# A MILP model for the long term academic staff size and composition planning in public universities ☆

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## ARTICLE INFO

## ABSTRACT

This paper proposes a model for dealing with the long term staff composition planning in public universities. University academic staff is organized in units (or departments) according to their field of expertize. The staff for each unit is distributed in a set of categories, each one characterized by their teaching hours, cost and other specificities. Besides the use for planning (and updating a plan), the model can be used to assess the impact that different strategies may have on the personnel costs and the structure of a university. The proposed model is formulated generally, so it can be applied to different types of universities attending to their characteristics. The model is applied to a real case and validated by means of a computational experiment considering several scenarios. The analysis is focused on achieving a preferable academic staff composition under service level constraints while also minimizing the associated economic expenditures considering a long term horizon. The results show that the model successes in approaching the staff composition to a previously defined pattern preferable one.

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## 1. Introduction

Universities are Knowledge Intensive Organizations, i.e. KIOs [28] in which having academic staff with certain knowledge and expertize may require several years (workers, which are highly qualified, are not easily replaced). Having the right academic staff size and composition in a university, as in other organizations, depends on decisions that must be taken in advance enough (for example, to have a certain amount of professors in a certain year is possible only if staff with the right profile is hired some years before and trained and promoted progressively from lower categories). Without an accurate strategic planning the available academic staff may not be appropriate for the requirements of the university, both regarding teaching capacity (teaching hours) and research and knowledge transfer activities. Thus, it is essential to have tools that enable an adequate planning for long term (strategic) academic staff size and composition. This is especially important for public universities, where there are normally strict regulations that do not permit to adjust easily the staff composition.

In most countries universities have been growing (both in number and size) as the education level of the population was becoming higher. The size of the academic staff in public universities has been increasing while the economic situation of countries was good and the demand for university courses was high. Generally, the academic staff was growing, but without the result of an analytical planning procedure and only as the result of short-term decisions taken normally with a reduced horizon (without considering for example future retirements). As Rowley et al. [25], Birnbaum [5] and Lillis [16] pointed out that usually the planning of the workforce in universities is mostly short-sighted and motivated from the need of solving punctual problems, or intensively explored for a short period of time only to be abandoned later, without any real attempt to assess their effectiveness.

The lack of an accurate planning may cause a too high cost of the staff, or a shortage or a surplus of academics with certain knowledge and/or expertize in some areas or departments or an inappropriate staff composition; note that, as Maenhout and Vanhoucke [20] state, in a university, where knowledge plays an important role, not only the economic criteria are necessary to be considered for determining a staff composition. Academic staff tasks include, besides of teaching, doing research and participating in knowledge transfer projects (also keeping some management responsibilities like a head of a department does). Hence, people who are able to do these tasks and also people who are able to manage these tasks are needed. This gives raise to the need of achieving an academic workforce with reasonable costs and a proper capacity in terms of research and knowledge transfer. Both costs and capacity outperforming those tasks grow with the category so both criteria have to be taken into account when planning the staff size and composition, reaching to a balanced workforce.

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If staff strategic planning is an important activity for any organization (its performance may depend on this), this is especially true for public universities for two reasons: first, because the flexibility to correct the size or the composition of the staff in the medium or short term is very limited (due both to regulations on promotions and hiring and to the difficulty in finding people with enough expertize and knowledge in some areas); and second, because the available budget to use on staff decisions (mainly on hiring and promotions) is tight, especially in situations of economic crisis like the actual one, with public funding becoming lower and lower. Resources have to be used in an efficient way, and this means leading to the workforce (size and composition) that covers the needs of the organization in an appropriate way, which obviously is not possible if a correct staff plan is designed in advance. Besides, it is important to note that the staff planning in universities is also a very relevant problem for other reasons, such as the competition to attract the best professors, pupils and research funding [29].

The numerous changes (both external and internal) that Higher Education Institutions (HEIs) have been facing during the last decades motivated for the first time in the eighties of the 20th century the development of the strategic management in universities (based on the experiences in companies). In the eighties also took place the widely movement of NPM (New Public Management), which hold the hypothesis that market oriented management of the public sector would lead to greater cost-efficiency for governments, without having negative side-effects on other objectives and considerations [13]. However, the staff planning was not included in the strategic management [17]. Several universities have carried out actions for the definition of the strategic planning. That is why the strategic staff planning in universities is a hot topic and very timely. In this sense, and as Hunt et al. [14] pointed out, the strategic staff planning would permit universities to optimize their resources, thus achieving greater institutional success (greater international projection, better academic environment, etc.). However, and despite the fact that several studies demonstrate that the number of strategic management-related practices is increasing [1,15,18,26,7,8], this positive change in the tendency is constrained by the academic and institutional regulations in universities.

Regardless the importance of the staff strategic planning for the design and viability of all type of organizations, few studies concerning the determination of the strategic planning for KIOs are reported in the literature [22,32]. In fact, as noted by Machuca et al. [19] and Roth and Menor [24], a gap between the increasing importance of the management in service organizations and the related studies is identified.

Since the early production planning model of Holt et al. [12], which considered hiring and firing of personnel in a very simple way, few authors have dealt with similar problems, mainly addressing manufacturing industry ([31,23,10,11,6]), but no one with the problem that is being addressed in this paper. Actually, to the best of our knowledge, there are no works in the scientific literature that propose tools for solving the problem of determining the size and composition of the academic staff of a public university and at the same time taking into account the regulations on hiring, firing and promoting, optimization criteria and relevant characteristics for this kind of organization as well. These characteristics are such as the heterogeneity of the workforce and the need of considering other factors apart from those purely economic, as the required service level, while determining the preferable staff composition (in size and expertize).

Our problem is partially considered in a few papers. For instance, Corominas et al. [9] propose a model for an aggregate planning problem that includes the hiring and firing of workers considering a learning period, but the transfers between categories (promotions within a given pathway) nor the staff composition criteria are not

included there. In the same line Song and Huang [27] present a model for hiring, firing and transferring employees (who are considered homogeneous, i.e. with the same capacity and skills) among different units and the main optimization criterion is to minimize the personnel cost. Such problem is also addressed in Ahn et al. [2], but considering heterogeneous workers in this case.

Attending to the scarcity of the literature concerning the long term staff planning in KIOs in general and in public universities in particular, the main contributions of this paper are: (1) to formalize the problem considering public university characteristics, especially those regarding planning criteria (such as achieving a certain composition) and those regarding hiring, firing and promoting possibilities (category pathways); (2) to propose a new Mixed Integer Linear Programming (MILP) model for dealing with the problem; and (3) to give some managerial insights that come from a computational study and the application of the model to a real case.

The paper is organized as follows: Section 2 describes the problem; Section 3 includes the description of the proposed mathematical model formulation; Section 4 presents a case study; Section 5 includes a computational study; and finally the conclusions and proposed further work are detailed in Section 6.

## 2. Problem description

Strategic staff planning may involve many kinds of decisions. Some of them (for example, the number of people to hire, dismiss and promote) can be taken by applying a formalized planning procedure (for example, based on a mathematical model, as it is proposed here), and others (such as deciding the kind of staff pyramid that is appropriate for a given university) would require other kind of procedures, probably not so formalised and more qualitative. The concrete strategic staff planning problem here addressed consists of determining, for each period of a long term horizon, the size and the composition of the academic staff for a public university. The university is supposed to be organized in units (for example schools, faculties or departments) and each member of the academic staff belongs to one and only one unit. Transfers between units are not considered since such decisions are quite singular and require dedicated analyses.

Each academic belongs also to a category, being possible to change from one category to another/s during the planning horizon, according to the established rules, which in public universities are normally clear and rigid. It is possible for a person to promote to a higher category once the required merits (for the upper category) are reached and, of course, if a job position in that upper category has been created or is available.

In most public universities there are also part time lecturers, which are hired only for teaching purposes and provide students with real world experience thus complementing their education. The proportion hold by these workers in university may be bounded by the government or by the university.

Of course the exact career pathway depends on the country/university legislation, but it can be considered that most public universities have common characteristics. In all of them there are temporary categories (this means that if after a certain time the person has not changed to an upper category, he/she is dismissed) and permanent categories. The academics that are needed for a certain category can come from a lower category (an internal promotion) or from the labor market. Fig. 1, presented and more widely described in Section 4, gives an example of a career pathway for the university workers, more widely described in Section 4.

There are two types of categories for workforce: temporary and permanent. In temporary categories, just after a member of the staff obtains his/her graduate and Ph.D., it is mandatory to follow a path of a certain duration. In these categories, the contracts are