Budgetary allocations and efficiency in the human resources policy of a university following multiple criteria

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Abstract

This study proposes a methodology to serve as a guiding mechanism for the allocation and management of university financial resources taking efficiency as its objective. Specifically, an aid model is provided for decision making, so that the planning of staff policy within a university guarantees an equal treatment of all the teaching and research units, greater transparency in the allocation of financial resources, as well as a rational monitoring of the allocations made and their effects on the university efficiency levels. The model we provide is based on the use of two quantitative techniques: data envelopment analysis (DEA) and multiple criteria decision making (MCDM), both techniques being linked in a way which makes it possible to transfer information from one to the other.

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1. Introduction

Spain, like the majority of European countries, has decided to adopt a non-market-based model, specifically the collegiate system, opting for state funding of higher education. The institutions which make up the Spanish higher education system, the universities, are endowed with an ample degree of autonomy in decision making regarding such essential matters for their functioning as the management of their financial resources, the human resources policy and the characteristics of the academic and other services they provide.

A considerable percentage of each Spanish university’s budget (53–58%) goes towards the remuneration of the teaching staff. The planning of these human resources aims, basically, to meet teaching staff requirements, without taking into account the objectives of the services provided and showing an incremental trend, which hinders the pursuit of efficiency. However, recent attempts have been made to break this dynamic, by linking part of the funding to the obtaining of results based on certain explicit objectives previously set by each university.

Thus, in this article we propose a methodology which admits the incorporation of efficiency and quality criteria in the planning and allocation of new human academic resources within a university, based on the combination of two quantitative techniques which provide support to decision-making: data envelopment analysis (DEA) and multi-criteria decision making (MCDM).

The literature in this field contains some significant studies in which the two techniques are applied separately in the area of higher education. Mustafa and Goh (1996) collect a bibliographical review of the MCDM applications in the education field. More recently, special
mention should be made of the work carried out by Fan-
del and Gal (2001), which uses goal programming and
different concepts of distance to deal with a real problem
of fund redistribution for teaching and research among
state universities in a German länder. On the other hand,
amongst the DEA applications to tertiary education,
some studies deserving special mention, amongst others,
are those carried out by Beasley (1995), which analyzes
the teaching and research efficiency in different depart-
ments of the same subject in the United Kingdom, and
by Arcelus and Coleman (1997), who analyze the
efficiency of 32 departments of the University of New
Brunswick (Canada), on the basis of which the budget
is distributed.

Although these two techniques were initially
developed separately, studies have subsequently emerged
which attempt to achieve an approximation between the
two, in the sense of combining them, thus demonstrating
that they are not as different as they might first appear
and that the multi-objective formulation of the DEA
problems gives rise to additional interpretations to be
considered [Stewart (1996); Joro, Korhonen and Wallen-
ius (1998); Yun, Nakayama and Tanino (2000)].

One of the first studies to combine both techniques
was presented by Golany (1988), who proposes the use
of an interactive linear multi-objective procedure to help
the decision maker to establish real efficient levels of
production for a given resources vector. Athanasso-
poulos (1995 and 1998) uses DEA and goal program-
ning for planning problems in public organisations with
a hierarchical system in the presence of local and global
objectives. On the other hand, Post and Spronk (1999)
combine DEA and interactive goal programming in order
to incorporate the wishes of the decision maker into the
original DEA model, contrasting all of this with data
taken from 50 physics departments in the United King-
dom. Li and Reeves (1999) put forward a multiple cri-
teria data envelopment analysis (MCDEA) model in
which they incorporate different measurements of
efficiency, and they apply their methodology, amongst
other examples, to evaluate the efficiency of one univer-
sity’s departments. Finally, the studies carried out by
Halme, Joro, Korhonen, Salo and Wallenius (1999); Kor-
honen (2000) and Korhonen, Tainio and Wallenius
(2001) incorporate, in the traditional DEA, the prefer-
ces of the decision maker, by choosing his most pre-
ferred point on the efficient frontier and, consequently
the efficiency evaluation of each unit is achieved in
relation to the indifference curve of the (approximate)
value function which passes through the aforementioned
point. Moreover, the last of the studies referred to ana-
lyzes the application of this approach to the evaluation
of the research efficiency in universities and research
institutions.

In this context, what we aim to do in this study is to
demonstrate the complementary relation that exists
between both techniques for the planning of academic
human resources within a university. Thus, in the follow-
ing section we develop the three phases which make up
our approach and which we have called DEA–MCDM–
DEA. In an initial phase, we shall use a DEA model to
evaluate the technical efficiency with which each pro-
ductive unit of a particular university makes use of its
human resources. Following this, we apply a goal pro-
gramming model for the allocation of new resources to
the above-mentioned units, incorporating information
taken from the previous phase and in accordance with
certain objectives and priority levels established by the
decision maker. Finally, in a third phase, an attempt is
made to analyze the situation created by the functional
units starting from the basis of the allocation made in
the previous phase. For this purpose, DEA is applied
again this time with the new input and current output
levels. In the third section the results obtained by apply-
ing our model to the University of Malaga (UMA) are
presented with data drawn from the 1997/98 course (142
departments with 1795 teachers giving classes to 40 329
students). The article ends with the most relevant con-
cclusions that emerge from our research.

2. Model

The approach we propose, as we have already men-
tioned, involves the application of three phases in
sequence: DEA–MCDM–DEA (Fig. 1).

In this context, we have chosen as the unit of analysis,
the department, being the entity that has the greatest
teaching affinity within the university system. On the
other hand, the increase in the university budget design-
nated for the teaching staff is distributed among the dif-
ferent departments taking into account, in the case of
Spain, only teaching criteria and it is on this basis that
we establish the goal programming model of phase 2.
For this reason, in evaluating the efficiency of these units
we have considered only the teaching aspect. Neverthe-
less, the plan presented is flexible and, if desirable, the
research aspect can be included.

2.1. Phase one: DEA model for the evaluation
of technical efficiency

In this phase we consider the departments as pro-
ductive units that employ human resources (inputs) to

![Fig. 1. Three phases: DEA–MCDM–DEA.](image_url)
carry out their teaching activity (output). The problem lies in making the right selection of the most significant indicators, given their incidence in the efficiency estimates.

Thus, focusing on human resources, we have established four indicators: the teaching capacity of the state employed teachers ($x_{ij}$) by which we mean, the sum of the credits\(^1\) assigned to each state employed teacher of the \(i\)th department, according to his contacts and current guidelines; the teaching capacity of the non-state employed teachers ($x_{2i}$), being the same as the previous one except that the teachers are not permanent members of staff. The other two variable inputs correspond to persons assigned to the department to carry out functions of assistance to the teaching staff: the number of grant workers ($x_{3i}$) and, finally, the number of administrative and laboratory service staff ($x_{4i}$). On the other hand, quantifying the teaching output is a complex task. However, given that our unit of analysis is the department, we shall use familiar indicators such as those of process.\(^2\)

Regarding this, in order to assess the quantity and quality of the students enrolled in a given department we take as first indicator the number of normalized students pertaining to department \(i\) ($y_{1i}$), in other words, the number of students enrolled in department \(i\), applying various weighting coefficients depending on whether they are first, second, or successive enrolments.\(^3\) Furthermore, there are other aspects which determine the spatial and human environment in which any teaching–learning process develops; these being, on the one hand, the average number of students per group receiving classes from the teacher in each of the subjects offered by the department, represented by the indicator for the average size of the department teaching groups \(i\) ($y_{2i}$) and, on the other hand, the number of credits imparted in real terms by each department, represented by the variable real teaching load of the department \(i\) ($y_{3i}$), which is obtained as the sum of the number of credits for each subject taught by the department multiplied by the number of student groups for each subject. This indicator would reflect the weight of the subjects of a department expressed in credits. Consequently, the three variables represent different aspects of teaching output.

On the other hand, it is necessary to select a specific model from amongst the different possibilities offered by DEA [see Charnes, Cooper, Lewin and Seiford (1994)].

We have opted for a BCC model (variable returns to scale model), with which we evaluate the efficiency of each unit by taking as a reference units that operate on a similar scale, thus obtaining a measurement of pure technical efficiency (PTE), uncontaminated by problems of scale that could occur in the CCR model (constant returns to scale). Finally, we have chosen an output orientation since in this first phase the target is to know whether the departments provide an adequate teaching service (output) with the teachers at their disposal (input). Therefore, in order to evaluate each unit \(I\) \((I = 1, 2, \ldots, n)\) we apply the following model:

\[
\max \phi_i + \left( \varepsilon \sum_{r=1}^{3} s^+_r + \varepsilon \sum_{l=1}^{4} s^+_l \right)
\]

subject to

\[
\sum_{j=1}^{n} \lambda_j x_{ij} + s^-_i = x_{ip}, \quad \sum_{j=1}^{n} \lambda_j y_{2j} - s^+_i = \phi y_{1p} \sum_{l=1}^{n} \lambda_l,
\]

\[
= 1, \lambda_i, s^+_i, s^-_i \geq 0 \quad l = 1, 2, 3, 4; r = 1, 2, 3.
\]

2.2. Phase two: MCDM model for the budgetary allocation of new funds

Once information has been obtained regarding the technical (in)efficiency of the units which make up the university system, we then proceed to establish, by means of a goal programming model, the human resources necessary to situate those units within efficiency levels that we shall define on the basis of the results emerging from the previous phase. The aim is to narrow the distance between the inefficient and the efficient units and, in addition, to determine the resulting economic cost for the university in question.

The goal programming model we present in this section attempts to improve different aspects of the one created by Caballero, Galache, Gómez, Molina and Torrico (2001), adapting it to the aim pursued in this study (the complete formulation is set out in the Appendix). Thus, we shall distinguish two types of decision variables, in accordance with the staffing policy followed in the Spanish university system. On the one hand, those which represent the number of new teachers belonging to a certain category \(k\) which can be hired by a department \(i\) and which we shall express as \(x_{ik}\) (new teaching staff hired) and, on the other hand those which represent the number of teachers moving from category \(f\) to category \(j\) in department \(i\) and which we shall express as \(T_{ij}\) (promotion of existing teaching staff). Logically, such variables must be integer.\(^4\)

---

\(^1\) One credit is equivalent to 10 teaching hours.

\(^2\) q.v. the studies carried out by Beasley (1995); Arcelus and Coleman (1997) and Hanke and Leopoldseder (1998).

\(^3\) \(y_{1i} = STUD^{(1)} + 0.85\cdot STUD^{(2)} + 0.80\cdot STUD^{(3)}\); \(STUD^{(h)}\) = Students department \((i)\) in \(h\)-th enrolment \((h = 1, 2, 3)\) (Contreras, Repeto, García, Álvarez-Manzaneda, Márquez, Hernández-Armenteros, Martín, Ferraro & Ramírez de Arellano (1995)).

\(^4\) It is important to point out that resolving the goal programming model has been difficult and complex specifically due to the fact that five problems have been solved using 4000 variables and 700 restrictions. For this, the software PROMO (Caballero, Ruiz, Luque and Molina (2000)) was used.
In the case of Spain, there are seven categories of teacher in ascending order according to the corresponding salary structure. The new hired staff can belong to any of the first five categories, whilst the promotion would refer to a teacher moving from any of these first five categories to one of the last two and/or a category higher than the one he belongs to. Each teacher is obliged to impart a certain number of credits per year, in accordance with the category to which they belong and this will be expressed by $C_j$ and when a teacher is promoted from category $f$ to category $j$ this causes a variation in the credits that they are obliged to impart per year and which we express as $\Delta C_{fj}$. Furthermore, in view of what is a habitual occurrence in the case of Spain, we have taken into consideration the fact that no promotional move can take place, but the sub-indices $f$ and $j$ of the variables $T_{fi}$ must necessarily belong to the following set:

$$S = \{(f,j)/f = 1, j = 2, 5; f = 2, j = 5, 6; f = 3, j = 4, 5, 6, 7; f = 4, j = 5, 6, 7; f = 5, j = 6, 7; f = 6, j = 7\}$$

Once the variables of the model have been fixed, the restrictions for each department and a specific academic course are established. Regarding the new contracts, restrictions are imposed in order to represent structural improvements within the university system and ensure that the existing departmental staff is not too destabilised by the hiring of teaching staff in very low salary categories (restrictions C1 and C2 of the Appendix). Concerning the variables that represent teaching staff promotions in each department, these are limited by the number of teachers in the section category (C3), where $N_i$ stands for the number of teachers in category $f$ belonging to department $i$. On the other hand, a teacher is not allowed to change category more than once in the same academic course (C4).

As we have previously mentioned, in the Spanish university system the needs of departmental teaching staff are justified on the basis of the teaching demand, in other words, by comparing the real teaching load of department $i$ ($RTL_i$),\(^5\) with the total teaching capacity of the aforesaid department ($TTC_i$), the total number of credits which must be imparted by teachers of department $i$, according to the corresponding category). On the other hand, those universities which, along with Malaga, belong to the region of Andalusia, also employ another indicator called the academic participation of the subjects of department $i$ ($APS_i$) which represents the total number of credits that the university is willing to finance for that department depending on its degree of experimental activity. Consequently, in order to reflect reality, our model contains these aspects in two blocks of objectives that we have formulated as goals:

1. To guarantee, in each department ($i = 1, 2, \ldots, n$), that there is a sufficient number of teachers (expressed in terms of credits) to meet the teaching requirements of the following course. As such, the $TTC_i$, once the new contracts and category improvements have been taken into account, must be higher than the $RTL_i$ and, furthermore, leaving enough slack to cover any unforeseen situation which may occur (slight variations to the number of students anticipated, days off work due to sickness, stays in foreign universities, etc.) all of which we express as a percentage, $G$, of the $TTC_i$. Thus, the first block of $n$ goals can be expressed by the inequality:

$$TTL_i - G \cdot TTL_i \geq \sum_{j=1}^{5} x_{ji} C_j + \sum_{(f,j) \in S} T_{fi} \Delta C_{fj} = RTL_i$$

Inserting the deviation variables and leaving the decision variables on one side of the inequality, we obtain the analytical formulation (G1) which is shown in the Appendix.

2. To satisfy the basic financial requirements of each department ($i = 1, 2, \ldots, n$), which is formalised in the following expression:

$$TTL_i + \sum_{j=1}^{5} x_{ji} C_j + \sum_{(f,j) \in S} T_{fi} \Delta C_{fj} = APS_i$$

Carrying out the same operation as before, we obtain the second block of goals (G2) which is shown in the Appendix. But we also proposed to improve the quality of the teaching and therefore, after holding a series of interviews both with heads of departments and with technicians from the Vice-Chancellor’s Office of Academic Planning of the University of Malaga (UMA), we have defined four further objectives, also formalised as goals (G3, G4, G5 and G6), which we shall proceed to comment on.

3. To assign more teaching staff to those functional units that have a ratio of students per teacher and subject in the academic course which is above a value deemed desirable and which will be denoted by $STUDPROF$. Consequently, the $n$ corresponding goals are:

$$TTL_i + \sum_{j=1}^{5} x_{ji} C_j + \sum_{(f,j) \in S} T_{fi} \Delta C_{fj} \geq \frac{STUDNRCREDSUB_i}{STUDPROF}$$

where $STUDNRCREDSUB_i$ is obtained as the sum of all those students receiving classes in each of the different subjects of department $i$ ($i = 1, 2, \ldots, n$) multiplied by the number of credits of those subjects.

\(^5\) $RTL_i$ is a fixed value that coincides with variable $y_{3i}$ defined in the DEA model of phase one.
4. To foment a higher level of qualification in the teaching staff, ensuring that in each department there exist a minimum number of professors in the categories for which a PhD degree is necessary. That minimum number is expressed as a percentage of the new TTL, reflected in the parameter DOCTLOAD. Consequently, these goals (G5) take the form:

\[ \text{TLSDoctor}_i + \sum_{j=1}^{5} T_{j|i} \leq \text{DOCTLOAD}(\text{TTL}_i) \]

where \( \text{TLSDoctor}_i \) is the teaching load, measured in credits, of the state employed teachers who are doctors in department \( i \) \( (i = 1, 2, \ldots, n) \).

5. To provide financial resources to those departments whose average real cost per credit imparted is lower than a specific value, AVCREĐ. This will be formulated as follows:

\[ \text{SAL}_i + \sum_{j=1}^{5} x_j C_j + \sum_{(f,j) \in S} T_{j|f} \Delta C_f \geq \text{AVCREĐ}(\text{RTL}_i) \]

where \( \text{SAL}_i \) is the total cost of the teaching staff of department \( i \) \( (i = 1, 2, \ldots, n) \).

6. Finally, within the group of solutions which satisfy the previous levels, to determine the cheapest contracts and/or promotions. Thus, the following goal (G6) is obtained:

\[ \sum_{i=1}^{n} \left( \sum_{j=1}^{5} x_j S_j + \sum_{(f,j) \in S} T_{j|f} \Delta S_f \right) \leq TL \]

We set the target value \( TL \) at a relatively low level so that this goal cannot be achieved and the nearest solution is obtained. This solution will therefore be that which, by verifying the demands imposed on the previous five priority levels, involves the minimum possible cost.

The parameters \( G, \text{STUDPROF, DOCTLOAD and AVCREĐ} \), which define the levels of aspiration of the corresponding goals, are fixed by the decision maker in accordance with his preferences and, for that reason, the information obtained in phase 1 can be of use to him. Thus, for example, it may be of interest to him to fix these levels according to the efficient units. All of this allows the university governing organs to, on the one hand, design a funding policy of human academic resources that responds more to a true planning system than to the pressure applied by different groups, and on the other hand, to determine the minimum amount required to carry out such a policy.

Among the different goal programming schemes, we have chosen the lexicographic approach given that there was a clear order of priority in the fulfilling of these goals, and it is the same as the one we have developed. On the other hand, the minimization of the vector achievement function of performance of each priority level is carried out using a weighted approach, giving identical weight to all the goals at the same level and normalizing the unwanted deviation variables dividing them by their corresponding aspiration levels.

2.3. Phase three: New DEA model to analyze the average efficiency of the system

Finally, in phase three, the results produced by the MCDM model of the previous phase are incorporated into the original DEA model. In this way there will have been an increase to the inputs of some departments and it is expected that the efficient units of the first phase will be those which for the most part have undergone this increase. In this third phase, the aim is to analyze whether or not these units continue to be efficient and whether a narrowing of the gap between efficient and inefficient departments has occurred.

On the other hand, in a real context in which the solution provided by the goal programming model will be put into practice, in this third phase an analysis can be made for subsequent academic courses of the situation deriving from the different units. Thus, taking as a starting point this new DEA, if we have at our disposal the real outputs emerging from each course, then this will enable us to incorporate different adjustments, where required, into the goal programming model, which would provide new solutions and give rise to new situations. In consequence, this will enable the implementation of different scenarios in line with the educational policy that the universities’ governing bodies should wish to put into practice.

3. Results

We have applied the methodology presented in the previous section to the 142 departments of the University of Malaga (1998). Thus in phase one an analysis was carried out, using DEA (BCC model), of the university system as whole. Regarding the inefficient units, in addition to the 42 efficient units (10% of the total number of departments of the UMA) there exist another 27 which come very close to a relative efficiency. However, there are 38 departments that we can consider as being very inefficient. The efficiency interval ranges between 1, which corresponds to the efficient units, and 2.17 to the most inefficient unit, with the average inefficiency being registered at 1.2948.

On the other hand, the departments can be grouped
together into five branches of knowledge: Experimental Sciences (ES), Health Sciences (HS), Social and Legal Sciences (SLS), Technical Sciences (TS) and Humanities (H). Taking this classification into account, it can be observed that the most inefficient departments correspond to the branch of experimental sciences, while the units pertaining to the branches of humanities and social and legal sciences are the most efficient. If we analyze the rate of frequency with which an efficient unit appears in a reference group of inefficient unit (see Smith and Mayston, 1987), we find 14 efficient units which can be considered atypical (reference less than two departments), where the departments corresponding to the branch of humanities represent the biggest percentage. On the other hand, 19 efficient departments out of the 42 can be considered as genuinely efficient, with the branch of social and legal sciences again being the one that has the best performance.

Concerning phase two, the values of the parameters that define the target values of the goal programming model have been set taking as a starting point those levels which represent efficient units and thus, $G$, STUD-PROF, DOCTLOAD and AVCRED take on the values 5%, 72, 42.53% and 1.512,98.

The departments of the University of Malaga (UMA) in accordance with the levels of aspiration established, can take on, for the next academic course, a total of 570 hired and/or promoted staff, which means a minimum additional budget of 4,827,828,48 €. Regarding the first group, there are 195 new additions to the different departmental staff numbers, and in the second group, 375 promotions have been approved. In this sense, it is logical that there should be a greater number of teaching staff promotions than hired staff given that the cost of a shift from one category to another is lower than that of hiring new professors. In Table 1, we present a breakdown of how the aforementioned budget has been distributed amongst the 90 departments that have been allocated funds, classifying them by groups of branches of knowledge and decision variables.

The departments belonging to the branch of social and legal sciences are, by far, those receiving the largest allocation, followed by those belonging to technical sciences. Secondly, it is surprising that no department of the branch of experimental sciences receives any allocation for the hiring of new teaching staff. This result appears congruent if we analyze the data relating to this branch of knowledge. On average it has the smallest teaching load, the greatest doctorate/non-doctorate professor quotient (10/11) and the highest of ratio of public functionary/hired professors (8/3). Consequently, this is a branch in which the departments are consolidated, in other words, with a stable student number, a teaching staff made up mostly of public functionaries, etc., and which therefore verify all the goals of the different priority levels.

It should be pointed out that there are only instances of nonfulfillment in the fourth goal for units 28, 45 and 72, given that they do not have teaching staff in categories 3 and 6 to promote. Nevertheless, this block of goals has been relaxed in order to enable the process to continue. It must be noted that there exist other approaches like referent point, etc. (see Wierzbicki (1980)). We have used this scheme because it has proved to be more intuitive for the decision maker in this particular problem.

Furthermore, in phase three, starting from the initial DEA model, we carry out a new data envelopment analysis in which we incorporate the results of the goal programming model into the current staff of each of the departments. It must be noted that there is a significant improvement to the average efficiency of the system as a whole: the number of efficient units has increased to 57, 13 have an efficiency index below 1.20 and only three show an inefficiency rate above 1.3. We have also found that with the allocation of new resources the average efficiency equally improves in the branches of knowledge.

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6 Terminology of the University Coordination Council, the organ which agglutinates all the universities in the Spanish university system

<table>
<thead>
<tr>
<th>Branch</th>
<th>No. units</th>
<th>No. new contracts</th>
<th>No. promotions</th>
<th>Total</th>
<th>% s/total budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental sciences (ES)</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>369.7</td>
<td>0.05%</td>
</tr>
<tr>
<td>Health sciences (HS)</td>
<td>8</td>
<td>21</td>
<td>77</td>
<td>117483.6</td>
<td>14.63%</td>
</tr>
<tr>
<td>Social &amp; legal sciences (SLS)</td>
<td>42</td>
<td>114</td>
<td>167</td>
<td>421992.2</td>
<td>52.53%</td>
</tr>
<tr>
<td>Technical sciences (TS)</td>
<td>20</td>
<td>24</td>
<td>106</td>
<td>160243.7</td>
<td>19.95%</td>
</tr>
<tr>
<td>Humanities (H)</td>
<td>19</td>
<td>36</td>
<td>24</td>
<td>103186.8</td>
<td>12.85%</td>
</tr>
<tr>
<td>Total</td>
<td>90</td>
<td>195</td>
<td>375</td>
<td>803283.0</td>
<td>100.00%</td>
</tr>
</tbody>
</table>
Regarding what type of action could be taken on the inefficient units, we should point out that those in charge ought to pay particular attention when drawing up the strategic plan of the institution to fomenting, for example, the offer of new optional subjects in the departments mentioned, the imparting of inter-discipline PhD courses, as well as the possibility of introducing new degree programs in which these inefficient units are included.

Finally, we wish to emphasize that with the inputs and outputs considered in phase one, but with the data taken from the academic year 1999/2000, the efficient units of the UMA total 44 (as opposed to 42), however, the value for the average inefficiency is very high (1.3397). In contrast, if the allocation of the goal programming model, which we have shown, had been used, in other words, incorporating the new staff members and taking into account the output values for the academic year 1999/2000, the number of efficient departments would have risen to 46, with an average inefficiency of 1.2851.

With regard to this, we should point out, yet again, that all the parameters of phase two of the model can be adjusted to suit the preferences of the governing body and, consequently, other results can be obtained through adjustment whichever personnel policy is adopted for the different academic courses.

4. Conclusions

In the decision-making process of a university, this new model of planning and allocation of human resources is a valid tool both for the detection of efficiencies and/or inefficiencies in the productive units of the system and for determining the link between the allocation of new resources to the departments and their average improvement. On the other hand, it provides the governing body of a university with a suitable instrument to ensure that the human resources funding policy responds more to accurate planning than to pressure exerted by different groups. The difference as compared with the process currently being followed is very great given that, up till now, in the majority of Spanish universities the process of meeting the demand for teaching staff is done without referring to the satisfying the aforementioned educational policy’s objectives.

Finally, we wish to draw special attention to the advantages of complementing the two quantitative techniques in this study. The transfer of information between them enriches the development of the model and as such, provides tools which can be of help to the university administrators in their daily task of analyzing the current situation as best they can so that the decisions taken benefit from a more frequent and better information source.

Our aim for the future is to complete the methodology proposed to take into account the dynamic character of the current university system, in such a way that the model should include any change which may occur, as well as reflect the new field of action, in such a way that it could be put into practice in any university institution.

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Appendix

The goal programming model proposed is as follows:

\[
\text{Lex } \min \left\{ \sum_{i=1}^{n} \frac{n_i}{u_i} \sum_{j=1}^{n} \frac{n_j}{u_j} \sum_{k=1}^{n} \frac{n_k}{u_k} \sum_{l=1}^{n} \frac{n_l}{u_l} \sum_{m=1}^{n} \frac{n_m}{u_m} \sum_{p=1}^{n} \frac{n_p}{u_p} \right\}
\]

subject to:

\[C1 \quad x_{ji} + x_{3j} \leq 1 + x_{5j}\]

\[C2 \quad x_{3j} - x_{3i} - x_{4i} \leq 0\]

\[C3 \quad 0 \leq T_{ji} \leq N_{ji}\]

\[C4 \quad \sum_{j} T_{ji} \leq N_{ji} \quad (f, j) \in S \quad i = 1, 2, 3, \ldots, n\]

\[G1 \quad \sum_{j=1}^{5} x_{ji} C_{ji} + \sum_{(j, f) \in S} T_{jf} \Delta C_{jf} + n_{j1} - p_{j1} = \text{RTL}_{i} + (1 - G) \cdot \text{TTL}_{i}\]

\[G2 \quad \sum_{j=1}^{5} x_{ji} C_{ji} + \sum_{(j, f) \in S} T_{jf} \Delta C_{jf} + n_{j2} - p_{j2} = \text{APS}_{i} - \text{TTL}_{i}\]

\[G3 \quad \sum_{j=1}^{5} x_{ji} C_{ji} + \sum_{(j, f) \in S} T_{jf} \Delta C_{jf} + n_{j3} - p_{j3} = \frac{\text{STUDENTCREDSUB}_{i}}{\text{STUDPROF}} - \text{TTL}_{i}\]

\[G4 \quad \sum_{j=3}^{6} T_{ji} 24 - \text{DOCTLOAD} \left( \sum_{j=1}^{5} x_{ji} C_{ji} + \sum_{(j, f) \in S} T_{jf} \Delta C_{jf} + n_{j4} - p_{j4} = \text{DOCTLOAD-TTL}_{i} - \text{TLSDoctor}_{i} \right)\]
\[
\begin{align*}
\text{[G5]} & \quad \sum_{j=1}^{5} x_j S_j + \sum_{(j,i) \in S} T_{ji} \Delta S_{ji} + n_5 - p_5 \\
& = \text{AVCREG-RTL} - \text{SAL}_p \\
\text{[G6]} & \quad \sum_{i=1}^{n} \left( \sum_{j=1}^{5} x_j S_j + \sum_{(j,i) \in S} T_{ji} \Delta S_{ji} \right) + n_6 - p_6 = TL
\end{align*}
\]

References


