

Multiple Attribute Decision Making, a Subject for Lifelong Learning

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Abstract. *The decisional process is a multitude of human activities, consisting mainly in the realization of the existence of more than one possible course of action in a certain given context, the analysis of their consequences with respect to the envisaged goal, the choice and the implementation of the action that is considered optimal in the axiological perspective that has been adopted. Every person currently makes decisions in his / her social live, “from the pre-school years to post-retirement”. The problem is: are these optimal?! The paper presents a set of tools for enhanced learning of making optimal decisions using the Multi-Attribute Decision Making paradigm.*

Keywords. ICT for content, creativity and personal development, LLL and key competences, Enhanced learning technology, Multi-attribute decision making.

1. Introduction

“Education and Training 2010” European Work Program [1] has a strong support in Romania. The rulers of the *National Excellency Research Program* encourage the *e-learning* domain. As an example, the project named „*Excellency Level Tools for Multi-Attribute Decision Making* [2, 3] *Field’s Promotion*”, belonging to this national program, opens a new era in the instrumentation of *lifelong learning* process [4, 5, 6]. The project benefit from the work of National Institute for Research and Development in Informatics – ICI Bucharest (two research workers, three programmers and other specialists), University of Bucharest - UB (two professors and three

students programmers) and Bucharest Academy of Economic Studies - ASE (five professors and four students programmers).

The project objective supposes a *research of fundamental nature* in the Multi-Attribute Decision Making (MADM) field, a sub-domain of Operations Research’s domain, that will represent an achievement itself, but, at the same time, a *precompetitive research* through the elaboration of the tools for MADM’s enhanced learning. As you will see yourselves in the following, the tool set is designed at the *excellency level*.

2. MADM – short history

In order to make an almost complete presentation of the MADM theory, the technique of proxy type and specific difference is used to structure the domain. Moreover, the *evolution* of this domain, from beginning to our days, will be emphasized. During the decade 1941 – 1950, two scientific results obtained in the mathematical area of *Operations Research* are proved as extremely important for what will later be the *Decision Theory*. The first result refers to the *Utility Theory*, developed by J. von Neumann and O. Morgenstern. The second result refers to the *Linear Programming* problem solving, revealed by G. Danzig in the *Simplex Algorithm*. On this base, strengthened by subjacent developments, an important domain of Operations Research evolved: namely the Multiple Criteria Decision Making (MCDM).

The researchers (mathematicians, engineers, economists) took into consideration the problem to use the previous mentioned scientific results in decision making that supposes *multiple criteria*. It is to notice that, simultaneously with the Information and Communication Technology (ICT) development, MCDA (Multiple Criteria

Decision Aids) is more frequently used instead of MCDM. This means that the mathematical models and solving methods of the problems generated over models are instrumented using informatics. Software tools are created to mediate decision making. From the beginning, in the MCDM domain, two sub-domains had differentiated: Multiple Objective Decision Making (MODM) and MADM. MODM refers to those models whose decisional variables are not explicitly presented; therefore they must result from an algorithm. MADM refers to those models whose variables are explicitly presented. As a consequence, MADM involves *design* and *choice*, and MADM involves directly *choice*. The Multiple Objective Linear Programming (MOLP), sub-domain of the MODM, knew a fast development: the P.L. Yu, S. Zionts, M. Zeleny and R. Steuer works had decisive contribution to the stabilization of the research results; so that P. Korhonen could put in circulation the first multi-criteria linear programming software called VIG. After that, the research extended to the cases of integer, Boolean, fuzzy, stochastic numbers, both for linear and non-linear models. Even shy at the beginning, MADM sub-domain development registered remarkable results; in our days these results vies with MODM as width and depth. The works belonging to K. May, E.W. Adams, R. Fagot, D.B. Yutema, W.S. Torgerson, R L. Keeney and H. Raiffa from the American School used the value theory for MADM problems solving, defining in this way the future well known *American paradigm*. On its basis, other methods has been developed, the most prominent one, belonging to L. Saaty, is the Analytic Hierarchy Process. French School, represented by B. Roy, P. Bertier, B. Mareschal, J.P. Brans and P.H. Vinke used the partial ranked sets, specifically some graph types, in order to offer a new vision and a different solving to the same sort of problems. Thus, in the MADM area, *French paradigm* appeared. Electre and Promethee methods became famous beside the American School elaborated methods. In Romania, the MADM preoccupations appeared very early. Among the first people ones can mention O. Onicescu and A. Rusu, because each elaborated their own methods, and also Gh. Boldur-Lătescu who sets up around him a real MADM school.

Until '70 years, knowledge in this domain was ahead in development, and ones tried to apply the specific principles and theoretical results in nearby domains, like multi-objective

mathematical programming. On the other hand, a reverse flow happened; methods and techniques belonging to game theory, fuzzy sets theory, mathematical statistic, stochastic processes etc. came to enlarge and improve qualitative the gamut of the problems solving methods taken into consideration, creating very interesting hybrids of mathematical nature. Finally, during last fifteen years, the research field is reactivated in the context of using of some instruments specific to artificial intelligence in order to approach more complex and more shaded difficult MADM problems. Three successful paradigms in the artificial intelligence frame stated in MADM: first *genetic algorithms*, then *feedback type neuronal networks* and, finally, *inferential computing* based on *production rules*.

MADM gave and give significant results in practical applications. Every human practice domain supposes *optimal choice problem*, or related problems: hierarchy, evaluation etc. The papers published in reviews, the debates at the conferences and congresses and the software market are showing the continuous domain effervescence. Today, such kind of optimal choice problems are solved using general use software. When a problem has a high degree of specificity or if it is not wanted that the user knows the domain specific mathematical knowledge, problems are solved using the general use software embedded in the software that is treating the entire problem.

3. MADM taxonomy

Taking into consideration *the modality to combine the computing and the decision process*, in order to find a solution, MCDM methods, and implicitly MADM, are divided in three classes. The first class, named with *a priori preferences articulation*, contains those methods in which the decision maker directly uses an aggregation function that combines individual objectives in order to transform the multi-criteria problem in a mono-criteria one. The second class, named with *a posteriori preferences articulation*, contains those methods in which a solutions set, usually mono-criteria ones, is offered; on this basis, the decision maker selects / elaborates a compromise global solution. The third and the last class contains those methods in which, in an iterative process, the optimization and decision steps are iterated, conducting to the solution improvement based on the information accumulated at each step. Another MCDM methods classification can

be made taking into account the *processed information nature*. Thus, there are methods that process *certain* or *uncertain* information. Uncertain information can come out from *stochastic* type models (models with risk) or from *fuzzy* type models (linguistic models). An important models classification can be made taking into account the validity of information processed by the methods. Thus, there are methods which process *valid* or *invalid* information. Information invalidity refers to its *syntactic/semantic incorrectness, incompleteness* or *incredibility*. In relation to the *decision theory* needs, methods can be classified in those that are treating *mono* or *multi decision maker* problems, and those that are treating *mono* or *multi state of nature*.

As ones can notice from above presented classifications, the domain benefited, during its existence, from many developments in the theory's frame but also from the hybridizations which appeared from practical necessities. The MADM actual development supposes a well done theory for the model containing a decision maker and a state of nature and over 20 solving methods, more or less diverse, which can solve decision problems generated over this model. Speaking about the possible attributes types to consider in the model, these can have Boolean, ordinal, cardinal, fuzzy, random variables and diverse functions (more often time function) expression but it is requested to work only in real numbers arithmetic or only in a fuzzy arithmetic. Also, a method offering a global optimum doesn't exist; it is known that different solving methods can provide different results because they are implementing different conceptions on problem treating. Although a lot of mathematical modeling methodologies exist but a MADM specific one doesn't exist. This is the reason why we decided to solve these problems having a fundamental research character, because we noticed that both at national and international level, no one is daring to do this.

4. Classical/modern promotion of MADM

Let's make some considerations regarding MADM domain promotion. Let's start with the years '50-'70. During those years, an enough number of papers treating the beginning period have been published. It is to notice that the MADM results appeared as Operations Research results, meaning that the promotion area wasn't very well structured. In order to cover the entire

field, starting with those that use to have a large coverage till those with European, regional, national coverage, it is to mention here journals like: *Mathematics of Operations Research, Annals of Operations Research, Journal of the Operational Research Society, International Transactions in Operations Research, Computer and Operations Research, Operations Research, European Journal of Operational Research, Central European Journal of Operations Research, Yugoslav Journal of Operations Research* etc. Beginning with the '70 years till our days, domain promotion became specialized through the *specialty paper*. *International Journal of Management Science, Journal of Multi-Criteria Decision Analysis, and Multiple Criteria Decision Making* appeared especially in order to encourage the MADM domain developing. The same phenomenon took place at international conferences and congresses level. If, at the beginning, each conference / congress included a small dedicated section afterwards appeared the domain's conferences / congresses. *International Conference on Multiple Criteria Decision Making* is the most important one in this domain and organizes *International Summer Schools on Multi-Criteria Decision Aid* to encourage young researchers. Today, most papers are not referring MADM theory but they cover its practical applications in the most various domains. If we are talking about the book referring the domain, ones can say, going through the years, that a real explosion took place. Almost all publishing houses are in competition for MADM books, one of the most important one, which housed the domain, is *Springer Verlag*. It is to notice that the books price is big enough, and thus a brake in the rapidly spreading of the respective knowledge is made. With the Internet appearance and development, it starts the *democracy* of the domain promotion. It can be founded electronic reviews, proceedings, books / software libraries, courses, discussions forums etc. offering, free or at low prices, MADM knowledge. This way, a strength competition appeared to promote the MADM domain.

In conclusion, nowadays, talking about the MADM domain promotion, it means to take into consideration the newest ICT type techniques. All Operations Research and MADM scientific forums, and we are referring here: *IFORS – International Federation of Operational Research Societies, EURO – The Association of European Operational Research Societies,*

INFORMS – Institute for Operations Research and the Management Sciences, ISMCDM - International Society on Multiple Criteria Decision Making, consider that only electronic promotion methods, some of them enumerated above, can ensure the domain’s *know-how* successful spreading. That’s the way we choose too.

5. MADM promotion tools

The project proposal addresses three levels of instruments to promote the MADM domain.

5.1. MADM electronic book

The electronic book, will contain the entire know-how achieved, during the years, by the team members involved in the MADM research and applications projects. The book will constitute the expression of the fundamental research in the MADM domain. Putting together the entire knowledge, harmoniously correlated, solving the observed unsolved problems yet and producing eloquency using examples, a book situated over the domain *state-of-the-art* will result.

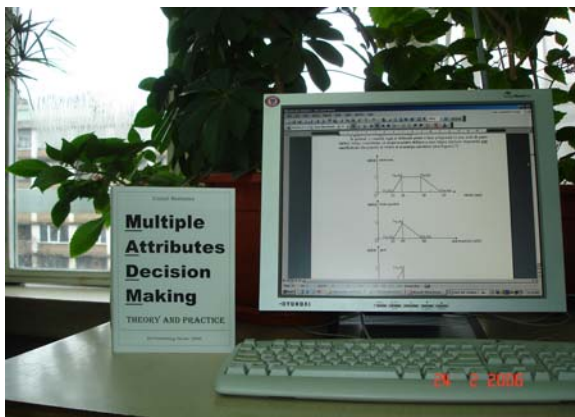


Figure 1. The electronic book

“MADM - Theory and Practice” will be situated over the domain *state-of-the-art* through:

- The mathematical defining and substantiating of a model that includes *structured information* (which are defining the common knowledge) concerning the sets of decidents, states of nature, objects / decisional variables, attributes / characteristics, connections between objects and attributes, relative / absolute importances etc. and *unstructured information* (which are defining the expert knowledge) concerning the sets of production rules over the model data and facts;

- The inferential computing standard procedure defining, which is treating the model possible inconsistence (incompleteness / incorrectness / incredibleness) [7];

- The extension of the problems solving methods, which are generated over a MADM model, by treating the cases “more decidents” and “more states of nature”. Concerning the solving methods with more than one decidents and states of nature, the extensions will be made according to the priciples: “keep the spirit of each method”. An extended version of the following methods will be presented: analyse of objects dominance, MAXIMIN, MAXIMAX, lexicographic, with ordinal preferences, conjunctive, disjunctive, elimination by aspects, permutation, linear attribution, simple additive weighting, hierarchical additive weighting, diameters, Onicescu, TOPSIS, TODIM, Pareto, Saphier-Rusu, mimization of deviation, scores, hierarchical combinations, LINMAP, multi-dimensional scalling with the ideal solution, ELECTRE, Saaty etc.;

- The inferential computing procedure defining, which determines the global optimum if multiple optimum exists. Production rules are easy to use, even without mathematical and informatics knowledge, because of their simple structure: *If condition then actions* [8]. Artificial intelligence software available on the market, are used to treat them. This justifies the orientation to inferential computing, which, in order to build the global solution, operates on the model data and the facts that are generated by the solving methods;

- The elaboration of MADM modelling and solving methodology;

- The presentation of real examples with high complexity in which optimal choice problem intervenes. Speaking from the practical point of view, MADM domain contributes today to *e-applications* development. A dedicated software avalanche is registered, both in our country and abroad. This is the dominant trend in the applicative plan. In order to attain a superior level, the theory must fit. On its turn, theory is assimilated in order to use it in practice.

The book will be written in Romanian and English and will be included in ICI, UB and ASE electronic libraries which are containing mathematical sections. At the same time, all the necessary efforts will be made in order to include it in *The Electronic Library of Mathematics* that is the library of EMS – *European Mathematical*

Society, library administrator beeing *FIZ Karlsruhe / Zentralblatt MATH*.

5.2. MADM electronic course

The electronic course, will follow the electronic book contents, the chapters becoming modules. It is not designed for the international scientific community, like the book, but for the people having high economical / technical / mathematical education or well prepared students wanting to rapidly assimilate [9] this area of knowledge. Because of this fact, the presentation will be made different: the explanations will give careful attention to details, much more examples will be gradually presented, connections with the assumed known basics will be presented, the approaching means of the novelities will exist, the interactivity technique will be used with predilection, most frequently formulated questions will appear at the end of each module, the questions for knowledge verification will be in large number and the design will be different. The course graduation exam and the proving certificate granting will also be made by electronic means. The MADM electronic course graduation will be on 3 levels (beginner, professional, expert). The random selection algorithm from tests base, models and problems base, with collisions minimization, the up-loading mechanism of the students proposed problems and the up-loading mechanism of the theoretical considerations concerning MADM domain made by the students will be another strong points of the electronic course.



Figure 2. The electronic course

The interactivity, housed by a content expressed in an attractive design, will be the didactic technique that will constitute a guarantee for course success. A context sensitive *Help* will lead the user during his / her working sessions,

making easier both the modelling and solving activities.

Afterwards a student cumulatively passes the tests, solves the proposed problems, and makes pertinent course amendments then at the course's graduation he / she is declared beginner / professional / expert correspondingly.

Electronic course will be presented in two versions. First one will free function on the UB and ASE Intranet, having the goal to contribute to the education of the students in the both institutions. Second one will function, in economic regime, on the Internet at ICI, having the goals to increase the number of MADM experts all over the world and to bring an income for the institute.

5.3. MADM electronic pervasive service

The modelling and solving pervasive MADM service (i.e. a free service available on the Internet to anyone, from any place and any time [10]) will cover the necessity to define optimal choice problems in the MADM paradigm.

It will allow to a user, registered in the system, to define classes of MADM mathematical models and models of real dimension. In order to solve the decision problems generated over these models, the user will have at his / her disposal 15 solving methods that can treat any kind of problem, no matter what is the application domain. It is also important to notice that entire contents of the book will be reproduced in the software. MADM service elaboration will start from *OPTCHOICE* (Optimal Choice), experimental software which is already designed and it proved that such kind of software is possible to transform into a pervasive service.

The user will work with the software carrying out the service like this software is installed on its computer. *Internet Computing* techniques will be used to allow to hundreds users, at the same time, to access the modeling and solving service in conditions of high informatic performance. Graduating the electronic course can be a favourable premise to approach the working on the Internet with *OPTCHOICE*, because the last module of the course will be a tutorial on this pervasive service. The software will be strong and robust, both from informatic and mathematical point of view.

The service will run on performant computers, administrated through the agency of

ICT modern techniques. It will be installed on the UB's and ASE's Intranet and on the Internet at ICI. The man-machine interface will be written in Romanian, French, Italian, Spanish, Portuguese, English and German languages.

The endowment equipment, powerful servers and dedicated computers, is strong enough in order to accomplish the service tasks. The software instruments, minimally presented, will be: MySQL, PHP, MSVC, Macromedia Dreamweaver MX, Flash MX, SnageIt, Voice, Mathematica etc.

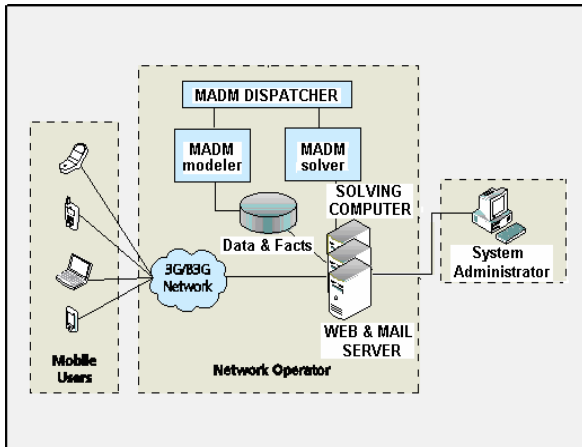


Figure 3. The electronic pervasive service

This kind of service is not available at this time anywhere in the world for none of Research Operations branch!

6. Conclusions

Any hands-on approach claims that the students become, from passive learners, very active participants. This fact is possible only if the learning system is designed by very good professors which known the teaching domain, the pedagogical art and the modern means that comes from ICT. The use of computer and the Internet, in the modern form of the hands-on learning, is essential.

As the project stated, the first beneficiaries of the project yields will be the advanced applications' designers. MADM is always necessary in *Decision Support Systems*, *Expert Systems*' and *E-applications*' design. Do remark that, in the most of cases, the theoretical MADM methods are informatics instrumented. This fact shows that the MADM theory interests the people who want to make optimal decisions and in consequence a modern management.

It is to say now that the researchers, university professors / students are interested as

well and, why not, the managers without high education, which are very well represented, numerically speaking, everywhere on the globe.

From the point of view of efficiency, the income problem, in money, is on secondary plan. However, in this case, the electronic book can generate income in libraries that will host it, the electronic course will bring an important income at ICI, and MADM modelling and solving pervasive service will attire a large number of consulting contracts for the specialists which worked at the project.

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