on questionnaires including experts from other countries

The specific objectives of this paper are:

- presentation and analysis of the results of questionnaire performed on expert group
- presentation of the theoretical model for decision making about e-learning implementation in HE, by means of factor analysis
- developed structure of AHP model for strategic planning of e-learning implementation on course and department level
- presentation of the results of group decision making on e-learning implementation supported by sw TeamEC2000
- developed structure of ANP model for strategic planning of e-learning implementation on institutional level
- presentation and analysis of the results of expert decision making on e-learning implementation supported by sw Super Decisions

We have treated decision making as consisting of four phases: (1) intelligence, (2) design, (3) choice and (4) implementation. Details can be found in (Begicevic, Divjak, Hunjak 2006).
The alternatives in decision making process on e-learning implementation are:

- Face-to-face learning,
- ICT supported face-to-face learning,
- Blended learning and
- Fully online learning.

In the statistical evaluation of the results we have used factor analysis to validate the theoretical model for decision making about e-learning implementation.
We have connected the results of the survey with the factor analysis and these results have served as input in the multicriteria decision model (AHP) that we have developed and described in (Divjak and Begicevic 2006).
In the decision making phase we have solved the problem of choosing the best option for e-learning implementation. This problem was solved with the assistance of AHP model developed and validated in the process of group decision

making supported by sw TeamEC2000. We have also developed ANP model which was used for defining the structure of the strategies for e-learning on the institutional level. The action plan and the monitoring system have followed the decision making phase.

3. Questionnaire description and response

After we had developed the theoretical model for decision making about e-learning implementation, 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 alternatives were not included in the questionnaire, but explanation of each criteria/subcriteria was attached to the questionnaire.
We have carried out the survey and collected a total of 90 questionnaires. The participants were: vice-rectors, vice-deans, members of relevant university bodies, members of government bodies responsible for implementation of e-learning methodology and technology, members of EQIBELT project team and university strategy teams, university teachers and student representatives involved or interested in e-learning etc. The criteria for the selection of experts were: expertise in e-learning and familiarity with HE environment. In other words, a representative sample of e-learning experts in Croatia was surveyed.

4. The results of the survey: ranking of criteria and subcriteria

In this section we present some of the results of the survey on the 90 experts on e-learning in the HE in Croatia. The complete results of the performed survey are presented in the paper "Development of AHP based model for decision making on e-learning implementation" (Begicevic, Divjak, Hunjak 2006).
In all questions the discrete scale for validation of importance was from 1 to 5. 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*, *Development of human resources*, *Availability of human resources* and *Availability of basic ICT infrastructure*. *Legal and formal readiness of environment* and *Availability of specific ICT infrastructure* are ranked below the average (Figure 1). This last ranking reflects stage of development 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.
Details about ranking of the proposed subcriteria are given in the Table 1.

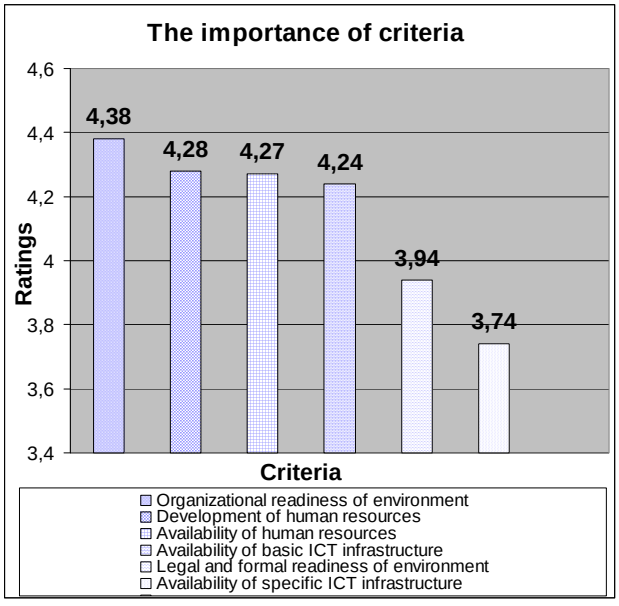


Fig. 1 The results of the survey - importance of criteria

Table 1 The results of the survey - 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	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

5. Results of the factor analysis

Factor analysis is a statistical data reduction technique that can simultaneously manage over a hundred variables, compensate for random error and invalidity, and disentangle complex interrelationships into their major and distinct regularities (Rummel, 1967). It is used to explain variability among observed random variables in terms of fewer unobserved random variables called factors.

We have used factor analysis to validate the theoretical model (Table 2), 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 (Begicevic and Divjak, 2006).

The extraction method which was used in the factor analysis was Principal Component Analysis (Brace et al., 2000) and the rotation method was the orthogonal Varimax rotation (Brace et al., 2000) 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 (Brace et al., 2000).

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 (Begicevic and Divjak, 2006). Experts did not agree upon importance of *Protecting intellectual property rights* and *Standardization of digital educational materials* and in our opinion it shows that in general the present state of e-learning implementation in HE in Croatia is at a rather early stage. Furthermore, the variables *Training of students for use of e-learning*, *Integral information system of universities/faculties*, *Virtual learning environment* and *Organizational readiness of universities/faculties for e-learning implementation* were excluded because of the redundancy with other variables in the theoretical model.

The factor analysis results have also confirmed 5 factors of the theoretical model for decision making about e-learning implementation (Table 2).

The factor analysis performed does not only confirm the major findings of prior data acquisition and analysis, but it also refines and better restructures our first theoretical model. We assume that there are two reasons for correspondence between the two models. Firstly, the fact that the qualitative analysis in the first part of research was thoroughly made on a considerable sample of strategic documents on e-learning implementation and, secondly, the use of experts in the survey. The latter was essential for this highly specific area which requires both familiarity with e-learning and expertise in the HE environment.

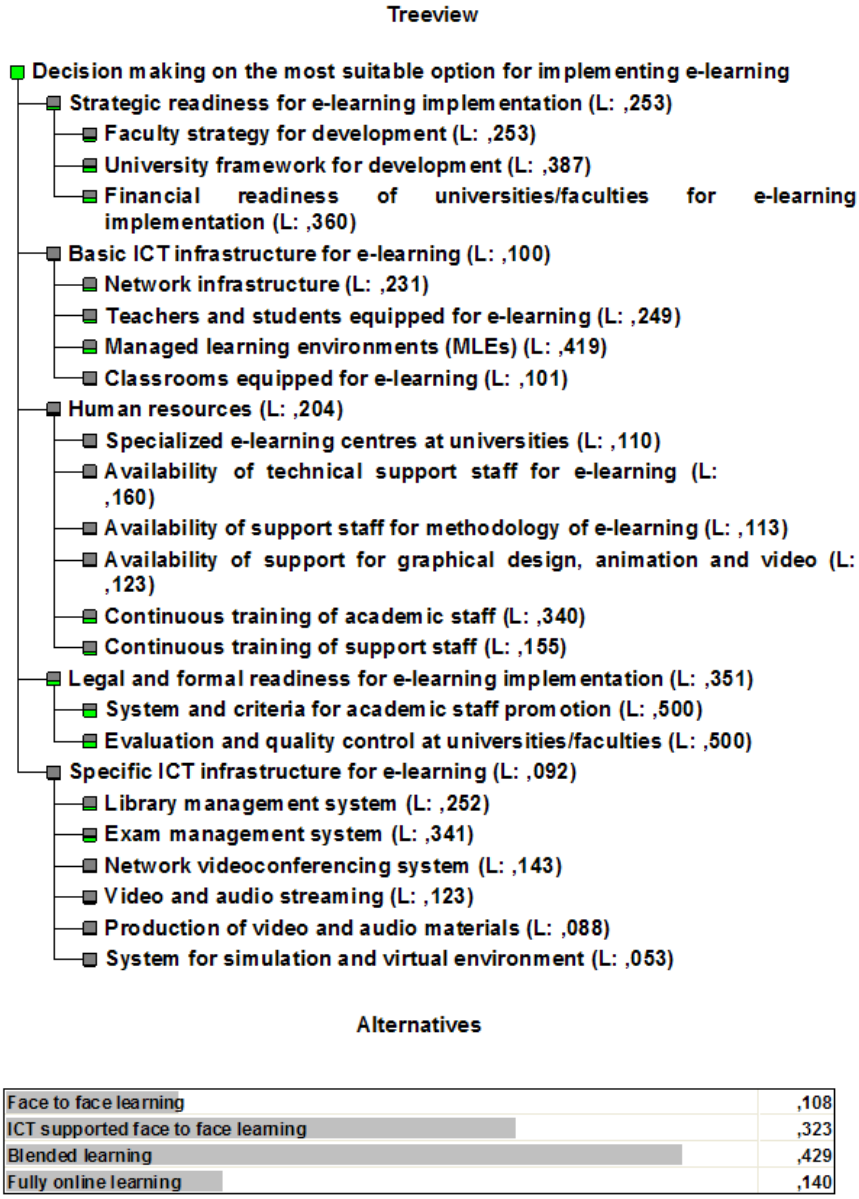
Table 2 The results of the factor analysis (*Rotated Component Matrix*)

	F 1	F 2	F 3	F 4	F 5
F1 - HUMAN RESOURCES					
Availability of support staff for methodology of e-learning	,883	3,415E-02	5,202E-02	-1,120E-02	-4,832E-02
Availability of technical support staff for e-learning	,835	6,881E-02	,119	2,543E-02	,103
Availability of support staff for graphical design, animation and video	,761	,118	9,200E-02	,105	1,353E-02
Continuous training of support staff	,709	,146	,164	,196	,106
Specialized e-learning centers	,652	-1,242E-03	,176	,206	4,064E-02
Continuous training of academic staff	,610	,175	,139	,238	,156
F 2 - SPECIFIC ICT INFRASTRUCTURE FOR E-LEARNING					
Video and audio streaming	-,196	,840	9,800E-02	-1,927E-03	,108
Network videoconferencing system	-5,610E-02	,806	,176	,204	,154
Systems for simulation and virtual environment	,265	,784	-9,944E-02	9,253E-02	,153
Production of video and audio materials	,214	,769	9,195E-02	-9,597E-03	-4,100E-02
Exam management system	,160	,609	,254	,136	-,101
Library management system	,242	,603	,179	9,750E-02	-,276
F 3 - BASIC ICT INFRASTRUCTURE FOR E-LEARNING					
Network infrastructure	,163	,193	,778	,107	3,312E-02
Teachers and students equipped with computers	,266	,105	,720	-6,693E-02	-1,287E-02
Classrooms equipped for e-learning	-3,167E-02	,183	,625	2,887E-02	,564
Managed learning environment	,268	,233	,528	,417	-,240
F 4 - STRATEGIC READINESS FOR E-LEARNING IMPLEMENTATION					
Faculty strategy for development	,191	3,302E-02	5,800E-02	,792	,154
University framework for development	9,796E-02	,282	-,100	,662	-3,168E-02
Financial readiness of universities/faculties for e-learning implementation	,194	-3,291E-02	,397	,558	7,218E-02
F 5 - LEGAL AND FORMAL READINESS FOR E-LEARNING IMPLEMENTATION					
System and criteria for academic staff promotion	,123	-9,182E-02	-4,377E-03	2,484E-02	,807
Evaluation and quality control at universities/faculties	,340	,251	6,778E-03	,289	,512

6. AHP based model for decision making on course level

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 (EC 2000) which is specially designed for making group decisions. We take in account that a group can generate a higher number of ideas and usually knows more than an individual does. It is also important that a group is more ready to bring riskier decisions, since risk is shared among all group members.
In our case of "Decision making on the most suitable option for implementing e-learning" for the course Mathematics on the Faculty of Organization and Informatics, we were using TeamEC2000 with wireless electronic keypads for 5 decision makers (participants) and top down structuring with numerical judgments mode. The model and the methodology can also be applied for the group of courses (department level).
All participants in the group decision making have specific knowledge which make them competent to assess and give judgments in the process of group decision making on the most suitable option for e-learning implementation on the course Mathematics on Faculty of Organization and Informatics.
The participants were equipped with the detailed instructions on definitions of criteria and subcriteria and tool that would be used, a week before the decision making event, in order to familiarize themselves with the task.
The competences of the group members are the following. One participant is associate professor and main lecturer at Mathematics, has Ph.D. in Mathematics and she is familiar with the strategic planning of e-learning at the Faculty and University level. Second participant is an assistant at Mathematics and has MA in Mathematics. Two other participants have MA in Information Science and they are PhD students. One of them is an assistant at Informatics and one is administrator of Learning Management System (LMS) at the Faculty of Organization and Informatics. Fifth participant is a student at Faculty and student tutor for Mathematics. During their studies and training, they have been several times included in lectures where e-learning was used as a support to the traditional classroom teaching. Four of them are involved in creating courses that integrate e–learning and traditional classroom teaching. All participants are working on e-learning projects. Three out of five are experts in programming and has experience in developing necessary infrastructure for implementation of e-learning courses. All participants are authors or co-authors of several scientific and professional papers in the area of e-learning.
These experts form a heterogeneous group of decision makers. The group possesses knowledge and responsibility to initiate and implement decision about the most suitable option for e-learning implementation at the course level. The results of the group decision making incorporates knowledge of all stakeholders in the process of group decision making and the process is concluded with the recommendation for applying the most suitable option for implementing e-learning.
Results of every participant's decision making and results of group decision making were available after the decision making event. Results of group decision making in TeamEC2000 i.e. hierarchy tree with objective's relative significance and priorities of the alternatives, gained by judgment synthesis of participants included in decision making process, are shown in Figure 2.
Criterion *Legal and formal readiness for e-learning implementation* has the highest relative significance – 0.351, which makes it the most important for reaching the goal. The reasons for enhancing significance of this criterion are efforts in HE system in Croatia for establishing academic staff promotion system for implementing e-learning, and for setting and implementing evaluation and quality control at universities and faculties in Croatia.
Criterion *Strategic readiness for e-learning implementation* was also recognized as very important with relative significance – 0,253. The lowest relative significance – 0,092 has the criterion *Specific ICT infrastructure for e-learning.*
Alternative *Blended learning* has the highest priority of 0.429, which means the recommendation is to apply blended-learning (hybrid) model, i.e. to the integrated e-learning and traditional classroom lectures, as the most convenient option for implementing e-learning at Mathematics on Faculty of Organization and Informatics. It is interesting that alternative *Fully online learning* has the higher priority (0,140) than alternative *Face to face learning* (0,108).

Fig. 2 The results of group decision making



7. ANP based model for decision making on institutional level

We have developed ANP based model with incorporated feedback structure for strategic planning and decision making on e-learning implementation for institutional level.

The model is based on the reduced and restructured theoretical model by means of factor analysis and the connections, interdependences and outer dependences have been reviewed by domain expert.

We have built the ANP model in Super Decisions software and the domain expert had also evaluated the model. On the Figure 3 there are presented clusters and nodes of a model for decision making on e-learning implementation on institutional level. The results of the validation are presented on the Figure 4.

Developed ANP model is used for structuring discussions on strategic decisions on e-learning implementation and decision making process for designing the strategy for e-learning implementation on the faculty and/or university level.

In our case of "Strategic planning and decision making on e-learning implementation on institutional level" the domain expert evaluated the model using Super Decisions with numerical judgments mode. The domain expert is a member of committee for e-learning strategy of University of Zagreb and member of committee for e-learning strategy of Faculty of organization and informatics. The results of decision making process, based on developed ANP model, were used for defining a structure of these strategies for e-learning on the institutional level.
There has been a crucial difference in way how we used AHP and ANP models. The AHP model was used for carrying out the recommendation for applying the most suitable option for implementing e-learning on the course or department level, but ANP model has been primary exploited for defining the structure of strategies for e-learning on the institutional level. The strategies, based upon developed ANP model, will be analysed in the implementation phase.
The Figure 4 presents clusters and elements with their priorities which have been crucial for structuring e-learning strategies and it can be said that these priorities have been a guideline for e-learning strategy creation and acceptance. The evaluation and quality control at universities and faculties has been recognized as very influential element in the process of strategic planning of e-learning implementation. Furthermore, the variables *Exam management system, Library management system* and *Systems for simulation and virtual environment* were identified as the most important in the frame of Specific ICT infrastructure for e-learning and *Managed learning environment* and *Teachers and students equipped with computers* within the frame of Basic ICT infrastructure for e-learning. The crucial points which must be taken into account in the process of strategic planning of e-learning implementation are establishment of the *Specialized e-learning centres* and *Continuous training of academic staff*. Alternative *Blended learning* has the highest priority and the alternative *ICT supported face to face learning* follows. At the end there is the alternative *Fully online learning*, which can be understand if we take into account that the University of Zagreb is old and traditional university which appreciates the face to face approach and pedagogies and considers the e-learning as a way to improve the quality of teaching and learning.

Fig. 3 Overview: The ANP network "Strategic planning and decision making on e-learning implementation on institutional level"

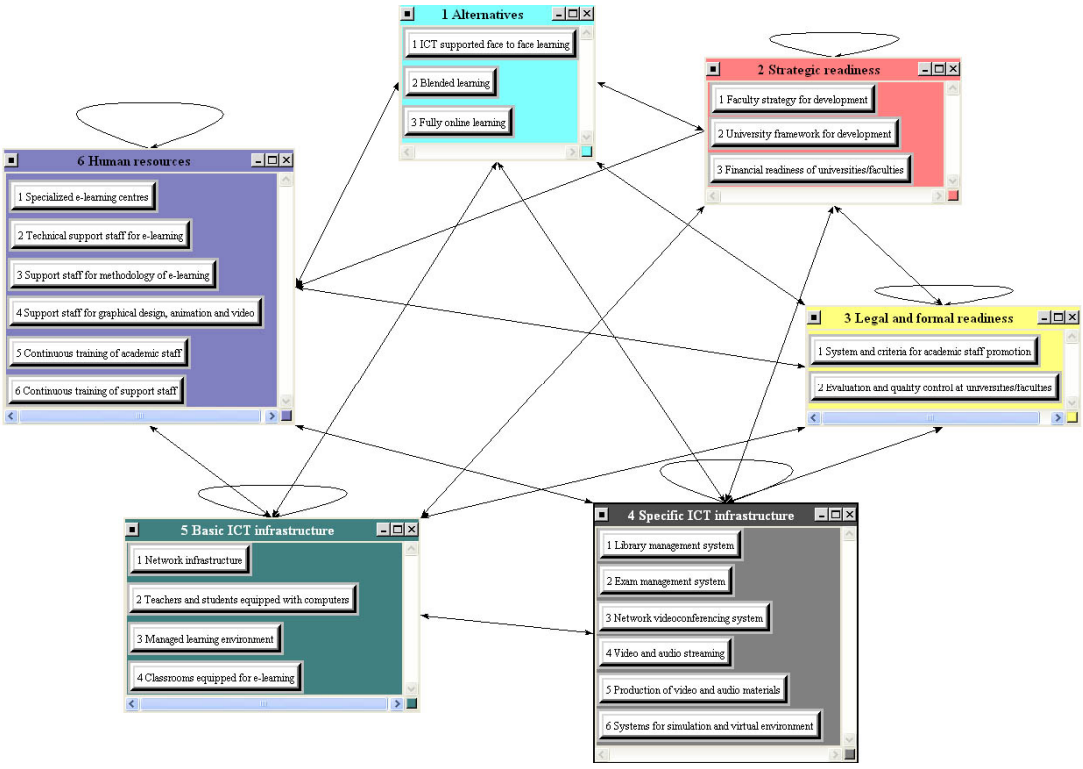
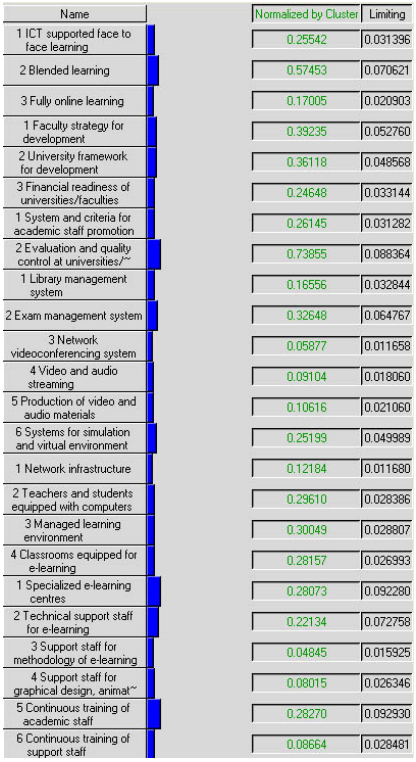


Fig. 4 The priorities of the elements



Name	Normalized by Cluster	Limiting
1 ICT supported face to face learning	0.25542	0.031396
2 Blended learning	0.57453	0.070621
3 Fully online learning	0.17005	0.020903
1 Faculty strategy for development	0.39235	0.052760
2 University framework for development	0.36118	0.048568
3 Financial readiness of universities/faculties	0.24648	0.033144
1 System and criteria for academic staff promotion	0.26145	0.031282
2 Evaluation and quality control at universities/~	0.73855	0.088364
1 Library management system	0.16556	0.032844
2 Exam management system	0.32648	0.064767
3 Network videoconferencing system	0.05877	0.011658
4 Video and audio streaming	0.09104	0.018060
5 Production of video and audio materials	0.10616	0.021060
6 Systems for simulation and virtual environment	0.25199	0.049989
1 Network infrastructure	0.12184	0.011680
2 Teachers and students equipped with computers	0.29610	0.028386
3 Managed learning environment	0.30049	0.028807
4 Classrooms equipped for e-learning	0.28157	0.026993
1 Specialized e-learning centres	0.28073	0.092280
2 Technical support staff for e-learning	0.22134	0.072758
3 Support staff for methodology of e-learning	0.04845	0.015925
4 Support staff for graphical design, animat~	0.08015	0.026346
5 Continuous training of academic staff	0.28270	0.092930
6 Continuous training of support staff	0.08664	0.028481

Alternatives	Total	Normal	Ideal	Ranking
1 ICT supported face to face learning	0.0314	0.2554	0.4446	2
2 Blended learning	0.0706	0.5745	1.0000	1
3 Fully online learning	0.0209	0.1701	0.2960	3

8. Conclusion

The results of the survey performed on group of experts on e-learning in HE were used as input for mathematical modeling. This modeling contributes significantly to institutional planning, management and quality development for online distance education and e-learning.

The problem of prioritization of e-learning options was solved with the help of multi-criteria modeling. The AHP model was developed and validated during the process of group decision making.

The ANP model was developed and then restructured during the process of reviewing the model by domain expert. The results of decision making process, based on developed ANP model, have been used for defining a structure of the strategies for e-learning on the institutional level.

Our experience shows that such models for decision making strongly motivate all participants in this process, speed up decision making, make the process more effective and serve as an indication of need for systematic e-learning usage in our educational institutions.

More details about the AHP model can be found on *www.projekti.hr* and the model can be used and tested in new situations just by acknowledging the authors.

REFERENCES

Bates T (2005) Strategy and Visions of e-learning in Higher Education, Zagreb, Croatia, URL: http://eqibelt.srce.hr/lectures/bates.html, 10.03.2006.

Begicevic N, Divjak B (2006) Validation of theoretical model for decision making about e-learning implementation. Journal of Information and Organizational Sciences, Faculty of Organization and Informatics, University of Zagreb, Vol. 30, No. 2, p. 171-185

Begicevic N, Divjak B, Hunjak T (2006) Development of AHP based model for decision making on e-learning implementation. 17th International Conference on Information and Intelligent Systems IIS 2006, Varaždin, Faculty of Organization and Informatics, University of Zagreb, p. 375-383

Brace N, Kemp R, Snelgar R (2000) SPSS for Psychologists: A guide to data analysis using SPSS for windows. New York, N.Y: Palgrave

Divjak B, Begicevic N (2006) Imaginative acquisition of knowledge - strategic planning of e-learning. ITI 2006 Proceedings of the 28th International Conference on Information Technology Interfaces, Cavtat, Croatia, p. 47-53

Rummel, R J (1967) Understanding Factor Analysis. The Journal of Conflict Resolution, URL: http://www.hawaii.edu/powerkills/UFA.HTM, 20.04.2006.

EQIBELT, Education Quality Improvement by E-Learning Technology. <http://eqibelt.srce.hr/>, 16.01.2006.