Application of Multi-Attribute Decision Making Approach to Learning Management Systems Evaluation

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***Abstract*—The article presents an approach to the development of multi-attribute decision making model that is based on DEX, an expert system shell for multi-attribute decision support. We demonstrate the applicability and flexibility of the approach presenting application of DEX in e-learning: assessment and evaluation of Learning Management Systems (LMS) where several conflicting objectives, like environmental, social and economic impacts, must be simultaneously taken into account. Decision analysis methodology can be of major assistance in tackling this kind of problem and has become the basis for developing and implementing better and better decision support models to try to overcome the increasing difficulties involved in complex decision making problems. With the multi-attribute decision making model, we illustrate its usefulness by showing its main features and its application to the above intervention problem.**

***Index Terms*—multi-attribute decision making, hierarchical models, function decomposition, e-learning, learning management system**

I. Introduction

Decision-making is undertaken everyday, in all walks of life, as a means of solving particular problems[1]. Many decisions are easily arrived at because the problem to be solved is trivial, for example “which shirt should I wear today?”. However, others are not, because the final decision needs to satisfy, simultaneously, a number of different stakeholders.

Some recent developments have made the hierarchical decision model approach very attractive also for problems in the field of *e-learning*. Parallel to the wide range of possibilities offered by new generations of educational technologies, a number of Learning Management Systems (LMSs) to support the e-learning have been developed and available at the market. Consequently customers are often faced with the dilemma how to choose the optimum technological environment for the implementation of education process for a definite target group. An increased demand for LMSs has redirected the research areas from traditional research topics, such as technical infrastructure and pedagogical innovations, to the study and analysis of *applicability, usability* and *adequacy* of LMSs, appropriate for different target groups, providing e-learning services: universities, companies and lifelong learning support organizations. Keenoy and Papamarkos in [1] define an LMS as a system supporting the creation, saving and presentation of subjects in a structured way. However, all LMSs are not appropriate for all environments and all users, due to their different functionalities. These are very complex systems which combine many organizational, administrative and technological components [2, 3]. Considering the abundance of LMSs it is not surprising that there has been growing interest in identifying design principles and features that can enhance user satisfaction. User satisfaction with technologies related to distance and collaborative learning applications [4] has been found to be significantly associated with usability, that is, the effectiveness, efficiency and satisfaction that it gives to its user in a given context of use and task. Despite the increased awareness of user satisfaction when adopting internet-based education, e.g., “Ref [5]”, the *applicability and usability* of LMSs has still not been sufficiently explored and solutions not yet provided.

These are some of the realizations that led us to perform the case study described in this paper and to analyse the results. The case study was undertaken as part of an EU project centered on the issues of introducing internet-based education in a region that suffers from a low level of business-oriented usage of the Internet and related e-learning together with a relatively high level of unemployment. We found the environment and the context of this study extremely suitable for an evaluation and assessment of the different Learning Management Systems.

[1] In this context, the term “problem” refers to a conundrum whose resolution depends on the choosing of one optimal decision from a set of two or more possible decisions.

Multi-attribute decision making method, which was taking as the base for the decision making model, is one of the decision-making support methods. The decision making model is based on a chosen list of criteria, parameters, variables or factors, which we wish to monitor in the decision making process [6]. The Multi-attribute decision making theory offers a formal base for the establishment of a model, in which the key criteria is the interconnectedness of assessments according to the individual parameters that result in an integrated assessment [7, 8]. Results of the case study can provide a better understanding of the development of multi-attribute decision making model and the cognitive mechanism underlying the observed effects and precise information about the tradeoffs in using task variants.

To achieve the proposed objectives, this paper is organized as follows: to begin, we will describe the theoretical framework which we have applied in this research [37]. We will present and describe multi-attribute decision support, a methodology aimed at the evaluation of options that occur in decision making processes. The applied method is followed by a description of the scenario and a study of the results. Finally, the chapter ends with a discussion of the overall results and conclusion remarks.

II. Hierarchical Decision Models

Decision making is a process of selecting a particular option from a set of possibilities, so as to best satisfy the aims or goals of the decision maker [9, 10]. In practice, the *options* (also called *alternatives*) are objects or actions of the same type, such as different computer systems, different people applying for a particular job, different investment strategies, and different e-learning technologies. Supporting humans in making complex decisions has long been a goal of many researchers and practitioners. A number of methods and computer-based systems have been developed [11]. They are mainly studied in the framework of decision support systems [12, 13, 14], operations research and management sciences, decision theory [15] or decision analysis [16].

One of the approaches to decision support, which is widely used in practice, is *multi-attribute* decision making [27, 7]. The basic principle is a decomposition of the decision problem into smaller, less complex subproblems (“Fig. 1”).

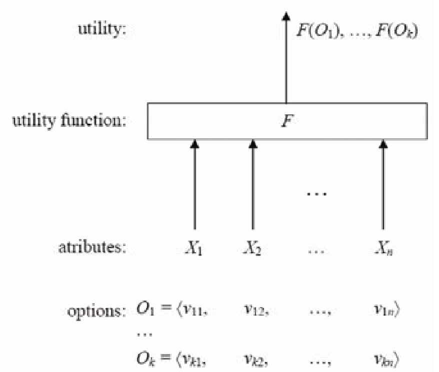

Figure 1. General concept of multi-attribute decision making [19].

Options are decomposed onto different dimensions X, usually called *attributes*, *parameters* or *criteria*. According to this decomposition, each option O is first described by a vector of values v of the corresponding attributes. The vectors are then evaluated by a *utility function F*. This function should be previously defined by the decision maker(s), representing his, her or their *goals*. When applied upon a particular option O, the function F yields a *utility* $F(O)$. According to this value, the options can be ranked and/or the best one chosen. In the multi-attribute paradigm, the decision makers' *knowledge* about a particular decision problem is therefore *described* by *attributes X* and a *utility function F*. In addition, there is a data base of *options*, consisting of vectors v.

The methodology of hierarchical decision models has been developed and extensively applied in relation to decision support [17]. There, the decision-makers are often faced with the problem of choice [18]: to choose an option from a set of available options so as to best satisfy the decision-maker’s goals. In complex real-life decision processes, the problem of choice can be extremely difficult, mainly because of complex, interrelated or even conflicting objectives. To support the decision-maker, a decision model is designed to evaluate the options. Also, it can be used for the analysis, simulation, and explanation of decisions. In practice, this approach has been most often used for technical or economical decision problems, such as project or investment evaluation, portfolio management, strategic planning, and personnel management.

The contribution to these fields has been the development of an expert system shell for multi-attribute decision support DEX [19]. DEX itself is designed as an interactive *expert system shell* that provides tools for building and verifying a knowledge base, evaluating options and explaining the results. The structure of the knowledge base and evaluation procedures closely correspond to the multi-attribute decision making paradigm. This makes the system specialized for decision support [8]. The development of multi-attribute decision making model is presented in more detail below.

A. Knowledge Representation in DEX

A particular *knowledge base* of DEX consists of (1) a tree of attributes and (2) utility functions (“Fig. 2”).

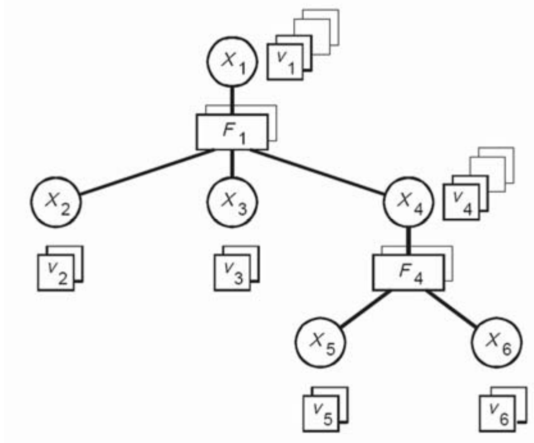

Figure 2. Tree of attributes with utility functions and options [19].

A *tree of attributes* represents the structure of a given decision problem. The attributes are structured according to their interdependence: a higher-level attribute depends on its descendants (sons) in the tree. Leaves of the tree, referred to as *basic attributes*, depend solely on the characteristics of options. Internal nodes of the tree are called *aggregate attributes*. Their values are determined on the basis of utility functions. The most important aggregate attribute is the root of the tree. Its purpose is to represent the overall *utility* of options. *Utility functions* define the process of aggregation of lower-level attributes into the corresponding higher-level fathers. For each aggregate attribute X, a utility function F that maps values of sons of X into values of X, should be defined by the decision maker.

Utility functions are represented by *elementary decision rules*. Let $X_1, X_2, ..., X_k$ be the sons of an aggregate attribute Y. Then, the function $Y = F(X_1,X_2,...,X_k)$ is defined by a set of rules of the form

$$\textbf{if } X_1 = x_1 \textbf{ and } \ldots \textbf{ and } X_k = x_k \textbf{ then } Y = y_m : y_M,$$

where x_i, y_m and y_M represent the values of the corresponding attributes. "$y_m : y_M$" stands for an interval of values between y_m and y_M, inclusive. Most commonly, y_m:y_M is a single-value interval. In this case, the rule is simplified to

$$\textbf{if } X_1 = x_1 \textbf{ and } \ldots \textbf{ and } X_k = x_k \textbf{ then } Y = y.$$

Sets of elementary decision rules are grouped into tables. In case when more decision making *groups* with different objectives are involved in the decision process, each group can define their own set of utility functions. In "Fig. 1", two such groups are assumed. *Options* are represented by the values of basic attributes, i.e. by values v_1, v_2, …, that are assigned to the leaves of the tree. In "Fig. 1", two options are assumed. Regardless of the number of groups, there can be only one value v_i assigned to a basic attribute for each option.

In the final stage of the decision making process, the above described components of the knowledge base are utilized in order to *evaluate options*, i.e. to determine the values of the root and the remaining aggregate attributes in the tree. Since there can be more than one group of utility functions, the evaluation process can result in several sets of aggregate evaluation results, as shown by separate sets of squares in "Fig. 2".

III. Development of the Multi-Attribute Decision Support Model

In this section we present the approach to the development of qualitative hierarchical decision model that is based on the DEX shell. It helps in the creation of decision models that consist of non-numerical (qualitative) criteria. The criteria are hierarchically ordered into a tree structure. The weights are replaced by rules that define the interdependence of the criteria and their influence on the final evaluation. Thus the influence of a criterion can depend on its value, which corresponds in utility theory [7, 8, 15] to the variability of the weights [20]. The qualitative hierarchical decision model is based on a chosen list of criteria, parameters, variables or factors, which we are going to monitor in the decision making process [21].

The decision making process was divided into five phases: (1) identification of the problem, (2) criteria identification and criteria structuring, (3) utility function definition (decision rules), (4) description of variants and (5) LMS evaluation and analysis. Individual decision making phases are presented in more detail below.

A. Identification of the problem

In accordance with the fact that human resource development has been recognized as one of the most important elements for the further development of modern societies, the current demands for new knowledge and skills has constantly increased. Parallel to the wide range of possibilities offered by new generations of educational technologies, a number of Learning Management Systems (LMSs) which support e-learning have been developed and are available on the market.

Learning Management Systems (LMS) are systems that support the creation (via authoring tools), storage (for example in a relational database) and presentation (often via a web browser) of learning materials in a structured way. They also include 'tracking' tools that allow for record-keeping on students enrolled in courses, and usage statistics for the system as a whole (one of the most important of these being statistical analysis of students' responses to questions, which enables validation of testing on the system).

Consequently, customers are often faced with the dilemma of how to choose the optimum LMS for the implementation of the education process for a definite target group. Precisely defined strategy in the sense of "who and what", sets the basis for further decision making and usability evaluation: *"Does the LMS gives proper and sufficient support for the execution of the exercises which lead to the planned objective realization"*. The usability evaluation then presents the real value of the system, its effect on communication, the anticipated benefits for the owner and user, and justification for the investment [37].

Recent studies of student perceptions of online education point to a number of benefits, such as convenience and flexibility, greater motivation to work, better understanding of the course material, more student communication, and immediate and extensive feedback. Some studies also note some of the disadvantages of a Web-based education, such as technical, logistical and *usability problems*, some frustration, lack of instructor interaction, etc.

The general aim of our case study was focusing on the usability and applicability aspects of LMSs in relation to definite target group and users: employees in the Drava-Mura Region SMEs with a basic knowledge of ICT.

The case study was done within the project titled »Creating innovative learning environment, e-skills and competences development for supporting the promotion of Informal education in Lifelong Learning« or in short E-VINTER. The project was launched after the call for proposals of the Phare 2003 – Economic and Social Cohesion – Lifelong learning programme for the Slovenian regions in the fall of 2004.

B. Identification, Description and Criteria Structuring

This section provides descriptions of criteria which are the components of the decision making model. When creating this model we tried to meet the requirements set by "Ref. [6]". We have taken into account the principle of *criteria integrity* (inclusion of all relevant criteria), *appropriate structure*, *comprehensiveness, non-redundancy*, and *measurability* [22]. Comprehensiveness means that all the data about the subject are actually present in the database. Non-redundancy means that each individual piece of data exists only once in the database. Appropriate structure means that the data are stored in such a way as to minimize the cost of expected processing and storage [23].

The criteria are divided into three main scopes: *Student's learning environment, System, technology & standards and Tutoring & didactics.* These three scopes represent the skeleton of the multi-attribute model. The criteria can include the following values: 'low', 'average' or 'high'; the only exception being the criteria where it is impossible to determine an intermediate value. All values have an increasing range (low value is worst than high value). The first group of criteria is merged into the *Student's learning environment* category composed of four basic attributes: *Ease of use, Communication, Functional environment and Help.* Web-supported communication tools and new technologies ensure and promote continuous communication and interaction processes between tutors and education participants. Information infrastructure enables *synchronous* and *asynchronous communication,* which is why the best LMSs combine both. The second group of attributes is merged into the *System, technology & standards* category. These groups of criteria are assessed through the basic attributes of *Technological independence, Security and privacy, Licensing & hosting* and *Standards support.* The attribute of technological independence is used for the evaluation of an LMS from the prospective of its technological accessibility, which is a pre-condition that has to be met if we wish to talk about system applicability and efficiency. The *Security and privacy* criterion focuses on two issues: *User security and privacy* and *security and privacy of an LMS.* User security and privacy should be at the forefront of attention; therefore an LMS must keep communication and personal data safe and avoid dangers and attacks on user computers. Application security and privacy assessment is made using authentication, authorization, logging, monitoring and validation of input. It is also important to consider *e-learning standards* – standards for description of learners' profiles and standards for the description of learning resources [24]. In the context of e-learning technology standards are generally developed to be used in system design and implementation for the purposes of ensuring interoperability, portability and reusability, especially for learning resources as they require for their preparation qualified professionals and are very time demanding [25]. Third group of criteria is merged into *Tutoring & didactics*. The tutor's quality of environment is assessed using the *Course development, Activity tracking and Assessment* criteria. Activity tracking undoubtedly provides important support to the tutor in the learning process. Here we have focused on monitoring students in the process of learning and the possibility of displaying students' progress, analysis of presence data, sing-in data and time analysis. "Fig. 3" presents the tree of attributes for assessment the applicability of LMSs.

Figure 3. Tree of attributes for assessment the applicability of LMSs.

C. Utility function

The *tree of criteria* defines the structure of the evaluation model by defining the criteria and their interdependence. In the final outcome, this means that the overall evaluation of the LMSs depends on 57 criteria. On the other hand, the criteria tree does not define the aggregation, i.e., the procedure that combines the values for the final evaluation. In DEX, the aggregation procedure is defined by *decision rules,* an example of which is shown in “Fig. 4”.

The rules determine the evaluation of the criterion, *Student’s learning environment,* based on four criteria: *Ease of use*, *Communication*, *Functional environment*, and *Help.* The first five rules determine the conditions by which the *Student’s learning environment* is evaluated as unsuitable (low grade). This is for example whenever: the LMS does not conform to ease of use, communication and help (regardless of the evaluation of the remaining criteria, denoted by an asterisk) (rule 2). On the other hand for example the *Student’s learning environment* is suitable (high grade) whenever the LMS respects the ease of use criterion at least on the average level (average grade) and the quality of the attributes communication, functional environment and help assessment are high (rule 6). The remaining rules can be interpreted similarly, with the symbols <= and >= representing "worse or equal" and "better or equal", respectively.

	Ease of use	Communication	Functional environment	Help	Student's learning environment
	39%	29%	21%	11%	
1	low	low	<=average	*	low
2	low	low	*	low	low
3	low	<=average	low	*	low
4	low	<=average	<=average	low	low
5	<=average	low	low	low	low
6	>=average	*high*	*high*	*high*	*high*
7	*high*	>=average	>=average	*high*	*high*
8	*high*	>=average	*high*	*	*high*
9	*high*	*high*	*	*high*	*high*
10	*high*	*high*	>=average	*	*high*

Figure 4. Utility function for criterion Student’s learning environment.

Obviously, there are many more such rules in the model. For each aggregate criterion (such as *Student’s learning environment),* a similar table is defined. In the entire model there are 108 rules defined in this way.

The tables were defined by a group of experts at the Jožef Stefan Institute using the DEX computer system. Experts contributed the contents of the rules, and the system made sure that the tables were complete (covering all possible combinations of the evaluation criteria) and consistent (an improvement of a single lower-level criterion could never decrease the overall value of the LMS). Decision rules therefore define the conditions under which an LMS is ranked.

D. Description of variants

The multi-attribute decision making model was tested on three LMSs: *Blackboard 6* (www.blackboard.com), *CLIX 5.0* (www.im-c.de) and *Moodle 1.5.2* (www.moodle.org). Blackboard is among the most perfected and complex LMSs on the market. The system offers various communication options (both synchronous and asynchronous) within the learning environment. The Blackboard LMS is designed for institutions dedicated to teaching and learning. Blackboard technology and resources power the online, web-enhanced, and hybrid education programs at more than 2000 academic institutions (research university, community college, high school, virtual MBA programs etc. CLIX is targeted most of all at big corporations, because it provides efficient, manageable, connected and expandable internet-based learning solutions. This scaleable, multilingual and customizable software aims at providing process excellence for educational institutions. For educational administrators, CLIX offers powerful features for course management and distribution. Additionally, it provides personalized learning paths for students, a tutoring centre for lectures and a whole bunch of innovative collaboration tools for both user groups, e.g. a virtual classroom. Altogether, CLIX makes planning, organizing, distributing, tracking and analyzing of learning and teaching a smooth and efficient process. Moodle is a free, open source PHP application for producing internet-based educational courses and web sites on any major platform (Linux, UNIX, Windows and Mac OS X). The fact that it is free of charge is especially attractive for schools and companies which always lack resources for the introduction of new learning technologies. Furthermore, the Moodle system is not only price-efficient – it can easily be compared to costly commercial solutions on all aspects. Courses are easily built up using modules such as forums, chats, journals, quizzes, surveys, assignments, workshops, resources, choices and more. Moodle supports localization, and has so far been translated into 34 languages. Moodle has been designed to support modern pedagogies based on social constructionism, and focuses on providing an environment to support collaboration, connected knowing and a meaningful exchange of ideas. The greatest disadvantage of Moodle is certainly support to e-learning standards, which is reflected on “Fig. 5”, showing evaluation results according to different assessment criteria for Blackboard, CLIX and Moodle.

E. LMS Evaluation and Analysis

After the knowledge base has been built, the second main part of DEX, i.e. *evaluation and analysis* of options, can be applied. At the beginning, the user activates a specialized editor of options in order to describe the options by assigning the corresponding values to basic attributes (Fig. 5). After this, DEX automatically evaluates the options.

The analysis of the results can follow which consists of one or more of the following activities [26]:

1. *Interactive inspection* of the results by "walking" around the tree and looking at the values that were assigned to aggregate attribute during the evaluation.
2. *Explanation* of the evaluation: DEX can explain how each particular value has been obtained in terms of attributes' values involved in the process, triggered rules and descriptions of computations performed by DEX.
3. *What-if* analysis is performed interactively by changing values of basic attributes, reevaluating options and comparing the obtained results with the original ones.

4. *Selective explanation* of options: DEX finds and reports those subtrees that expressed the most advantageous or disadvantageous characteristics of a particular option. The main point is in the explanation of options using only the most relevant information.

In the design of DEX, one of the most important goals was the transparency to the user. For this reason, the user can access a powerful *report generator* during all the stages of working with DEX. The generator is able to prepare complete or partial reports showing the components of the knowledge base, evaluation/analysis results and different kinds of explanation. The user can choose between different levels of detail and different forms of representation. The reports can be inspected interactively or printed out.

The evaluation of LMSs is carried out according to the tree of criteria from the basic criteria up. The method of aggregation is determined by the decision rules. The variant which is awarded the highest grade should be the best one. To illustrate the use of the decision model, we consider Blackboard, CLIX and Moodle. The results of assessment are given in "Fig. 5". The systems obtained high, average and low grades in the evaluation assessment process.

Criterion	Blackboard 6	CLIX 5	Moodle 1.5.2
Applicability of LMS	average	high	low
Student's learning environment	average	high	average
Ease of use	average	high	average
Keyword search	high	high	low
Metadata search Engine	high	high	low
Navigation	average	high	high
Print current page	low	low	high
Communication	high	high	high
Asynchronous communications	high	high	high
Internal mailing system	high	high	high
Instant messaging	high	high	high
Discussion forums	high	high	high
Synchronous communications	average	average	average
Chatrooms	high	high	high
Chatroom logfile	high	high	high
Audio/videoconferences	low	low	low
Functional environment	high	average	average
Configurable environment	high	average	average
Network search	average	high	low
Collection of tools	high	high	high
Browser bookmarks	low	low	high
Help	average	high	average
System, technology & standards	high	high	average
Technological independence	high	high	high
Compliant with common web technology	high	high	high
Transfer speed	high	average	high
Graphical independence	average	high	high
Advanced technologies	average	average	average
Security & privacy	high	high	average
User security and privacy	high	high	average
Security and privacy of LMS	high	high	average
Authentication	high	high	average
Authorization	high	high	average
Logging and monitoring	average	high	average
Validation of input	average	high	average
Licensing & Hosting	high	high	*
Standards support	high	high	average
ADL SCORM	high	high	high
IMS QTI	high	high	low
IMS LIP	high	low	low
AICC CMI	high	high	low
Tutoring & didactics	high	high	high
Course development	high	average	high
Online editor for course organization	average	high	high
Up/download of resource packages	high	low	high
Linking	high	high	high
Activity tracking	average	high	high
Monitoring student in the learning process	high	high	high
Activity tracking during the learning process	high	high	high
Statistical reports of student progress	high	high	high
Course analysis	low	high	high
Participant administration	high	high	high
Login analysis	low	high	high
Time analysis	low	high	high
Assessment	high	high	high
On-line quiz editor	high	high	high
Extensible quiz engine	high	high	high
Quizzes import	high	low	high

Figure 5. Examples of evaluation and analysis of LMSs.

Due to the complexity of LMSs and a large number of criteria it is essential that the decision making model allows us to obtain not only the final assessment, but also a detailed partial analysis of individual elements ("Fig. 6"). In this way we can detect weak points and disadvantages of the system, which can be used as the basis for system improvements. We can anticipate how specific criteria improvements would influence quality and we can achieve a more optimal distribution of resources at our disposal. The immense importance of individual criteria and their autonomy prevents the average of one or more criteria to automatically become the average of the entire system. For example, an LMS that was awarded an average grade in all three criteria (e.g. average *Student's learning environment*, *System, technology & standards, Tutoring & didactics*), cannot be called average, because it could be even worse, under average. On the other hand, a system with excellent technological and standardization solutions cannot be considered of high quality also from the methodology and didactics point of view, if the system does not provide an adequate *Student's learning environment*, which is essential for e-learning users, since it does not fulfil their objectives. Besides these, there are also some excluding factors that must be met in order for an LMS to achieve a certain level from the point of view of security and privacy for example. We can renounce the safe SSL transfer in order to enhance the operational speed (this is especially important for users still using modems to connect to the Internet) and consequently positively influence applicability of the system. However, such a system does not meet security requirements, which are important in e-learning (they are considered important also by the decision making model).

The advantages and disadvantage of the evaluated systems are reflected in "Fig. 6", showing results according to attributes *Functional environment*, *Ease of use*, *Course analysis*, *Tutoring & didactics*, *Assessment* and *Standards support* for Blackboard, CLIX and Moodle.

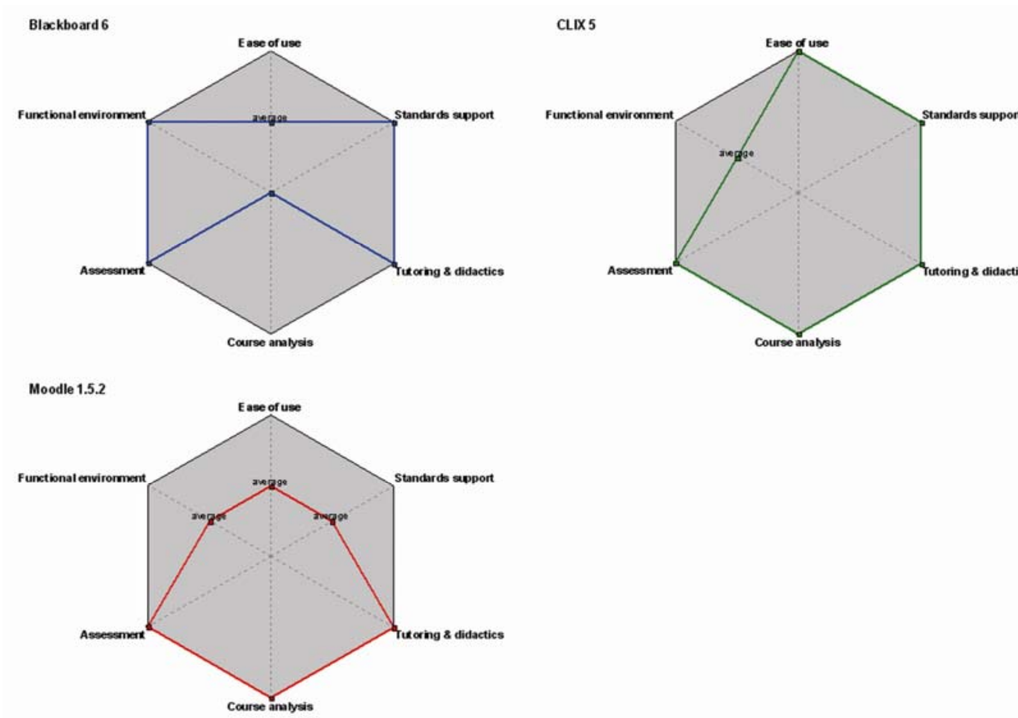

Figure 6. Evaluation results for Blackboard 6, CLIX 5.0 and Moodle 1.5.2.

IV. Analysis of Results and Findings

The main goal of the case study was the selection of the most suitable and appropriate LMS among the three available (BlackBoard 6, Moodle 1.5.2 and CLIX 5.0), which would to the greatest degree possible, satisfy the requirements and needs of the target group: employees in small and medium-sized enterprises with a basic previous knowledge of information-communication technologies.

As was already expected at the beginning of evaluation, a system which would entirely satisfy the target group of users was extremely difficult to find. Each system observed had its strengths and weaknesses, thus the choice of the most suitable system was that much harder. With the development of a multi-attribute decision support model we foresee the choice of only one of a number of solutions, namely that which best satisfies the criteria defined especially for the aforementioned target group.

Based on the results of multi-attribute decision support model it is evident ("Fig. 5"), that the CLIX 5.0 obtained the best marks of all three main criteria, at the same time coming closest to the criteria of an optimal solution. Due to the extreme complexity of LMS and the large number of criteria used it was essential that in addition to the final assessment, a detailed analysis of individual elements ("Fig. 6") impacting quality and the suitability of the LMS was also obtained from the decision support model. Thus we were able to precisely define the weak points and deficiencies of the system or respectively, where the system could be improved.

During the testing of CLIX 5.0 LMS several deficiencies were ascertained which, according to experts, represent merely minor corrections (e.g. *facilitation of navigation to e-testing, improvement of on-line help features, facilitation of terminological support texts in on-line documents, better colour reconciliation* *and fonts,* etc.). The main strengths and weaknesses of the LMS CLIX 5.0 are presented in Table 1 below.

TABLE I.
THE STRENGTHS AND WEAKNESSES OF THE EVALUATED SYSTEM CLIX

	Strong points		Weak points
✓	Large palette of tools	x	Insufficiency and unintelligibility of help-texts
✓	Good support for external content	x	Navigation to the e-tests
✓	Syllabus/learning plan with branching options	x	Terminology of supporting information given in the on-line documents, limited support for e-learning specifications
✓	Powerful rights management system	x	No search function in contents (only in descriptions of elements)
✓	"Mandanten" concept (one installation for several units with their own courses)	x	Too many different colors and fonts in the graphical user interface

Based on the results of the case study we can concluded that the selected LMS – CLIX 5.0, was suitable for the chosen target group of users – employees in small and middle-sized companies and was also recommended for use.

V. Areas and Possibilities of Practical Application of the Decision Model

The multi-attribute decision making model can be widely applied. We can use it to analyse our own Learning Management System, it can be used by organisations that wish to achieve better e-learning efficiency (importance of specific criteria) or create innovative learning environment. Different application areas prove that its applicative value is universal.

The decision making model can be used by e-learning and training providers and financers, who are often faced with the dilemma which technological environment would be the most appropriate for the educational process targeted at a specific group (our research study). The decision making model can be applied throughout the e-learning process (*time analysis*): at the beginning (evaluation of the initial situation and system choice) or after a certain period of e-learning implementation. The purpose of such system assessment is to evaluate system's advantages and disadvantages according to the time of e-learning implementation. The model can also be used for comparative analysis of competitive systems. In this case the strengths and weaknesses (advantages and disadvantages) analysis can be broadened to include also opportunities and threats (SWOT analysis). In this case the model can also be used for *if-what analysis*. Namely, introduction of new system functionalities influences different segments of the system. With the what-if analysis we can determine how these novelties influence specific segments and the entire system. The model can also be used for *sensitivity analysis*, which identifies the criteria with which we could most effectively influence the quality of specific system segments or the entire system. By applying this analysis we can also determine the change in the final or partial assessment influenced by the change of value of chosen criteria. The model can also be used for the so called *fast tests*, which normally include heuristic and other fast, cost-effective methods that produce relatively good results (for ex. computer-supported methods for technological criteria analysis). This approach is especially useful when we lack time, resources and/or sources for a detailed analysis. The model results may also be used for *aggregate analyses*. Due to its simplicity and possibility of fast implementation the model can be used for analysis of a larger number of systems. These assessments can later be used for aggregate analyses, when we analyse only specific types of Learning Management Systems, systems designed for a specific target group, etc. In this case we can use just the upper part of the decision-making tree.

VI. Related Work

The problem of criteria identification and their structuring in terms of a decision model is central to multi-attribute decision making [27], decision analysis [28], and related fields. The research reported here was motivated by a practical need for a method that would automate and/or assist the decision-maker in developing a multi-attribute model from decision examples. The representation of decision models developed by the proposed method closely resembles that used in a multi-attribute decision support expert system shell DEX [19].

The decomposition method is based on the function decomposition approach to the design of digital circuits by Ashenhurst [29] and Curtis [30]. Their approach was recently advanced by [31, 32, 33]. Given a Boolean function partially specified by a truth table, their methods aim to derive switching circuits of low complexity [38].

The problem of developing hierarchical models from examples has been also studied within machine learning. There, the decomposition approach was first used by Samuel [34] in checkers playing programs. His methods relied on a given concept structure but learned the corresponding functions from the training sets.

Another technique that uses a predefined structure, known as structured induction [35], was independently developed by Shapiro [36] and originally used for the classification of a fairly complex chess endgame. It was shown that the obtained solutions were both comprehensible and of high classification accuracy.

The method presented in this paper is thus closely related to the primary research area: it shares the motivation with multi-attribute decision making and structured induction.

VII. Conclusion Remarks

Both theory and practice are becoming more and more focused on Human-Computer Interaction (HCI), also in the area of e-learning. They are focusing even more on the applicability, usability and adequacy of Learning Management Systems. Theory and practice base their assumptions on environment's and user's objectives. The question is how successfully, if successfully at all, is the Learning Management System providing efficient e-learning and its monitoring? An answer to this question is given by the multi-attribute decision making model which accurately evaluates the quality and adequacy of Learning Management Systems. Due to a very complex list of all functionalities provided by such systems, the model considers a wide spectrum of various criteria merged into three fundamental groups: *student's learning* *environment; system*, *technology & standards*; and *tutoring & didactics*. The model can be used for an aggregate assessment which includes individual assessment criteria in a transparent way and through specific utility functions.

Throughout the paper the problem has been analysed step-by-step according to the decision making phases on which the multi-attribute decision support model is based, showing the main features and the usefulness of this computerized decision support system. The decision support process begins with problem structuring, criteria identification and criteria structuring, utility function definition, description of variants and at the end LMS evaluation and analysis. Possible weaknesses of the method are twofold. Practical experience indicates that, in comparison to traditional quantitative modelling techniques, the development of qualitative models may take more time, and require more effort and skills from both the decision maker and decision analyst. This is because qualitative models in general need a more detailed and refined hierarchy of attributes than their qualitative counterparts, and also requires a detailed elaboration of decision rules. Another potential problem of DEX is that it currently supports only qualitative attributes and utility functions, but provides no facilities for dealing with quantitative ones.

Its key contributions is reflected by the choice of adequate criteria, definition of relations between the criteria and the final result – the decision making model provides an integral Learning Management System quality and adequacy assessment.

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