A Comprehensive Evaluation of Engineering Students by a Multicriteria Methodology

Luís Alberto Duncan Rangel[1], Luiz Flavio Autran Monteiro Gomes[2*] and Bruno Carlos da Silva Souza[3]

[1]Department Production Engineering, Federal Fluminense University, Rio de Janeiro, Brazil
[2]Department Department of Business Administration, Ibmec, Rio de Janeiro, Brazil
Av. Presidente Wilson, 118, Room 1110, Centro, Rio de Janeiro, RJ, 20030-020
[3]Department Production Engineering, Federal Fluminense University, Rio de Janeiro, Brazil
emails: duncan@metal.eeimvr.uff.br; autran@ibmecrj.br; brunocarloss@hotmail.com

Abstract

This article presents a new way to evaluate engineering students. This was accomplished through a pilot study carried out with a small group of students belonging to the same class. The article initially presents the traditional method used by the university in order to evaluate the academic performance of students. Next, it introduces a general description of the various extracurricular activities which complement the knowledge acquired by the students in the classroom. Following this, it shows the multicriteria evaluation process that was used for a more global evaluation of students. That process was based on the use of the multicriteria method TODIM. As a conclusion, some forms to improve the evaluation of engineering students' performance relying on the use of TODIM are suggested.

Keywords: decision support systems, TODIM method; faculty evaluation, management of engineering education, multicriteria decision analysis.

1. Introduction

The academic attainment of university students can be evaluated from many different perspectives. University students will be better prepared for the work market, the better their performance is at the university, the more extracurricular activities they undertake, the more they absorb knowledge, and the higher their attainment in the subjects taken.

The majority of students, generally, seek solely to graduate in a university level course, limiting themselves to the classes in the subjects which make up the curricular outline of their course. The knowledge acquired in the classroom by these students is often only truly made concrete in their first jobs, when the student is confronted with real problems. In these cases, the student feels great difficulty in associating the theoretical knowledge obtained in the classroom with the practical problems which need to be resolved.

* corresponding author.

Universities offer other essential extracurricular activities to provide a better foundation for individuals, such as scientific initiation studies, monitor programmer, lessons of theoretical disciplines and practices in laboratories, participation in extension projects, junior enterprises and social projects, among others. These activities often go unnoticed by the students, who evaluate them as time consuming activities which do not aggregate any value, focusing their attention exclusively on the Attainment Average (AA). In this way, the AA represents the academic attainment of a student based on the performance obtained in the subjects taken during the course, without taking into consideration any extracurricular activity which the student may participate in. It is considered to be an important and representative index, serving as a criterion, and often the sole one, to judge the student's performance, to obtain credits at the university and even in some cases to obtain a position in the professional world. With the purpose of evaluating the performance of a relatively homogeneous group of university students from other perspectives, the study presented in this article seeks, through a multicriteria analysis methodology, to evaluate the academic attainment of students enrolled in the course of Production Engineering at a Brazilian federal university, using other extracurricular activities as evaluation criteria.

In this article we compared the evaluation of students based on the strict academic achievement (i.e. course scores) against a broader, multicriteria form of students' evaluation (i.e. course scores plus participation in extra-class activities in the university). Therefore the common evaluation question has to do with the differences between that traditional, course scores-based evaluation against the broader, multicriteria evaluation. Although student evaluation has been a major topic of research for years [1, 2, 3, 4, 5, 6], practically none of the key authors have looked at that problem from a multicriteria analytical point of view.

This article presents a pilot project for the evaluation of university students beyond what is commonly denoted by Attainment Average. The process of evaluation within a university has been a fertile area for applied research. An example has been the need to use a transparent model for evaluating the performance of a university's faculty such as presented by Bana e Costa & Oliveira [7]. Other research approaches have focused on the use of decision analysis for evaluation in universities [8]. Particular applications have dealt with performance evaluation of business colleges [9]. Meredith and Steward [10] evaluated published perceptions versus academic reality, while Donohue and Fox [11] evaluate journals in the field of decision and management sciences.

We the authors of this article believe that students must be evaluated not based on course scores only. We are not indeed interested in the discussion if course scores are the best way to represent students' academic achievement: regardless of how academic achievement is measured a global evaluation of students must take into consideration not only academic achievement but also voluntary participation of students in extracurricular activities.

2. Study Context

The Fluminense Federal University (Universidade Federal Fluminense, here denoted by UFF) is a public institution founded on the 18th December 1960, in Niteroi, Brazil, initially under the name of Federal University of the State of Rio de Janeiro (Universidade Federal do Estado do Rio de Janeiro – UFERJ), by the union of the faculties of that municipality. Only on the 5th of November 1965 did it come to have the name by which it is known today. UFF is indeed a self-governing federal institution under special regime, with didactic-scientific, administrative, disciplinary, economic and financial autonomy, exercised according to its statute and the existing legislation, currently composed of more than 20,000 enrolled students and around 2,600 teachers and 4,700 other staff [12].

The University Pole of Volta Redonda (Pólo Universitário de Volta Redonda - PUVR) is one of the campi of UFF located in the neighborhood of Vila Santa Cecília, in Volta Redonda, which offers the courses of Agribusiness, Production, Mechanical and Metallurgical Engineering, as well as the courses of Business Administration, Accounting, Mathematics and Computational Physics [12].

2.1. Method of Performance Evaluation

The current measurement used to analyse the academic achievement of the students of UFF is the AA. The AA is an index which expresses the academic attainment of the student at the university, with its calculation based on the scores obtained by the student in all of the subjects taken since entering the university. The AA is calculated by equation (1) [12].

$$CR = \frac{(Ch_1.N_1) + (Ch_2.N_2) + ... + (Ch_n.N_n)}{Ch_1 + Ch_2 + ... + Ch_n} \qquad (1)$$

where, C_{hi} means the course hours of the subject i, where i = 1, 2, ..., n; and N_i means the score obtained by the student in the discipline i, where i = 1, 2, ..., n.

The AA is updated every semester according to the progression of the student through the university. The AA is therefore calculated in each semester based on the subjects taken and the performance of the student in these subjects until that moment. The calculation of the AA does not consider cancelled subjects, subjects from which the student is dispensed, the closing of matriculations and complementary activities [13].

2.2. Complementary Activities

Every university generally offers its students a number of possibilities in terms of extracurricular activities in which they can voluntarily participate. Students normally compete among themselves for participating and receiving compensation such as junior

research scholarships, teaching assistantships or recognition by engaging in social projects. A multicriteria approach to the evaluation of students' performance cannot underestimate the involvement of students in that wide range of possibilities.

The PUVR of UFF in Volta Redonda offers its students diverse activities to complement its graduation courses, permitting greater experience of and training in the theoretical knowledge obtained in the classroom. Numbered among these activities are Scientific Initiation, the Monitor Program and Extension Projects in addition to others.

2.3. Scientific Initiation

Scientific Initiation is an activity which provides the potentially most promising undergraduate students with an introduction to scientific research. It creates the possibility of placing the student, from the beginning, in direct contact with scientific activities and engaging them in research. From this perspective, Scientific Initiation is characterized as an instrument of theoretical and methodological support for the realization of a research project and constitutes a suitable channel of support for the formation of a new mentality, with a clear orientation for the production of knowledge by the student. The purpose of Scientific Initiation is to awaken a scientific vocation and encourage potential talents among the students, through participation in activities of scientific or technological research, guided by a qualified researcher, in institutions of further education or research institutes / centers [14].

At UFF, the Scientific Initiation Grant Program, administrated and coordinated by the Pro-Rectory of Research, Post-Graduate Studies and Innovation (Pró-Reitoria de Pesquisa, Pós-Graduação e Inovação – PROPPI), constitutes an instrument to stimulate those students who stand out during the undergraduate course. Those who demonstrate aptitude for study and research and present good scholastic performance are strong candidates to receive a Scientific Initiation Grant. This grant, as a rule, is associated with a research project under the responsibility of the supervising teacher. This activity is proposed by the supervising teachers who assume the responsibility of selecting those students who will develop the research project. Few teachers manage to obtain the funds to implement their Scientific Initiation research project, but, even so, they implement many other Scientific Initiation projects without grants. In this way, those who manage to participate in this activity, with or without a grant, are considered good students according to the view of the supervising teachers [12].

2.4. Monitor Program

The Monitor Program is a modality of teacher training designed for regularly matriculated students. It aims to awaken an interest for teaching through the carrying out of activities connected to teaching, permitting the student an experience of academic life and the learning of skills in didactic activities.

At UFF, the Monitor Program aims to permit regularly enrolled students to have contact with activities of Higher Education. For this reason, a competition is held annually to fill the places in the Teaching Department. The program requires the monitor student to fulfill twelve hours per week in the discipline for which they applied, with the right to a paid grant and, at the end of the program, which lasts for two consecutive semesters, the student receives a certificate [12].

This activity is proposed by UFF to serve those disciplines which require monitors. Normally a high number of candidates enter the monitor program competition for the places available in the discipline, but generally, only one student is selected for each place.

2.5. Junior Enterprises

Junior Enterprises are non-profit making associations, created for purely educational ends and composed exclusively of university level students. They are generally made up of students from different courses and are managed by the students themselves, with the aim of encouraging the personal and professional growth of the students involved in the projects to be developed, preparing them better for the work market.

At the PUVR of UFF of Volta Redonda, Pulso.Con is the Junior Enterprise Consultancy in Engineering and Business Administration. This company provides the students with the necessary conditions for them to apply the theoretical knowledge acquired at university to practical projects in the work market. Through these activities, they carry out studies, projects and prepare diagnostic studies in specific subjects in the areas of production, mechanical and metallurgical engineering. All of these projects are supervised by UFF teachers.

This activity is only carried out by a small number of student members of the Junior Enterprise. Each year the company itself selects candidates to compose the team who will develop the consultation projects under their own responsibility.

2.6. Other Projects and Activities

As well as the activities of Scientific Initiation, the Monitor Program and the Junior Enterprise, Brazilian universities in general provide other projects which contribute significantly to the personal and professional growth of their students. These include activities generally associated with the planning and creation of prototypes, social projects within the universities, the preparation of scientific articles and exchange programs among others.

The SAE BAJA Project in Brazil, administered by SAE BRASIL, the body responsible for the technical aspects of the competition, consists of a competition between teams from higher education institutions [15]. Each team, composed exclusively of engineering students from a single institution, develops a real prototype of a car, an off-road vehicle,

applying the knowledge acquired in their courses. The teams must project, develop and construct a safe, reliable, off-road vehicle which is easy to maintain and which copes with difficult terrain without suffering any damage. At the PUVR of UFF of Volta Redonda, the project has existed since 2006 [15].

The Social Projects are individual or collective initiatives which seek to provide improvements in the quality of the lives of individuals and communities. They arose from the need to solve concrete social problems. When implemented, they aim to support or solve problems in such a way that ideas are transformed into actions. In the development of the social projects, it is essential to make the objectives clear, to specify the funds, declare the partners and state how the results will be analyzed [16]. In the PUVR of the UFF in Volta Redonda, the Social Project "Close and Closer" ("Próximo + Próximo") seeks to help those students with financial difficulties to remain at the university.

A Scientific Article is the part of a publication with declared authorship which presents and discusses ideas, methods, techniques, processes and results in diverse areas of knowledge. At UFF, students have the opportunity to prepare articles after carrying out works of Scientific Initiation, Extension Projects or even the Course Conclusion Project Those activities are carried out by small groups of students from the PUVR of UFF.

In the Baja Project, for example, there is a prior selection of the students who will make up the team, who are directed to act in a specific subdivision of the project, whether of a technical, marketing or management nature. The Social Project requires the dedication of the students, who make themselves available to help other students with financial difficulties. This project also relies upon the participation of teachers and staff of the school. The Scientific Articles are prepared after a study or research. In this way, the students can only publish after implementing a prior work [17].

3. Multicriteria Decision Aiding Methodology

Multicriteria Decision Aiding (MCDA) is a methodology used as a tool to help in decision making under multiple criteria. As a segment of Operations Research, MCDA is normally applied in the presence of conflicting criteria, with the aim of: (i) finding one alternative or a set of alternatives which are presented as solutions for the problem, from a group of viable or possible alternatives; (ii) classifying the alternatives; (iii) ranking the set of alternatives; or (iv) describing every alternative in a comprehensive way. This methodology considers in its multiple applications both the human factor and subjectivity, always present in decision making problems [18, 19, 20].

Some concepts of MCDA are fundamental to the understanding of a decision making problem, such as: (1) the Decision Maker or the Decision Owner: the person responsible for making the decision, for the choice of the criteria and their importance. In a multicriteria problem there may be one or more decision makers; (2) Analyst: the person or group of people responsible for the analysis of the opinion of the decision maker, as

well as, those of the Decision Agents. He conducts the choice and preparation of the multicriteria analysis model and the publishing of the results obtained; (3) The Decision Agents: the people who are heard by the Analyst, with the aim of preparing a representation of the problem, which, when analyzed, contributes to the solution of the problem itself; (4) Criteria: Precepts which will serve in judging the choice of an alternative; and (5) Alternatives: Possible choices to be made. They are options which may present different characteristics and opinions.

3.1. The TODIM method

The TODIM method [21, 22] is a Multicriteria Decision Aid method. This method is based on Prospect Theory [23]. This means that, underlying the method, there is a psychological theory, coauthored by one of the recipients of the Nobel Prize for Economics awarded [24]. Besides TODIM, the multicriteria decision analytical approach used by Salminen [25] is also founded on Prospect Theory. TODIM makes use of a global measurement of value calculable by the application of Prospect Theory. In this way, the method is based on a description, proved by empirical evidence, of how people effectively make decisions in the face of risk. TODIM is a non-compensatory method in the sense that tradeoffs are not dealt with in the modeling process [26].

The additive difference function of TODIM is indeed a global multiattribute value function and reflects the dominance measurements of each alternative over each other alternative. From the construction of that additive difference function, which performs as a multiattribute value function and, as such, must also have its use validated by the verification of the condition of mutual preferential independence [27], the method leads to a global ordering of the alternatives. This method combines aspects of Multiattribute Utility Theory and ELECTRE method [19]. Barba-Romero & Pomerol [18] comment in their book that the TODIM method has the idea of flow in common with the PROMETHEE II method. However, the TODIM method is based on Prospect Theory's value function [23] instead of using the classical utility function of Multiattribute Utility Theory [28]. The Figure 1, resembles the Prospect Theory function [23].

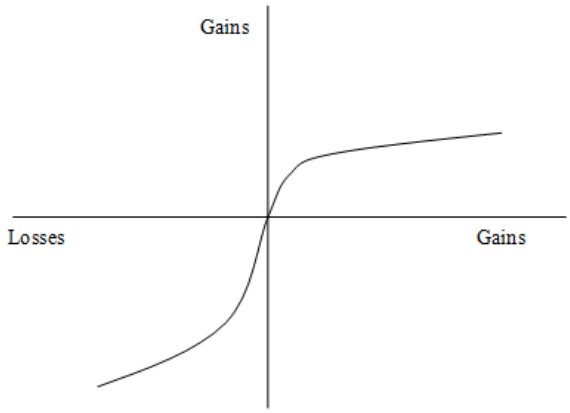

Figure 1. Value function of TODIM method

Consider a set of n alternatives to be ordered in the presence of m quantitative or qualitative criteria, and assume that one of these criteria can be considered as the reference criterion. After the definition of these elements, experts are asked to estimate, for each one of the qualitative criteria c, the contribution of each alternative i to the objective associated with the criterion. This method requires the values of the evaluation, of the alternatives in relation to the criteria, to be numerical and to be normalized; consequently the qualitative criteria evaluated in a verbal scale are transformed into a cardinal scale. The evaluations of the quantitative criteria are obtained from the performance of the alternatives in relation to the criteria.

The relative measure of dominance of one alternative over another is found for each pair of alternatives. This measure is computed as the sum over all criteria of both relative gain/loss values for these alternatives. The parts in this sum will be either gains, losses, or zeros, depending on the performance of each alternative with respect to every criterion.

The evaluation of the alternatives in relation to all the criteria produces the matrix of evaluation, where the values are all numerical. Their normalization is then performed, using, for each criterion, the division of the value of one alternative by the sum of all the alternatives. This normalization is carried out for each criterion, thus obtaining a matrix, where all the values are between zero and one. It is called the matrix of normalized alternatives' scores against criteria. $P = [P_{nm}]$, as shown in Table I.

After the attribution of the weights of the criteria and their normalization, the partial matrices of dominance and the final matrix of dominance must be calculated. The decision makers must indicate which criterion r is to be chosen as the reference criterion for the calculations according to the relative importance assigned to each criterion. Thus, w_{rc} is the weight of criterion c divided by the weight of the reference criterion r. Using w_{rc} allows all pairs of differences between performance measurements to be translated into the same dimension, i.e. that of the reference criterion.

The measurement of dominance of each alternative A_i over each alternative A_j, now incorporated to Prospect Theory, is given by the mathematical expression (2). Three situations can occur: gain on an alternative by other, expression (3); neither gain nor loss, expression (4); loss on an alternative by other (5). P_{ic} and P_{jc} are, respectively, the performance of the alternatives Ai an Aj in relation to criteria c, and θ is the attenuation factor of the losses, different choices of θ lead to different shapes of the Prospect Theoretical Value Function associated losses.

$$\delta(A_i, A_j) = \sum_{c=1}^{m} \phi_c(A_i, A_j) \qquad (2)$$

For the calculation of $\phi_c(A_i, A_j)$ can occur:

$$if\ (P_{ic}, P_{jc}) > 0, \qquad \phi_c(A_i, A_j) = \sqrt{\frac{w_{rc}(P_{ic} - P_{jc})}{\sum_{c=1}^{m} w_{rc}}} \tag{3}$$

$$if\ (P_{ic}, P_{jc}) > 0, \qquad \phi_c(A_i, A_j) = 0 \tag{4}$$

$$if\ (P_{ic}, P_{jc}) < 0, \qquad \phi_c(A_i, A_j) = \frac{-1}{\theta}\sqrt{\frac{\sum_{c=1}^{m} w_{rc}(P_{jc} - P_{ic})}{w_{rc}}} \tag{5}$$

Therefore, the global measures obtained computed by (6) permit the complete rank ordering of all alternatives.

$$\xi_i = \frac{\sum_{j=1}^{n} \delta(A_i, A_j) - \min \sum_{J=1}^{N} \delta(A_i, A_j)}{\max \sum_{j=1}^{n} \delta(A_i, A_j) - \min \sum_{j=1}^{n} \delta(A_i, A_j)} \tag{6}$$

A sensitivity analysis should then be applied to verify the stability of the results based on the decision makers' preferences. The sensitivity analysis should therefore be carried out on as well as on the criteria weights, the choice of the reference criterion, and performance evaluations. Recent publications of this method are [29], [30] and [31]. It is through the implementation of the TODIM method that the value function obtained, displayed in Figure I, resembles the Prospect Theory function [23].

Table I: Matrix of normalized alternatives' scores against criteria

Alternatives	Criteria					
	C_1	C_2	. . .	C_j	. . .	C_m
A_1	P_{11}	P_{12}	. . .	P_{1j}	. . .	P_{1m}
A_2	P_{21}	P_{22}	. . .	P_{2j}	. . .	P_{2m}
. . .	. . .	. . .	. . .	. . .	. . .	. . .
A_i	P_{i1}	P_{i2}	. . .	P_{ij}	. . .	P_{im}
. . .	. . .	. . .	. . .	. . .	. . .	. . .
A_n	P_{n1}	P_{n2}	. . .	P_{nj}	. . .	P_{nm}

4. Implementation and Results

This paper presents a pilot study in which 25 students graduating in production engineering were evaluated. From those 25 students 10 participated in extra-class actives in the university. The TODIM method was presented as a multicriteria tool that allows

taking multiple criteria into consideration in that students' evaluation. One of these criteria was the weighted average of course scores. Other criteria were extracurricular activities. The results from applying TODIM indicated that the 10 students that participated in extra-class activities presented an overall performance higher that the other students.

TODIM method is one of the available methods for evaluation under multiple criteria. Although the authors of this paper understand that pedagogical evaluation and multicriteria analysis have not had many points in common in the education literature so far, they do believe that a greater synergy between the two could be highly beneficial to society.

Although it has been recognized that extra-class activities are important for university students the number of references on their evaluation is indeed small [1, 2, 3, 5, 6]. In Brazil for instance the Ministry of Education has one division in charge of evaluating undergraduate courses. That division considers extra-class participation as one important factor in course evaluation [4].

The academic performance of university students is often evaluated by the AA obtained during the undergraduate course. This form of analysis is an oversimplified, narrow way of evaluating how students have benefitted from the university, as it solely considers the scores obtained in the disciplines and the number of absences during the course.

A university student will truly have a good foundation for his future professional life if he participates in various activities during the university course and does not limit his participation to the classroom. Participation in Scientific Initiation projects allows students to experience life as a researcher, experience in the preparation of scientific reports and the real application of theories and knowledge acquired through research and in the classroom, generally permitting them to apply them to real problems.

Participation in activities in the Monitor Program, as well as giving students experience as a teacher, allows them to carry out research in the discipline in which they act as monitors. Participation in Extension Projects, such as Junior Enterprises, Social Projects, Prototype Construction Projects, among others, allow students to apply theoretical knowledge in the preparation of real projects as well as improving the capacity of the student to work in a team.

The preparation of Technical Articles provides the student with knowledge of the scientific area and helps develop the capacity of technical writing. In addition to these activities, voluntary participation in Social Projects works on the human level and complements the formation of future engineers.

This research was carried out with a group of teachers as decision makers and analysts, and the authors of the research as decision agents. A group of ten engineering students

from the same undergraduate set was considered in the study. The other students from the set were not considered in the study as they did not participate in any extra-class activity.

The criteria were defined by the decision makers and included the following criteria: AA, number of participations in Scientific Initiation projects, the number of participations in Monitor Program activities, the number of participations in Extension projects and the number of Scientific Articles prepared.

Universities have normally forms for compensating students by their participation in some of these extra-class activities, such as junior scholarships or assistantships. Those forms suggest that that participation is important for the preparation of future engineers.

In most Brazilian universities students and teachers compete for having access to these resources as well as for the consequent recognition. It is therefore only natural to infer that the evaluation of students should take into account that participation besides scores from academic courses.

This research was carried out with the purpose of observing the students who knew how to best take advantage of the academic environment and were thus more prepared for the job market. The performance matrix of the alternatives can be observed in Table 2 and the weights of the criteria used in the study are in Table 3.

Table 2: Performance Matrix of the Alternatives

Students	Criteria				
	AA	SI	Monitor Program	Extension	Articles
A	7.0	0	0	3	1
B	8.6	3	0	2	3
C	7.8	1	0	0	0
D	9.5	1	0	0	0
E	7.3	0	2	0	0
F	6.2	1	0	1	0
G	8.4	1	1	0	0
H	6.4	0	0	0	0
I	5.5	0	0	1	0
J	7.1	0	0	1	0

Table 3: Criteria Weights in the Study

Criterion	AA	SI	Monitor Program	Extension	Articles
Weights	5	3	3	3	1

The performance of the alternatives A_i an A_j in relation to criteria c by the TODIM method is calculated by the equations (2), (3), (4) and (5). Equation (6) obtained the global measures computed permit the complete rank ordering of all alternatives.

Through the result of the application of the multicriteria methodology, it is possible to observe that the ranking using the AA differs from the ranking of the TODIM method. A student with a lower AA, although having undertaken extra activities at the university (Student B, Student A), scores more highly according to the methodology than another student with a higher AA, although having undertaken fewer extracurricular activities at the university (Student D, Student C). Table 4 shows a comparison between the usual classification via the AA and the ranking generated by the TODIM method.

Table 4: Comparative Ranking by AA and by the TODIM method

Rankings	Attainment Average		TODIM Method	
	Students	AA	Students	ξ_i (θ=1)
1st	D	9.5	B	1.000
2nd	B	8.6	A	0.505
3rd	G	8.5	G	0.490
4th	C	7.8	D	0.402
5th	E	7.5	F	0.356
6th	J	7.1	C	0.315
7th	A	7.0	E	0.305
8th	H	6.5	J	0.240
9th	F	6.2	I	0.101
10th	I	5.5	H	0.000

A sensitivity analysis was carried out on the study. A variation of ten percent in the values of the criteria weights, both above and below, did not cause any differences in the ranking by the method. There was a difference in the value of each alternative in the problem. However, the final classification remained the same. Table 5 shows the comparative ranking obtained from the TODIM method considering the initial information (Analysis 1), with the ranking obtained with θ equal 1, θ equal 5 (Analysis 2) and θ equal 10 (Analysis 3).

Table 5: Comparison of the Effect of the Sensitivity Analysis of the TODIM method

Ranking	Analysis 1		Analysis 2		Analysis 3	
	Students	ξ_i (θ=1)	Students	ξ_i (θ=5)	Students	ξ_i (θ=10)
1st	B	1.000	B	1.000	B	1.000
2nd	D	0.505	G	0.502	G	0.506
3rd	G	0.490	A	0.502	A	0.501
4th	A	0.402	E	0.377	E	0.402
5th	E	0.356	D	0.374	D	0.365
6th	C	0.315	F	0.296	F	0.275
7th	J	0.305	C	0.263	C	0.246
8th	F	0.240	J	0.199	J	0.185
9th	H	0.101	I	0.101	I	0.101
10th	I	0.000	H	0.000	H	0.000

Aiming to compare students' performances in the three analyses that were carried out with different values for the parameter θ (loss attenuation factor), the graph in Figure 2 was built. Such graph shows that the differences in performances between alternatives in the domain of gains do not change with values of θ. In the domain of losses, however, the higher the value for θ the lower the losses are.

This paper does not defend one way to train engineers. What is proposed here is indeed a broader, multicriteria way for evaluating graduating engineers. This broader way takes into account not only the weighted average of course scores bout also participation in extracurricular activities. In practically all Brazilian higher learning institutions students are evaluated based upon their academic achievement only. In essence the goal of a multicriteria evaluation is to provide a broader, comprehensive way to evaluate students such that participation in extracurricular activities is also taken into account.

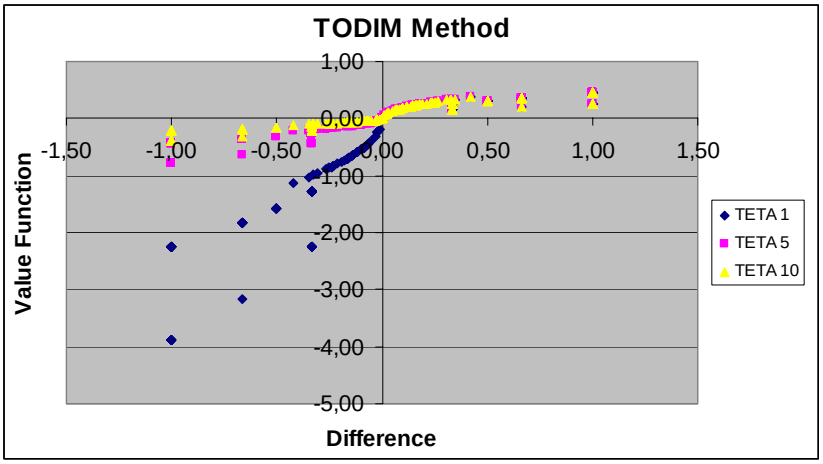

Figure 2. Value function of TODIM method for θ iqual 1, 5 and 10

This pilot study was the first attempt to use the multicriteria method for a broader evaluation of engineering students. Taking into consideration that every method has limitations it is our intention to make use of different methods in future studies and to run comparative analyses of their uses.

6. Conclusion

The use of a scientific methodology, such as the TODIM multicriteria method, which permits the evaluation of students, analyzing not only the Attainment Average but also diverse academic projects in which the student participates during the course of university studies, is shown to be completely viable. This methodology permits not merely a single evaluation criterion to be considered in the evaluation process but multiple criteria, such as: Scientific Initiation Projects, the Monitor Program, Extension Projects, the Junior Enterprise and Scientific Articles.

The evaluation of students' performance solely by the accumulated AA does not show in its entirety how a student has benefited from and made use of the university. Many students with a slightly lower AA but who have participated in extracurricular projects are better prepared for the first challenges in the work market. Through the analysis employed, it was discovered that the student with the best AA (Student D) was not the best student when analysed using all the criteria, and that Student B presented a better performance due to participation in various extracurricular activities at the university.

This evaluation process can also be optimized according to its use. New criteria can be integrated into the analysis, such as University Exchange Programs or Laboratory Work. In this way, other points of view can be considered in this new process of student evaluation and thus, the multicriteria method can be applied not only internally in the university environment, but also in companies in selecting trainees or even permanent employees in their selection processes.

Acknowledgements

This work was partially supported by CNPq / Brazil through research projects 305732/2012-9 and 302692/2011-8.

References

[1] Ali, N.; Josoff, K.; Ali, S.; Mokhtar, N. & Salamat, A.S.A., 2009, The Factors Influencing Students' Performance at University Technology MARA Kedah, Malaysia, *Management Science and Engineering*, 3(4), 81-90.

[2] Broh, B.A., 2002, Linking extracurricular programming to academic achievement: Who benefits and why? *Sociology of Education.* 75, 69-91.

[3] Felder, R.M. & Brent, R., 2003, Learning by doing. *Chemical Engineering Education*, 37(4), 282–283.

[4] INEP, 2011, *Instituto Nacional de Educação e Pesquisa Educacionais Anísio Teixeira.* Available on: http://inep.gov.br/. Accessed on: April 20.

[5] Nonis, S.A. & Wright, D., 2003, Moderating effects of achievement striving and situational optimism on the relationship between ability and performance outcomes of college students research in higher education. *Research in Higher Education*, 44(3), 327-346.

[6] TREE, 2011, *Teaching and Research in Engineering in Europe Special Interest*, Group C8 "Extra Curricular Activities in Engineering Education", Available on: http://www.unifi.it/tree/dl/oc/c8.pdf. Accessed on: April, 20.

[7] Bana e Costa, C.A. & Oliveira, M.D., 2012, A multicriteria decision analysis model for faculty evaluation. *OMEGA - The International Journal of Management Science*, 40, 424 – 436.

[8] Mustafa, A. & Goh, M., 1996, Multi-criterion models for higher education administration. *OMEGA – The International Journal of Management Science*, 24, 167-78.

[9] Kong, W.H. & Fu, T.T., 2012, Assessing the performance of business colleges in Taiwan using data envelopment analysis and student based value-added performance indicators. *OMEGA – The International Journal of Management Science*, 40, 541-549.

[10] Meredith, J.R. & Steward, M.D., 2011, Lewis B.R. Knowledge dissemination in operations management: Published perceptions versus academic reality, *OMEGA - The International Journal of Management Science*, 39(4), 435-446.

[11] Donohue, J.M. & Fox, J.B., 2002, A multi-method evaluation of journals in the decision and management sciences by US academics. *OMEGA - The International Journal of Management Science*, 28(1), 17-36.

[12] COSEAC, 2011, Available on: http://www.coseac.uff.br/cidades/nithist.htm. Accessed on: April, 23.

[13] PROAC, 2011, Available on: http://www.proac.uff.br/apoio-curricular/calculo-do-coeficiente-de-rendimento-escolar-cra. Accessed on: April, 23.

[14] CNPq, 2011, Available on: <http://www.cnpq.br/normas/rn_06_017_anexo5.htm>. Accessed on: April, 23.

[15] SAE BRASIL, 2011, Regulamento da XIV Competição Baja SAE Brasil. 2008. Available on: http://www.saebrasil.org.br. Accessed on: January, 25.

[16] PROJETOS SOCIAIS, 2011, Available on: http://projetossociais.wordpress.com/. Accessed on: April, 24.

[17] ABNT, 2003, *NBR 6022: Informação e documentação: artigo em publicação periódica científica impressa: apresentação*. Rio de Janeiro, 5 p.

[18] Barba-Romero, S. & Pomerol, J.C., 2000, *Multicriteria Decision in Management: Principles and Practice.* Kluwer Academic Publishers, Boston.

[19] Roy, B. & Bouyssou, D., 1993, *Aide Multicritère à la Décision: Méthodes et Cas*. Paris, Ed. Economica.

[20] Belton, V. & Stewart, T.J., 2002, *Multiple criteria decision analysis: an integrated approach*. Kluwer Academic Publishers, Massachusetts.

[21] Gomes, L.F.A.M. & Lima, M.M.P.P., 1991, TODIM: Basics and application to multicriteria ranking of projects with environmental impacts, *Foundations of Computing and Decision Sciences*, 16 (4), 113-127.

[22] Gomes, L.F.A.M. & Lima, M.M.P.P., 1992, From modelling individual preferences to multicriteria ranking of discrete alternatives: A look at prospect theory and the additive difference model, *Foundations of Computing and Decision Sciences.* 17 (3), 171-184.

[23] Kahneman, D. & Tversky, A., 1979, Prospect theory: An analysis of decision under risk. *Econometrica*, 47, 263-292.

[24] Roux, D., 2002, *Nobel en Économie*, 2nd éd., Economica, Paris.

[25] Salminen, P., 1994, Solving the discrete multiple criteria problem using linear prospect theory, *European Journal of Operational Research*, 72(11), 146-154.

[26] Bouyssou, D., 1986, Some remarks on the notion of compensation in MCDM, *European Journal of Operational Research*, 26(1), 150-160.

[27] Clemen, R.T. & Reilly, T., 2001, *Making Hard Decisions with Decision Tools*, Duxbury / Thomson Learning, Pacific Grove.

[28] Keeney, R.L. & Raiffa, H., 1976, *Decisions with Multiple Objectives*. New York: Wiley.

[29] Gomes, L.F.A.M. & Rangel, L.A.D., 2009, An application of the TODIM method to the multicriteria rental evaluation of residential properties. *European Journal of Operational Research*, 193(2), 204-211.

[30] Gomes, L.F.A.M.; Rangel, L.A.D. & Maranhão, F.J.C., 2009, Multicriteria analysis of natural gas destination in Brazil: An application of the TODIM method. *Mathematical and Computer Modelling*, 50, 92-100.

[31] Gomes, L.F.A.M.; Machado, M.A.S.; González, X.I. & Rangel, L.A.D., 2013, Behavioral multi-criteria decision analysis: The TODIM method with criteria interactions. *Annals of Operations Research*, DOI: 10.1007/s10479-013-1345-0, available on line in March 2013.