

THE LEARNING OF THE MATHEMATICAL MODELS TO AID DECISION MAKING IN THE HIGH LEVEL ENGINEERING SCHOOLS

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ABSTRACT

At present, in the University curricula in most countries, the decision theory and the mathematical models to aid decision making is not included, as in the graduate program like in Doctoral and Master's programs.

In the Technical School of High Level Agronomic Engineers of the Technical University of Madrid (ETSIA-UPM), the need to offer to the future engineers training in a subject that could help them to take decisions in their profession was felt. Along the life, they will have to take a lot of decisions. Ones, will be important and others no. In the personal level, they will have to take several very important decisions, like the election of a career, professional work, or a couple, but in the professional field, the decision making is the main role of the Managers, Politicians and Leaders. They should be decision makers and will be paid for it. Therefore, nobody can understand that such a professional that is called to practice management responsibilities in the companies, does not take training in such an important matter. For it, in the year 2000, it was requested to the University Board to introduce in the

curricula an optional qualified subject of the second cycle with 4,5 credits titled "Mathematical Methods for Making Decisions ". A program was elaborated, the didactic material prepared and programs as Maple, Lingo, Math Cad, etc. installed in several IT classrooms, where the course will be taught. In the course 2000-2001 this subject was offered with a great acceptance that exceeded the forecasts of capacity and had to be prepared more classrooms. This course in graduate program took place in the Department of Applied Mathematics to the Agronomic Engineering, as an extension of the credits dedicated to Mathematics in the career of Engineering.

Keyword

Life Long Learning, Decision Theory, Multi-criteria Decision Methods, University Plans, Mathematics.

1.-INTRODUCTION

In Spain, the Engineering programs were introduced from the second half of the XVIII Century with the School of Mines and the Civil Engineers and following with the Agricultural School, at the middle of XIX Century and also with Forest and with Industrial Schools, and finally with the newest ones at half of XX Century. Many of them, responded mainly, to a need for the various Ministries, to have high-level technical staff trained. So, there were "numerus clausus" that is, where only could pass entrance exams to these courses, a slightly higher number than the officials who needed the Ministry. Later on, in 1957, the Engineering Schools were placed under the Ministry of Education and in 1971 the Technical University of Madrid (UPM) was created, which for Madrid brought together all the Technical Schools of Higher Engineering and also for Intermediate Engineers (called formerly of "Peritos" and "Ingenieros Técnicos" now). During the last years the engineering schools system evolved, and the number of Schools was increased, and in course 2010/2011 it was completely modified with the new qualifications from the European Higher Education Area, (Plan Bologna), towards a new panorama that in fact is not yet well known what will it be nor completely defined. Within the Plan called "Old" (before 1957), the student from High School had to pass an entrance exam for the chosen Engineering, and in it, Mathematics were essential for the access and therefore, an engineer should be brilliant in that discipline, as it was considered not only an essential tool for learning other subjects, but also for the practice of the career and even a training course for the future engineer.

Within the following Plan, called "Plan 57", the entrance examination was changed by two selective courses, known as "Selective and Initiation". To go from the Selective to Initiation, the student should pass all subjects up to 5 calls and the same for passing Initiation to course. The ones that did not succeed had to leave it, and look for another course. The number of admissions in Initiation was still kept limited.

Both, in Selective and Initiation, Mathematics was a basic subject, determinant in order to become an Engineer. That continued with less intensity in the following Plans, in which there was no longer Selective and Initiation, although they were studied in 1st and 2nd year of the

course, at a rate of 7 hours per week of Calculus and also 7 for Algebra in the first year, and 7 hours per week for “Ampliación” in the second year.

Here, the level begun already to go lower and part of the mathematical foundations and applications were no longer taught. With the latest changes, Mathematics has been reduced and they are no longer a training subject, neither fundamental.

2.-STATEMENT

Due to the lack of mathematical training during the University courses, it seems necessary to introduce this matter within Life Long Learning.

Engineers are called to leadership positions in the Administration and in private companies, and therefore, they should make important decisions of all kind: economic, technical and social ones.

Now then, are they ready for this?. Are they doing it at the best possible way?

It is a paradox that for such an important part of their professional development, they had generally not been prepared in the Schools of Engineering, studying the appropriate subjects for this.

The lack of this training encouraged us to prepare a subject that could help engineers in making decisions, and proposed it to the Polytechnic University of Madrid to be introduced into the official curricula.

At first, an optional course (obligatory for some orientations) of the second cycle, of 4.5 credits, entitled "Mathematical Methods for Making Decisions" aimed at students who already had a major insight into the Engineering course and what could be the development of a professional life.

In addition, it was to be prepared some notes and text material for the audiovisual and computer math programs, such as Maple, and MathCad, Lingo. As well as the classroom, in order to be able to teach theoretical and practical subjects.

Acceptance among students was so great, that for the next year a new classroom had to be prepared.

3.-COURSE PROGRAM

In undertaking the program of the subject was taken into account, the lack of mathematical knowledge that students had, to whom it was addressed.

In the new curriculum, Geometry and Topology have been abandoned, so it has been necessary to give a few chapters on metric spaces, with measure and dimension theory deepening in the distance concept. These skills are essential, both for understanding this subject as for the one that we have also included in the curricula, called “Maple and Geometry”, that also includes fractal geometry.

That course, and the other related courses effectuated by the authors recently, are exposed in short in the following, aiming to have patterns for future courses, that can start from these experiences with some adaptations, as convenient to the new evolving education frames, and to the evolving state of art of OR or MCDM tools, selected in a simple way in view for application for effective decisions in real scenarios, sometimes now, it is called Decision Support Systems (DSS). The main goal is to get in the student an aptitude to perceive the real decision problems in his professional life ,and many times, considering a variety of

outcomes with some probabilities of occurrence.

The program of the course is basically the following one:

One first part, with 3 items, concerning with the general aspects about Decision Theory

1. Decision Theory. Historical evolution . Decision in deterministic environment. Objectives and constraints. Optimization Methods.
2. Updated value referred to monetary units, NPV, IRR. Choice of real and financial investments.
3. Decision in uncertain environment. Decision Maps. Methods. Decision in random environment. Subjective probabilities. Risk aversion. Bayesian Methods. Groups Decision. Theory of games. Methods with Graphs. Dynamic programming.

Second part, with two items more, giving the mathematical concepts that have despaired, at present, in the Mathematic courses

- 4.-Optimization. Optimization Methods: Linear Programming. Mathematical Foundations. Mathematical programs(Maple, MathCad, Lingo, MatLab)
- 5.-Metric spaces: Definition. Definition of distance. Types of distances. Examples of metric spaces. Metrics and topology.

Third theoretical and practical part, dedicated to most important Multi-criteria Decision Methods

6.- Multi-criteria Decision Methods (MCDM). Attributes, Objectives, Criteria. Utility Functions. Trade-off. An approach to the different methods. Connections among the different approaches

7. -Notions of Fuzzy sets. Application to MCDM

8.- Continuous Multi-criteria Decision Methods. Trade-offs. Pay-off Matrix

8.1 Multi-objectives Programming: Basic Aspects.

8.2.-Compromise Programming: Basic Aspects. Use of different distances.

8.3.- Goal Programming: General Structure. Weighted Goal Programming.

Lexicographic Goal Programming.

8.4.- Interactive Methods: Structure of the process. The STEM Method.

9.- Discrete Multi-criteria Decision Methods : Introduction. Out-ranking Methods.

9.1.- Electre Methods

9.2.- AHP Method

9.3.- PROMETHEE Methods

9.4.-Other (Grau-Antón Method)

Finally, one chapter about real applications

10. Applications

10.1-. Financial applications. Theory of the portfolio of values, market equilibrium, risk analysis, valuation of contracts, of options. Selection of investments with risk.

10.2.-To the environment,

- 10.3.-To the quality control
- 10.4.-To the water resources
- 10.5.-To the regional development.
- 10.6.-Telecommunications network management
- 10.7.-Climate Change

4.-LIFE LONG LEARNING

As we said, this lack of mathematical knowledge and training to play a leadership role in professional life, and to make decisions with greater security, makes it necessary to teach also this subject in graduate courses. In fact, it has been taught in the doctoral program in AE Technology and has already been read a doctoral thesis "*Bases para el ordenamiento territorial del sur de Córdoba(Argentina). El caso de la Cuenca de los Arroyos Menores*" and there are two more already in its final stage. It has also been taught at the Ph.D. in "*Systems and Radio Signals*" and it will start in the new "*Technology and Communication Systems*"

The level and the extension of this subject in these masters are variables, deeping into the mathematical concepts, when the students have a solid knowledge in mathematics or giving the concepts and applications, without entering into the mathematical development of the same ones, when they have a lower level.

The problems also exist in Universities of Latin-American countries, and for that reason, we are collaborating with the authorities to implement this matter. In the majority of Universities, we are offering this course on the basis of seminars, as a first step until to be included in its curricula.

Finally, the most important to long life learning, is that now is included in the different courses offered by Business School for professional associations, entities and firms.

5.-CONCLUSIONS & RECOMMENDATIONS

Mathematics is a basic and training subject in engineering courses, and it is an integral part to study other subjects. It must be studied within the curricula of graduate, but also in the postgraduate and masters in Business Schools. In addition to basic mathematics, Applied Mathematics subjects must be included in the curricula of the Engineering courses. These courses are directed to the development of the profession. Engineers are professionals who are destined to leading positions, both in Government and in private Companies. In these management positions, they should make important decisions and have to do it the best way possible. They must learn to do it scientifically and help themselves with the mathematical methodology. In the curricula of engineering courses, they have studied subjects such as: Operations Research, Statistics, etc., but they needed to study rather graduate or postgraduate, a subject that should be structured taking into account Decision Theory, Operations Research, Measure Theory , Metric Spaces, Optimization and other branches of science.

This course provides the appropriated methodology to choose the closest option to the ideal for the decision-maker. The importance of this subject is that it can be coursed at anytime of Lifelong Learning

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