



A decision support system and a mathematical model for strategic workforce planning in consultancies

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Abstract

Strategic staff planning in consultancies is a major problem that directly affects the firm's performance and capacity for dealing with projects appropriately. Furthermore, the decisions taken now will have long term consequences, because consultants are highly qualified workers who need very long learning periods to achieve enough expertise. In other words, the size and composition of the future workforce depends on the decisions taken today. It is important to underline that the system anticipates future capacity adjustment in response to forecasted demand requirements; therefore, it is flexible to plan the workforce in different scenarios and time horizons. This paper proposes a decision support system based on a mathematical optimization model for solving strategic staff planning, taking the company's strategies, policies and objectives into account and optimizing both the costs and the staff composition. The tool is tested by applying it in an office belonging to a multinational consulting firm.

Keywords Capacity planning · Decision support systems · Mathematical programming · Staff planning · Strategic capacity planning · Consultancies

1 Introduction

This paper deals with the problem of strategic capacity planning in consultancies. For these companies the principal resources required are the professionals, so the capacity depends basically on the size and composition of the staff; therefore, dealing with the strategic capacity planning is, essentially, solving a strategic human resource planning problem. Consultancies, like other professional service firms (PSFs), have a highly educated and professionalized workforce that provides clients with customized, complex solutions. Both inputs and outputs are expert knowledge (Fu et al. 2012, 2015). The strategic capacity planning problem

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typically sets a long-term planning horizon. Depending on the industry, and the environmental uncertainty, it could range from 18 months to 10 years. Nevertheless, the problem is characterized more by the type of decisions to be made in each period (hiring, firing, and transferring) in order to meet future requirements, than by the length of the horizon.

This sector has been chosen because the consulting industry is an attractive field of research (Donnelly 2011; Martinez-Costa et al. 2015; Richter et al. 2008), being one of the main players in the knowledge based economy (Creplet et al. 2001; Fu et al. 2012). The role of human resources in their firm's performance has been widely recognized (Carvalho and Cabral-Cardoso 2008; Kim and Lee 2012). Consultancies are knowledge-intensive organizations, and their main asset is human capital, since the expertise and competence of their consultants play a key role in their competitive advantage (Anand et al. 2007; Donnelly 2011).

Strategic capacity planning is of crucial importance for all companies, and capacity planning has been an important research topic in Operations Management (see Martinez-Costa et al. 2014a for an updated review). In recent years, human resource planning in service organizations is receiving more attention (Hargaden and Ryan 2015; Huang et al. 2009), and there is increasing interest in the literature regarding the development of quantitative tools to support strategic capacity decisions in professional service organizations (De la Torre et al. 2016; Martinez-Costa et al. 2014b, 2015).

It should be considered that knowledge workers are highly skilled professionals who need quite a long time to develop (Dong et al. 2008). Professional service firms, such as consultancies, should plan their capacity with a sufficiently broad horizon to ensure a workforce of the appropriate composition and size. Otherwise they may encounter many difficulties in finding people with the right skills at a specific time. The learning period for newly-hired and newly-promoted consultants should also be considered. Selective staffing, training and development, and performance appraisal are common human resource practices widely implemented in professional service firms. Employees with poor performance are invited to leave the company. Furthermore, consulting work is highly demanding and turnover is a characteristic of this industry. These firms should consider how both turnover and retirements will impact their capacity and then take the required decisions to meet demand.

Long-term capacity and flexibility may be seen as two main issues to face the demand uncertainty. They have been considered in manufacturing (Stephan et al. 2010), but no so frequently in services like the consultancy. Therefore, this paper analyses the capacity planning problem in consultancies, identifying the key factors and decisions involved, and designs a decision support system to help managers solve the problem and define the most appropriate promotion policies. Specifically, this paper proposes a system based on a new mathematical optimization model for long-term capacity planning in consultancies, as a tool to: (1) support the hiring, firing, and promoting decisions, for each period of the planning horizon, considering the organizational structure, turnover and learning period (low productivity for newly-hired or newly-promoted); and (2) evaluate the impact that different objectives, strategies and Human Resources (HR) policies may have on staff movement,

the company's capacity and the workforce costs. Validation of both the model and the tool is by means of a real case study of a multinational consulting firm.

The remainder of this paper is structured as follows. The next section provides a brief review of the literature. Section 3 contains the problem description. The system and the model formulation are described in Sect. 4. After that, the case study and the main results are presented and discussed in Sect. 5. The model is tested on a set of different scenarios in Sect. 6. Finally, the research is concluded and further research avenues are proposed in Sect. 7.

2 Literature review

Most of the existing literature on strategic capacity planning has focused on manufacturing (e.g., Stephan et al. 2010), and among them, few contributions include workforce decisions in aggregate planning problems (e.g., Corominas et al. 2012). Another set of papers address the strategic capacity planning in service companies (such as restaurants, hotels, gas stations, and stores).

Furthermore, most contributions to capacity planning in labour intensive firms deal with tactical decision-making, and are focused on short-term workforce capacity planning, addressing the deployment of human resources, workforce scheduling and workforce allocation problem (e.g., Brennan 2006; Dixit et al. 2009; Dong et al. 2008; Gresh et al. 2007; Hargaden and Ryan 2015; Sungur et al. 2017). Defraeye and Van Nieuwenhuysse (2016) provide a literature review on staffing and scheduling problems.

Few papers concerning long-term human resource capacity planning can be found in the literature involving decisions about the number of people to hire, dismiss and promote, or considering the heterogeneity of the staff and the organizational structure of the organization. Ahn et al. (2005) present a model of staff capacity planning in a firm that employs heterogeneous workers, who have different skills, speed and/or quality, and turnover. The model considers integer values of the number of workers at any time, the number to be hired or fired, and the random number that leave.

Another study is by Li et al. (2007), which proposes a multiple objective linear programming model for integrated nurse staff planning and scheduling decisions in the health service sector. The problem considers different job types and categories of full-time staff, and decisions regarding the number of employees to be recruited or dismissed and for professional development (training).

Dealing with the professional service context, Subramanian and An (2008) present a mixed integer linear programming formulation to address the problem of optimal staff planning in the service industry with an expected demand outlook for various skills. An and Subramanian (2008) extend their work by offering an integrated model for short-term staffing and long-term capacity planning, using the same mathematical programming formulation as in their previous paper. Staffing problems in a business service organization are also addressed by Song and Huang (2008). They consider the planning problem of transferring (through cross-training), hiring and firing employees among different departments or branches. Turnover or voluntary leaving is also considered.

Huang et al. (2009) mainly focus on project-based service companies, such as consultancies. A discrete event simulator is developed along with a linear mathematical program model for the workforce capacity planning problem. The model determines the number of man-hours and skill sets needed, as well as the targeted man-hours to be hired or fired in each year. Different skill categories and leaving incidences are included. Decisions considered are the number of employees advanced (transferred) from one category to another and the amount of the workforce to be hired/fired in each category.

Most of the above-mentioned research has considered economic criteria in formulating the capacity planning problem, generally minimizing the cost. Nevertheless, De la Torre et al. (2016) study the preferable composition of the staff in public universities, so the objective is to minimise a function that contains the staff costs and the discrepancy between the composition of the staff and the one desired. The most closely related work is Martinez-Costa et al. (2015), which proposes a mathematical model to deal with the strategic capacity planning problem in consulting firms. The problem considers the organizational structure of a consulting firm (where professionals are organized into categories, business lines and industries), and the preferable composition of the staff. This introductory work does not provide any application of the model or model validation.

Research on the promotion process in professional service firms, especially consultancies, is scarce (Kumra and Vinnicombe 2008). Some companies organized such a traditional Professional Partnership (the P2 archetype characterized by the partnership form of ownership and governance, Greenwood et al., 2017) apply a stricter up-or-out system, or promotion to partner model. The up-or-out policy is a form of promotion based on meritocracy (Richter et al., 2008). Employees who do not have a good performance and are not promoted to the next organisational level within a specified time period are encouraged to leave the organisation (Kumra and Vinnicombe, 2008). However, consultants with a good performance appraisal results are promoted automatically in within the specified time period. As a consequence of this strict application of up-or-out policy usually a high rotation is necessary to respect the organizational pyramid.

Nevertheless, in unfavourable economic contexts, lower growth prospects may impede consultancy firms' capacity for rapid promotion. In addition to these market pressures, because of the emergence of work-life balance demands from professionals most companies have introduced most flexible career policies and alternative roles to partnership, creating new positions for non-partners (Malhotra et al., 2010; Noury et al. 2016; Smets et al., 2017).

This paper extends the previous research in several ways. First, the problem takes into account the career model in consultancy, as well as different promotion policies to be implemented (e.g. all the candidates eligible for promotion are automatically promoted, or conversely, only the highest performers are promoted). This allows for the fact that not promoting all the consultants who could be promoted induces an increase in turnover (i.e., turnover depends on the promotion policy). Next, the problem addresses turnover in addition to retirements, as well as employee training, and the learning curve affecting the chargeability (proportion of time to invoice clients) of newly-hired and newly-promoted consultants.

Finally, the decision support system has been applied to a real case company, and validated by means of a computational experiment considering several scenarios.

3 Problem description

The problem addressed here involves determining, for each period of the planning horizon, the size and the composition of the staff, both of which directly affect the capacity and the performance of the company. Also, solving this planning problem with different human resources strategies gives very valuable information about the impact that each of these strategies or policies would have both on the workforce and on the performance or results of the company. Accordingly, the problem is two-fold: on the one hand, a planning tool for staff planning is needed for use as a decision support system; and on the other hand, a tool for evaluating the impact of different strategies is needed for strategic planning purposes.

In order to capture the most relevant real-world issues that consultancies face in the staff planning process, structured interviews were conducted with six international consultancies. We found that all companies are organized in a very similar way (staff is organized by categories, industries and business lines) and, even if they may have different objectives or HR policies, from the exploratory study it can be clearly seen which issues have to be considered and which can be discarded as not being sufficiently relevant. The problem description given in this section is the result of that analysis.

The staff is organized in **categories** (from junior consultant to partner), **industries** (public administration, bank and accounting, manufacturing, etc.) and **business lines** (technology solutions, business models, etc.), and only movements between categories are considered by the company. This means that, with some few exceptions, consultants always remain in the same industry and business line, since they are considered to have an expertise that is very difficult to acquire and, of course, to replace.

Taking into account the above mentioned conditions, decisions regarding staff size and composition are, basically:

1. Hiring consultants from the labour market for a given category, industry and business line: it happens mainly for the bottom category (though not exclusively) and, besides the hiring costs, involves a training period and a training cost.
2. Promoting consultants from one category to the next: not all consultants are eligible for promotion, so the number of consultants to be promoted is upper bounded (a promotion ratio for this upper bound is assumed to be known).
3. Firing consultants from a given category, industry and business line: this may happen when the demand for projects belonging to that industry and business line decreases during a consecutive number of periods; otherwise, firing happens only in the case of the person not fulfilling his/her objectives.

Other movements that affect the workforce and the capacity include retirements, sick leaves, maternity and paternity leaves, reduction of working hours or part-time contracts and turnover. For this kind of company, the latter has become a real problem and great efforts are being made to understand and reduce the high turnover ratio. In principle, the turnover is supposed to be independent from the decisions described above. At the time of the study the company that provided the data was promoting all the workers who had acquired enough merits and expertise to be promoted. However, other consultancies do not follow such a policy and, indeed, one could argue that promoting all the candidates might not be the best strategy (depending on the economic situation, the labour market and the company's objectives), and that other policies should be examined. In the case that the company decided not to promote the maximum number of workers, some of them might be disappointed and decide to leave the firm. In this scenario, it would be advisable to consider that turnover (or at least a part of the turnover) is proportional to the consultants who, although eligible for promotion, are not automatically promoted. Also, demotivated workers could even perform poorly, negatively affecting the success of the projects.

The main differences between categories are the type of tasks performed, the salary and the number of hours dedicated to working on projects for the clients. Projects normally need a certain composition regarding categories (for example, one manager, two analysts, five junior consultants, etc.) which, of course, may depend on the industry and the business line; so, if the company has a forecast of the demand, it can estimate the number of hours of each type of consultant (including category, industry and business line) required in a given period.

The objective is to plan the workforce (hiring, firing and promotion) in the best manner possible. In this case, two evaluation criteria have been defined: (1) the first and obvious one is profit; (2) and the second one is the composition of the workforce, considering that a preferable composition exists and that the objective is to have a real composition as close as possible to it.

The definition of the most suitable preferable composition is a strategic issue that depends on many factors and, therefore, is beyond the scope of this paper. Nevertheless, the main contribution of this paper, a workforce planning tool for the consultancy company, can be used to evaluate the impact of different preferable pyramids for the company.

Below, the characteristics of the workforce planning problem are summarised:

- The structure of the company is known (i.e., categories, industries and business lines).
- Each worker belongs to one industry, one business line and one category.
- The initial size and composition of the staff are known.
- The professional career is known, and also the proportion of consultants from each category who annually become eligible for promotion to the upper category, which gives an upper bound of the number of people that can pass from one category to the next.
- An average proportion of workers being retired is known (for each category, industry and business line).

- The proportion of workers leaving the company due to turnover is known (for each category, industry and business line and under different promotion policies).
- An average proportion of loss of capacity (in hours) due to sick leaves, maternity and paternity leaves, part time contracts, etc. is known (for each category, industry and business line). The reason for considering all the above together is that individually they are very small and unpredictable whilst the aggregate ratio remains more or less constant and its estimation is more reliable.
- An average proportion of workers being fired because of poor performance is known (for each category, industry and business line).
- The maximum number of hours to be worked on projects (for each category) in a period is known.
- There is a forecast of the lower bound and the upper bound of the income for each industry, business line and time period (this can lead to demand).
- The proportion of workers of each category, for projects belonging to each industry and business line, is assumed to be known.
- It is supposed that when a worker is hired from the labour market and when a worker is promoted, there is a training period for which a cost must be considered.
- It is considered that when a worker (from outside the company or from the lower category) attains a category there is a period in which, due to the learning curve, efficiency is lower than average.
- The preferable composition of the staff, in terms of categories, is given by the managers of the company.
- Decisions to be taken include the number of workers to hire, to dismiss and to promote, for each category, industry, business line and period. It is assumed that, for each category, industry and business line, if there are workers hired or promoted to that category, then no workers can be fired (except those because of poor performance). Also, it is assumed that all eligible workers will be promoted to a category before hiring workers from the labour market (for each category, industry and business line).
- The objective is to optimize a function that contains the profit (to be maximized) and the discrepancy (to be minimized) between the resulting composition of the staff and the preferable one. The income depends on the satisfied demand, and the costs include those of labour as well as training, hiring, retirement, and firing.

4 Decision support system

The tool that has been designed is depicted in Fig. 1. The system is based on a mathematical optimization model that has been designed for solving the staff planning problem while taking into account the company's objectives on the income target as well as the human resources strategies and policies regarding preferable staff composition, promotions and dismissals. The information is collected from the company's databases and treated to accumulate the data to be used by the optimization planning model. The strategic parameters and

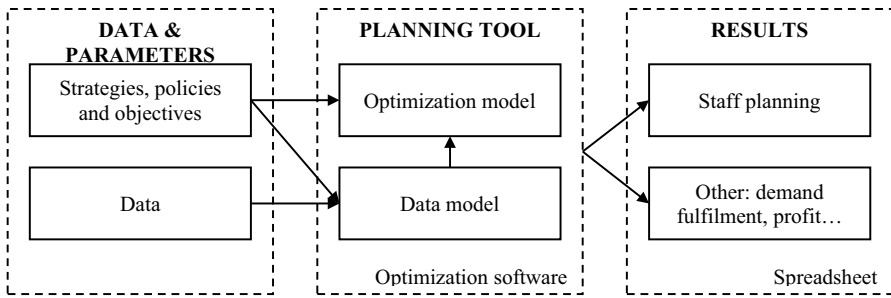


Fig. 1 Scheme of the decision support system

information, which come from the company managers and partners, is introduced in the spreadsheet once a consensus has been built.

The optimization models, and the data they use, have been codified using the IBM ILOG CPLEX Optimization Studio package, which allows a connection with the spreadsheet both for reading and writing. Hence, the results of the optimization are written on the spreadsheet and different performance measures are computed from those results; before achieving a consensus on the different strategies, these measures allow the managers and the partners to assess their impact.

The staff planning problem has been modelled as a Mixed-Integer Linear Program (MILP). As usually occurs, it may be adapted to other particular cases. Below, the sets and indices that are used, the strategic parameters, the objective data and the variables are described and the Section finishes with the model formulation.

Indices

- T Planning horizon (t is used for time periods)
- K Number of categories (k and sometimes j are used for categories)
- I Number of industries with which the consultancy was (i is used to refer to industries)
- L Number of business lines in which projects are divided (l is used to refer to business lines)

Strategic parameters

- PRP Promotion policy, which is equal to 1 if workers are promoted when they reach the merits and 0 otherwise
- LI_{ilt}, UI_{ilt} Lower and upper bound for the expected incomes, for period t , due to projects of industry i and business line l ($\forall i, l, t$), in $[\mu]$. This is a strategic parameter that has to be aligned with the objectives of the company

- LK_{kt}, UK_{kt} Lower and upper bound for the desired proportion of consultants of the company belonging to category k , in period t ($\forall k, t$). These are strategic parameters to be decided by the company
- λ_k Penalty for the discrepancy between the desired and the planned number of consultants belonging to category k ($\forall k$). Giving a high value to these parameters results in a staff composition closer to the preferable one, possibly at the expense of decreasing profits.

Data

- e_{kil} Proportion of consultants from category k in the projects belonging to the business line l and industry i ($\forall k, i, l$). This data is used to estimate the capacity requirements by category, industry, business line and time period
- h_{kilt} Average number of hours that each consultant of category k , industry i and business line l is expected to be able to dedicate to projects in period t ($\forall k, i, l, t$)
- rr_{kilt} Proportion of consultants from category k , business line l and industry i , in period $t-1$ who can be promoted to category $k+1$ at the beginning of period t ($\forall k < K, \forall i, l, t$)
- r_{kilt} Proportion of consultants belonging to category k , industry i and business line l that are expected to be retired at the beginning of period t ($\forall k, i, l, t$)
- rt_{kilt} Expected proportion of consultants belonging to category k , industry i and business line l in period $t-1$ who leave the company due to turnover at the beginning of period t ($\forall k, i, l, t$)
- prt_{kilt} Proportion of consultants belonging to category k , industry i and business line l in period $t-1$, who could be promoted to category $k+1$ in period t and have not been, that leave the company due to turnover at the beginning of period t ($\forall k < K; \forall i, l, t$). Necessary when $PRP=0$ (non-automatic promotion)
- fr_{kilt} Proportion of workers belonging to category k , industry i and business line l who are expected to be fired at the beginning of period t due to poor performance ($\forall k, i, l, t$)
- α_k, γ_k Reduction in the efficiency of one working hour of consultants being promoted and being hired, respectively, in their first period in category k ($\forall k$)
- β_{kilt} Proportion of working hours that cannot be used in projects due to sick leaves, maternity and paternity leaves, part time contracts, etc. in category k , industry i , business line l and period t ($\forall k, i, l, t$)
- cl_{kilt} Labour cost for consultants belonging to category k , industry i and business line l in period t ($\forall k, i, l, t$), in [mu/consultant]
- cq_{kt} Average training cost for consultants being promoted to category k in period t ($\forall k, t$), in [mu/consultant]
- ch_{kt} Average training cost for consultants being hired for category k in period t ($\forall k, t$), in [mu/consultant]
- cr_{kt} Average retirement cost for category k in period t ($\forall k, t$), in [mu/consultant]

- cf_{klt} Average firing cost for consultants of category k and business line l in period t ($\forall k, t$), in [mu/consultant]
- p_{ilt} Average price in [mu/hour] that the company expects to charge clients for each working hour in projects belonging to industry i and business line l , in period t ($\forall i, l, t$)

Variables

- P Expected profit, considering the income and all theour costs
- DSC_k Function of the discrepancy between the number offts belonging to category k and the preferable one ($\forall k$)
- $W_{kilt} \in \mathbb{Z}^+$ Number of consultants of category k , experts in industry i and business line l available in period t ($\forall k, i, l, t$)
- $H_{kilt} \in \mathbb{Z}^+$ Number of consultants of category k , industry i and business line l hired at the beginning of period t ($\forall k, i, l, t$)
- $F_{kilt} \in \mathbb{Z}^+$ Number of consultants of category k , industry i and business line l who are dismissed at the beginning of period t ($\forall k, i, l, t$)
- $R_{kilt} \in \mathbb{Z}^+$ Number of consultants belonging to category k , industry i and business line l that are expected to be retired at the beginning of period t ($\forall k, i, l, t$)
- MQ_{kilt} Number of consultants belonging to category k , industry i and business line l in period $t - 1$ who can be promoted to category $k + 1$ in period t ($\forall k < K; \forall i, l, t$). Necessary when $PRP = 0$ (non-automatic promotion)
- $Q_{kilt} \in \mathbb{Z}^+$ Number of consultants of industry i and business line l who are promoted to the category k at the beginning of period t ($\forall k, i, l, t$)
- $T_{kilt} \in \mathbb{Z}^+$ Expected number of consultants of category k , industry i and business line l who leave the company due to turnover at the beginning of period t ($\forall k, i, l, t$)
- $FBBP_{kilt} \in \mathbb{Z}^+$ Expected number of consultants of category k , industry i and business line l who are fired due to poor performance at the beginning of period t ($\forall k, i, l, t$)
- $D_{kilt} \in \mathbb{R}^+$ Expected requirements (in hours dedicated to projects) of consultants of category k , industry i and business line l at period t ($\forall k, i, l, t$)
- $\delta_{kt}^+, \delta_{kt}^- \in \mathbb{R}^+$ Excess and shortage of consultants of category k in period t , compared to the desired number of consultants belonging to category k ($\forall k, t$)
- $d_{kt} \in \mathbb{R}^+$ Discrepancy between the desired and the expected number of consultants belonging to category k in period t ($\forall k, t$)
- $y_{kilt} \in \{0, 1\}$ Auxiliary binary variable ($\forall k, i, l, t$)
- $s_{kilt} \in \{0, 1\}$ Auxiliary binary variable ($\forall k, i, l, t$)

Model

$$[MAX]z = P - \sum_k \lambda_k \cdot DSC_k \tag{1}$$

$$P = \sum_{k,i,l,t} p_{ilt} \cdot D_{kilt} - \sum_{k,i,l,t} (cl_{kilt} \cdot W_{kilt} + cq_{kt} \cdot Q_{kilt} + ch_{kt} \cdot H_{kilt} + cr_{kt} \cdot R_{kilt} + cf_{kt} \cdot (F_{kilt} + FBP_{kilt})) \tag{2}$$

$$DSC_k = \sum_t (d_{kt})^2 \quad \forall k \tag{3}$$

$$\frac{LI_{ilt}}{p_{ilt}} \cdot e_{kil} \leq D_{kilt} \leq \frac{UI_{ilt}}{p_{ilt}} \cdot e_{kil} \quad \forall k, i, l, t \tag{4}$$

$$\left(LK_{kt} \cdot \sum_{j,l} W_{jilt} \right) - \delta_{kt}^- \leq \sum_{i,l} W_{kilt} \leq \left(UK_{kt} \cdot \sum_{j,l} W_{jilt} \right) + \delta_{kt}^+ \quad \forall k, t \tag{5}$$

$$d_{kt} = \delta_{kt}^+ + \delta_{kt}^- \quad \forall k, t \tag{6}$$

$$\left[(W_{kil,t-1} - Q_{k+1,ilt} - R_{kilt} - T_{kilt} - F_{kilt} - FBP_{kilt}) \cdot h_{kilt} + Q_{kilt} \cdot (1 - \alpha_k) \cdot h_{kilt} + H_{kilt} \cdot (1 - \gamma_k) \cdot h_{kilt} \right] \cdot (1 - \beta_{kilt}) \geq D_{kilt} \quad \forall k, i, l, t \tag{7}$$

$$W_{kilt} = W_{kilt-1} + Q_{kilt} + H_{kilt} - (Q_{k+1,ilt} + R_{kilt} + T_{kilt} + F_{kilt} + FBP_{kilt}) \quad \forall k, i, l, t \tag{8}$$

$$r_{kilt} \cdot W_{kil,t-1} - 1 \leq R_{kilt} \leq r_{kilt} \cdot W_{kil,t-1} \quad \forall k, i, l, t. \tag{9}$$

$$fr_{kilt} \cdot W_{kil,t-1} - 1 \leq FBP_{kilt} \leq fr_{kilt} \cdot W_{kil,t-1} \quad \forall k, i, l, t \tag{10}$$

$$F_{kilt} \leq M \cdot y_{kilt} \quad \forall k, l, t \tag{11}$$

$$Q_{kilt} + H_{kilt} \leq M \cdot (1 - y_{kilt}) \quad \forall k, i, l, t \tag{12}$$

If $PRP=0$

$$rr_{kilt} \cdot W_{kil,t-1} - 1 \leq MQ_{k+1,ilt} \leq rr_{kilt} \cdot W_{kil,t-1} \quad \forall k < K; \forall i, l, t \tag{13}$$

$$Q_{k+1,ilt} \leq MQ_{k+1,ilt} \quad \forall k < K; \forall i, l, t \tag{14}$$

$$\begin{aligned}
 &rt_{kilt} \cdot (W_{kil,t-1} - MQ_{k+1,ilt} + Q_{k+1,ilt}) + prrt_{kilt} \cdot (Q_{k+1,ilt} - Q_{k+1,ilt}) - 1 \leq T_{kilt} \\
 &\leq rt_{kilt} \cdot (W_{kil,t-1} - MQ_{k+1,ilt} + Q_{k+1,ilt}) + prrt_{kilt} \cdot (MQ_{k+1,ilt} - Q_{k+1,ilt}) \quad \forall k \\
 & &&< K; \forall i, l, t
 \end{aligned} \tag{15}$$

$$rt_{kilt} \cdot W_{kil,t-1} - 1 \leq T_{kilt} \leq rt_{kilt} \cdot W_{kil,t-1} \quad \forall i, l, t \tag{16}$$

$$Q_{kilt} \geq MQ_{kilt} - M \cdot s_{kilt} \quad \forall k > 1, i, l, t \tag{17}$$

$$H_{kilt} \leq M \cdot (1 - s_{kilt}) \quad \forall k > 1, i, l, t \tag{18}$$

If $PRP = 1$

$$rr_{kilt} \cdot W_{kil,t-1} - 1 \leq Q_{k+1,ilt} \leq rr_{kilt} \cdot W_{kil,t-1} \quad \forall \forall i, l, t \tag{19}$$

$$rt_{kilt} \cdot W_{kil,t-1} - 1 \leq T_{kilt} \leq rt_{kilt} \cdot W_{kil,t-1} \quad \forall k, i, l, t \tag{20}$$

The objective function (1) includes the maximization of profit (considering the income and all the labour costs), determined in Eq. (2), and the minimization of the discrepancy between the preferable and the obtained staff composition, determined in Eq. (3). To avoid large values of the discrepancy, these variables are penalized by minimizing their square value [see Eq. (3)]. To linearize this non-linear convex function by means of a piecewise function is straightforward.

Constraint (4) links the requirements (in hours) with the expected income and takes into account the price of hours pertaining to projects of different industries and business lines and the structure of the team in those projects. Constraint (5) gives the shortage and the excess of consultants belonging to each category and period, compared to the lower bound and the upper bound of consultants that, ideally, should belong to that category. Equation (6) computes the absolute value of the discrepancy. Constraint (7) imposes that the available hours are sufficient for fulfilling the requirements (for each category, industry, business line and period); here it is considered that the efficiency of new consultants (those that have just been promoted or hired for category \notin) is lower than the rest in that category due to the learning period. It is also considered that there is a capacity shortage due to sick leaves, maternity and paternity leaves, part time contracts, etc. Equation (8) is the balance of consultants for each category, industry, business line and period. Equations (9) and (10) impose, respectively, the number of consultants that are expected to be retired and the number of consultants that are expected to be fired due to poor performance. A lower and an upper bound ensure that those values are integer, since the result of applying a proportion to an integer number can be a non-integer value. Equations (11) and (12) prevent the company of adding (by hiring or promoting) and subtracting (by firing) workers at the same time (for each category, industry and business line).

The company can decide, to increase profits, that not all the consultants that have acquired the merits to be promoted will immediately reach the upper category (i.e., $PRP = 0$). In this case, it is considered that part of the turnover depends

on the number of consultants who, being eligible for promotion, are disappointed because they are not promoted. Constraint (13) imposes the value on the number of consultants that can be promoted to category $k + 1$ in period t , which is the upper bound used in constraint (14) for the number of consultants being promoted. Constraint (15) imposes the value on the number of consultants that leave the company due to turnover, and takes into account that the proportion can be different for those consultants who, eligible for promotion, are not promoted; note that constraint (16) imposes the turnover for the last category (no one can be promoted from this category). Constraints (17) and (18) prevent from hiring workers for a given category, industry and business line when not all eligible workers from previous category have been promoted.

Instead, the company may decide that all eligible workers are promoted (i.e., $PRP = 1$). In this case, constraints (19) and (20) impose, respectively, the number of consultants to promote and the number of consultants who leave the company due to turnover. A lower and an upper bound ensure that those values are integer, since the result of applying a proportion to an integer number can be a non-integer value.

5 Case study

5.1 The consulting firm

The designed system has been applied to a real consulting firm in order to test and validate it. It is a multinational consulting firm offering business solutions, strategy, outsourcing, technology application development and maintenance. In this case, the company staff is divided into 6 categories ($K=6$). Moreover, each consultant is assigned to one of the 7 service lines ($L=7$) and one of the 6 industries ($I=6$), including manufacturing, public administration and healthcare sectors, among others. Initially the planning horizon was set at 3 years ($T=3$), as the consulting firms usually plan no further, due to the uncertainty involved. Nevertheless, a test with a horizon of 8 years is also performed in order to obtain more information for strategic decisions (Sect. 5.5). No changes in the personnel assignment to a service line are considered during the horizon. The pilot test was carried out in an office with an initial workforce of 1887 people.

5.2 Objective data

Below, the parameters required for the model are shown. The data e_{kil} are not given due to confidentiality. The distribution of the staff among business lines (in %) is respectively for the 7 lines: 1.33; 15.90; 9.59; 14.52; 2.33; 27.82; 28.51. In the same way, for the 6 industries it is respectively: 43.72; 21.25; 8.37; 7.21; 2.01; 17.44. And finally, for the 6 categories the distribution is respectively: 13.06; 55.97; 22.56; 4.62; 2.01; 1.76.

Given parameters from the firm: $R_{kilt} = 0$ (no retirements expected during the planning horizon); $prt_{kilt} = 0.2$; $fr_{kilt} = 0$; α_k, γ_k : $\alpha_k = 0 \forall k$; $\gamma_k = 0.3$ for $k = 1, 2$;

$\gamma_k = 0.1$. for $k = 3$; and $\gamma_k = 0$ for $k > 3$; $\beta_{kilt} = 0$ (company decision); cq_{kt} =(negligible for the company); $cr_{kt} = 0$

Once the average number of working hours for a consultant is known, according to the business line, the average capacity (in hours) devoted to the projects is estimated between 1298 and 1766 h/year.

Moreover, the company has information about the proportion of consultants that may change to the upper category, based on real data from the previous year. As has been mentioned, the consultants are only allowed to be promoted to the immediate upper category. These values rr_{kilt} are considered constant during the whole horizon of study ($\forall t$): 38.89% for category 1, and between 10.20 and 21.43% for the rest. Although in the higher category the percentage is considerably higher, in absolute value it translates into a few consultants.

Turnover is another key aspect. The estimate is made from the number of people who left the firm during the last year. This proportion of turnover on the staff for each line and category (rt_{kilt}) is considered constant during the planning horizon and independent of the industry (it varies from 0 to 33.33).

A set of important parameters are related to costs, which are assumed to remain constant during the planning horizon. The annual labour costs assigned to a consultant depend only on the business line and the category. For confidential issues, the lowest cost, which is obtained for business line 5 and category 1, is considered as the base cost. The rest of the costs included in Table 1 are given as a proportion of the base cost.

Furthermore, it is necessary to take into consideration the costs related to dismissals (cf_{kilt}) as they involve the payment of compensation, which depends on business lines and categories. In fact, they depend on seniority, but as each consultant is not treated individually, this is an average value. The costs are in the range between 0.1 and 6.95, also as a proportion of the cl_{kilt} base cost.

Additionally, when the consultants are hired they require training courses, the cost of which depends basically on the category. This cost includes paying the trainers and other expenses such as trainer travel costs or room rental. The costs are considered as a proportion of the aforementioned base cost, being $ch_{1t} = ch_{2t} = 0.069$; $ch_{3t} = 0.096$; $ch_{4t} = 0.157$; $ch_{5t} = 0.007$; $ch_{6t} = 0.039$.

Table 1 Annual labour costs per consultant (cl_{kilt}), given as a proportion of the base cost

cl_{kilt}	Category (k)						
	1	2	3	4	5	6	
Business line (l)	1	2.10	2.90	4.53	6.82	9.54	12.74
	2	1.79	2.47	3.86	5.81	8.13	10.85
	3	1.87	2.58	4.03	6.07	8.49	11.32
	4	1.14	1.58	2.46	3.71	5.19	6.92
	5	1.00	1.38	2.16	3.25	4.55	6.07
	6	1.92	2.66	4.15	6.25	8.75	11.67
	7	1.59	2.20	3.43	5.16	7.22	9.64

Table 2 Lower and upper bound for the expected income, for periods $t = 1, 2, 3$, due to projects of industry i and business line l ($\forall i, l, t$) (LJ_{ilt} and UJ_{ilt} , given as a proportion of the c_{kilt} base cost)

$LJ_{ilt} = UJ_{ilt}$ ($t = 1, 2, 3$)	Business line (l)						
	1	2	3	4	5	6	7
<i>Industry (i)</i>							
1	41.07	698.19	246.42	451.77	82.14	1026.75	1601.73
	43.12	733.10	258.74	474.36	86.25	1078.09	1681.81
	45.28	769.75	271.68	498.08	90.56	1131.99	1765.91
2	100.81	181.45	443.55	403.23	20.16	665.33	221.78
	105.85	190.53	465.73	423.39	21.17	698.60	232.87
	111.14	200.05	489.02	444.56	22.23	733.53	244.51
3	0.00	251.06	117.16	16.74	0.00	75.32	359.86
	0.00	263.62	123.02	17.57	0.00	79.09	377.85
	0.00	276.80	129.17	18.45	0.00	83.04	396.74
4	55.61	104.26	62.56	104.26	6.95	243.28	118.17
	58.39	109.48	65.69	109.48	7.30	255.45	124.07
	61.31	114.95	68.97	114.95	7.66	268.22	130.28
5	0.00	0.00	0.00	154.88	0.00	0.00	3.16
	0.00	0.00	0.00	162.63	0.00	0.00	3.32
	0.00	0.00	0.00	170.76	0.00	0.00	3.48
6	5.12	254.46	97.34	0.00	52.94	807.79	490.14
	5.38	267.19	102.21	0.00	55.59	848.18	514.65
	5.65	280.54	107.32	0.00	58.37	890.59	540.38

Table 3 Lower and upper bound for the desired percentage of consultants of the company belonging to category k ($\forall t$)

Category (k)	1	2	3	4	5	6
LK_{kt} (%)	10.45	44.78	18.05	3.70	1.61	1.41
UK_{kt} (%)	15.68	67.16	27.07	5.54	2.41	2.11

The incomes are obtained from the average price given to each client per consultant hour (p_{ilt}), according to the business line l (neither categories k nor industries i have influence). Once again, they take into account the base cost, obtained for category 1 and business line 5. The rest of the values are given as a proportion of the base price: $p_{i1r} = p_{i7r} = 0.00429$; $p_{i2r} = 0.00320$; $p_{i3r} = 0.00336$; $p_{i4r} = 0.0023$ $p_{i5r} = 0.00222$; $p_{i6r} = 0.00324$.

5.3 Evaluated scenarios

Considering the income in the last fiscal year, the demand forecast for the following years may be drawn. Three cases have been studied according to the evolution of demand: an optimistic scenario (A), with an increase of 5% regarding the previous year; a very optimistic scenario (B), with an increase of 10%; and a pessimistic

scenario (C), with a decrease of 5%. The problem is also analysed modifying some strategic parameters, according to management policies of human resources: Automatic promotion ($PRP=1$) and Restricted promotion ($PRP=0$). Due to the firm's preference for evaluating the new model with $PRP=0$ (Sect. 5.4.2), the model with $PRP=1$ is not applied in scenarios B and C (Sect. 5.4.1).

The rest of the strategic parameters to be used in this case are:

LI_{it}, UI_{it} : The company defines a lower and an upper bo the expected income (Table 2).

LK_{kt}, UK_{kt} : They will be given in Table 3.

$$\lambda_{kt} = 1.$$

The lower and the upper bounds for the desired proportion of consultants belonging to each category (LK_{kt} and UK_{kt}) are obtained by multiplying the current proportion of consultants in that category per 0.8 and per 1.2, respectively (Table 3).

5.4 Results

The mathematical model with a planning horizon of 3 years has 10,394 constraints in the model with $PRP=0$ or 12,284 in the model with $PRP=1$, and 7999 variables, 1512 of which are binary and 6487 are integer. The experiments have been carried out on an ASUS laptop computer. The optimal solution is obtained in less than 4 min when the horizon is set at 3 years. When the horizon is enlarged to 8 years, the solver reaches an optimal or near-optimal solution in a reasonable time: a maximum solution time of 1 h is set and the gap is about 0.2%, which means that in the event that the solution was not optimal, the relative difference between the objective function and the optimal value would be, for sure, no greater than 0.2%.

Table 4 Evolution of the capacity for each period with a policy of automatic and restricted promotion

Policy	t	Total number of consultants in the workforce	Hired consultants	Promoted consultants	Fired consultants	Consultants who leave the firm due to turnover
$PRP=1$	0	1887	–	–	–	–
	1	2227	612	310	10	262
	2	2382	462	373	5	302
	3	2604	535	386	0	313
	Tot		1609	1069	15	877
$PRP=0$	0	1887	–	–	–	–
	1	2060	489	113	17	299
	2	2127	402	132	1	334
	3	2244	458	130	0	341
	Tot		1349	375	18	974

5.4.1 Results for model with $PRP=1$ (all eligible consultants are promoted)

The first scenario is optimistic, with $T=3$ years. The optimal solution leads to an excess of capacity in some cases, i.e. there are more consultants than required. The promoted consultants exceed the rising requirements from the combination of higher demand and turnover. The evolution of the capacity for each period given the number of hired, promoted and fired consultants and the turnover is shown in Table 4.

The results show very few dismissals. In this case, most of them (87%) are concentrated in the business line 6 and industry 3. Therefore, one advantage of this model is that it clearly underlines whether a section of the firm is oversized with regard to the expected demand. The profit with this policy is 7169.9 times the base cost (annual labour cost of one consultant of category 1 and business line 5).

5.4.2 Results for model with $PRP=0$ (restricted promotion)

The time horizon ($T=3$ years) and the optimistic scenario are maintained. This model ($PRP=0$) analyses the possibility of an increase in voluntary turnover of the firm proportional to the consultants who are candidates for promotion but remain in the same category. Regarding the model with automatic promotion, the profit increases by nearly 40%: 9998.4 times the base cost. Going into more detail, the number of consultants leaving the firm voluntarily increases by 15.3% and, on the other hand, the number of promoted and hired consultants decreases by 64.9% and 16.2%, respectively (Table 4).

Table 4 compares, for scenario A, the results of the human resources policies. The model with automatic promotion ($PRP=1$) gives a workforce at the end of the horizon with nearly 400 workers more than the one with restricted promotion ($PRP=0$). The number of promoted workers is around three times more in automatic than in restricted promotion (1069 versus 375). The model with automatic promotion shows a higher hiring (1609 against 1349) and a lower turnover (877 against 974).

If the demand rate increases from 5% in scenario A to 10% in scenario B, the profit increases by 4.76% (from 9998.4 to 10,477.7). On the other hand, if scenarios A and C are compared, the reduction in the profit is around 8%, slightly lower (9998.4 respect to 9229.7) than the reduction in income (10% as it goes from 28,383.8 to 25,683.2) because the reduction in costs is around 11% (18,385.4 respect to 16,453.6), higher than the reduction in the income.

Table 5 Workforce, hiring, promotion, dismissal and turnover for the three scenarios ($PRP=0$)

Scenario	Number of consultants in the workforce at the end of the horizon	Total hired consultants	Total promoted consultants	Total fired consultants	Total consultants who leave the firm due to turnover
A	2244	1349	375	18	974
B	2467	1596	384	17	999
C	1800	983	352	32	813

Table 5 compares scenarios A, B and C regarding changes in the workforce. In the comparison of scenario B with scenario A, the number of hired consultants increases significantly (18%). Additionally, the number of promoted consultants only increases by 2%. The number of dismissals remains very low.

On the other hand, hiring in scenario C diminishes considerably with respect to scenario A (27%) and promotions are decreased by only 6%. But in this case, the number of dismissals increases very significantly (78%), due to the fact that the company is clearly oversized considering the expected demand of the pessimistic scenario C.

The results have been also analysed according to the weight given to the two criteria in the objective function. In the first test, the one yet presented, the profit has been prioritized and a small weight it has been given $\lambda_{kt}=1$. In the rest of tests, the given values to the penalty λ_{kt} were $\lambda_{kt}=10, 100, 1000, 10,000$. This maximum value is similar to the profit in the first test. If a greater weight is given to this parameter for discrepancy, the profit decreases by approximately 6%, the incomes are equal, but the proportion of consultants in each category always respects the established limits (the addition of DSC_k for all the categories is 0 from $\lambda_{kt}=1000$). If the discrepancy prevails over the profit, the solution assigns consultants to industries of certain business lines without enough demand, since in this way a better distribution between categories is achieved. On the other hand, if a greater weight is given to the profit, small discrepancies are detected between the obtained proportions and the set limits (the addition of DSC_k for all the categories is lower than 100 for $\lambda_{kt}=1$).

5.5 Results for extended horizon

A final evaluation considers an extended horizon in the planning ($T=8$ years). The number of constraints in the model is 27,704 and the number of variables is 21,319, 4032 of which are binary and 17,287 are integer. The model with $PRP=1$ is tested in scenario A. The percentage of annual demand variation with respect to the previous year ($t-1$) is for $2 \leq t \leq 8$, respectively: 4%; 5%; 3%; 1%; -3%; -1%; 2%. These

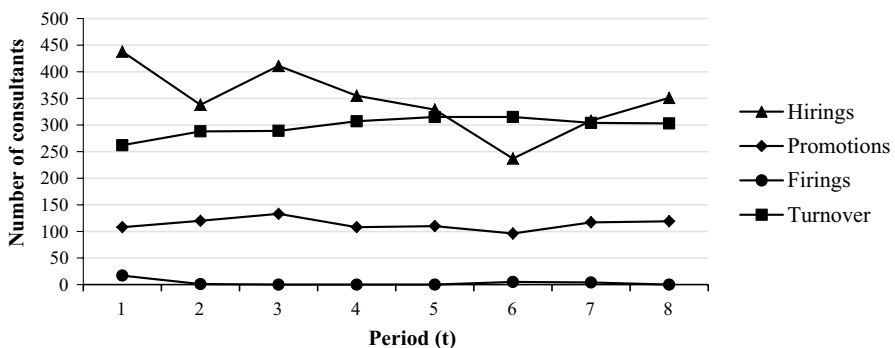


Fig. 2 Evolution of hiring, promotions, firing and turnover in an extended horizon ($T=8$ years)

values reflect that demand diminishes in periods 6 and 7. Figure 2 shows the results (number of hired, promoted and fired consultants and the turnovers).

If the firm faces an uncertain future (with a combination of increasing and decreasing annual demands), the hiring may drop by half in some periods (6 and 7 in the example) compared to the ones with the highest values; the promotions may decrease around 25% comparing both kinds of periods; turnovers are inversely proportional to the demand variation; and firing is very similar (and low) at any period.

Looking at the results, the adaptation of the workforce size to the demand is based mostly on hiring. For example, a hiring peak appears in period 3, when the demand increases more. On the other hand, the reduction in the demand in period 6 leads to a lower number of consultants hired (27). The entire capacity is reduced, as the addition of turnover and firing exceeds the workers hired.

6 General experimentation

This Section has the objective to validate the model in a wider set of situations than the particular case study presented in above Section. The performance of the model will be analysed focussing on four elements whose behaviour has influence in the business evolution: the policy on the staff in the company, which can permit or not automatic promotions; the turnover rate into staff, whose level reflects somehow the situation in the job market; the turnover rate into that part of staff whose desire for a change in the category is not accomplished; and the clients, shown through the expected demand. Combining values for the four ones will lead to consider different scenarios.

First of all, the horizon length considered is 8 years. The company can decide to promote automatically anyone who reaches the objectives ($PRP=1$) or not ($PRP=0$). For the turnover different values, there will influence on the data rt_{kilt} (general turnover rate) and prt_{kilt} (additional turnover rate). We establish two general turnover levels: high (rt_{kilt} take similar values than in the case study) and low (60% of the rt_{kilt} in the high level). In case of $PRP=0$, there are two levels for the additional turnover: high (prt_{kilt} take similar values than in the case study) and low (60% of prt_{kilt} in the high level). Finally, for the demand, we test five profiles for the data e_{kit} : constant, increasing (with annual demand variation of 5%), decreasing (with annual demand variation of -5%), increasing for the first half of the horizon (also with an annual demand variation of 5%) and decreasing for the second half (annual demand variation of -5%) and decreasing for the first half of the horizon (annual demand variation of -5%) and increasing for the second half (annual demand variation of 5%).

The rest of the values for the parameters will be considered constant in order to focus on these three main aspects. Some of them have been slightly modified to be considered mean values, like the initial workforce. Besides, some data that had a null value in the study case (rr_{kilt} ; fr_{kilt} ; β_{kilt} ; cq_{kt} ; cr_{kt}) now have a value different from zero.

The model was solved by using IBM ILOG CPLEX Optimization Studio (version 12.6) in an Intel Xeon E5-2630, 4 CPUs 2.2 GHz, 64 GB RAM, allowing 3600 s for each instance and a relative gap of 0.01%. The description of the 30 different scenarios and their results are given in Table 6. For the company policy, the values for PRP are 1 and 0. The general and additional turnovers can be H (high ratio) and L (low ratio).

Table 6 Analysis for the staff evolution in the 30 defined scenarios

#	PRP	G Turn	A Turn	Dem.	Final work	Total hired	Total promo	Total fired	Fired poor	Total retired	Total turn
1	0	L	L	C	2084	2212	1171	0	489	69	1347
2	0	L	L	I	2903	3378	1692	0	575	85	1592
3	0	L	L	D	1479	1371	697	75	402	49	1143
4	0	L	L	ID	1976	2263	1150	31	522	68	1443
5	0	L	L	DI	2170	2167	1071	31	450	55	1238
6	0	L	H	C	2085	2435	1287	0	489	69	1569
7	0	L	H	I	2904	3581	1780	0	577	87	1790
8	0	L	H	D	1479	1574	800	68	403	47	1354
9	0	L	H	ID	1976	2479	1256	28	522	68	1662
10	0	L	H	DI	2171	2379	1178	29	451	57	1448
11	0	H	L	C	2084	2572	1304	0	489	69	1707
12	0	H	L	I	2906	3784	1811	0	577	87	1991
13	0	H	L	D	1478	1674	837	61	402	47	1463
14	0	H	L	ID	1976	2631	1292	25	522	68	1817
15	0	H	L	DI	2170	2522	1208	27	451	57	1594
16	0	H	H	C	2085	2797	1402	0	489	69	1931
17	0	H	H	I	2907	4009	1906	0	576	86	2217
18	0	H	H	D	1480	1896	966	56	403	48	1686
19	0	H	H	ID	1974	2885	1425	24	523	69	2072
20	0	H	H	DI	2176	2732	1315	26	452	58	1797
21	1	L	N/A	C	2820	3189	3148	6	478	243	1419
22	1	L	N/A	I	3669	4367	3591	5	571	259	1640
23	1	L	N/A	D	2202	2283	2725	33	389	222	1214
24	1	L	N/A	ID	2778	3289	3296	18	509	254	1507
25	1	L	N/A	DI	2836	3044	2944	17	433	229	1306
26	1	H	N/A	C	2820	3189	3148	6	478	243	1419

Table 6 (continued)

#	PRP	G Turn	A Turn	Dem.	Final work	Total hired	Total promo	Total fired	Fired poor	Total retired	Total turn
27	1	H	N/A	I	3637	4756	3586	5	576	255	2060
28	1	H	N/A	D	2130	2529	2704	33	394	216	1533
29	1	H	N/A	ID	2730	3640	3303	17	518	247	1905
30	1	H	N/A	DI	2836	3044	2944	17	433	229	1306

For the profiles of the demand, we use the following notation: C (constant), I (increasing), D (decreasing), ID (increasing and later decreasing) and DI (decreasing and later increasing).

The rest of the columns are: *Final work*, number of consultants at the end of the horizon ($t=8$); *Total hired*, total number of promoted consultants during the horizon; *Tot promo*, total number of promoted consultants during the horizon; *Tot fired*, total number of fired consultants during the horizon; *Fired poor*, total number of fired consultants due to poor performance during the horizon; *Total retired*, total number of consultants who are retired during the horizon; *Total turn*, total number of consultants who leave the firm due to turnover during the horizon.

Some conclusions to be taken from these results are:

- The final workforce and the total hired depend heavily on the demand profile, and consequently the total promoted and the total fired workers, these last ones due poor performance, are also highly dependent on the demand. The more the demand increases, the higher the values are. For the final workforce, values are ranged between less than 1500 (#13, if the demand is decreasing) up to 3669 (#22, if the trend is the opposite). The hired consultants range from the 4756 (#27, scenario of increasing demand) to 1371 (#3, scenario decreasing demand). In a similar way, it can be observed for the promoted consultants (3591 is the maximum value for #22 and 697 is the minimum value for #3) and the fired consultants due to poor performance (577 is the maximum value for #7 and #12 and 389 is the minimum value for #23).
- For the number of fired consultants, the results are inverse respect to the just commented variables. Their values are higher (between 75 and 33 for decreasing demand) and lower (between 6 and 0 for increasing or constant demand).
- Retirements depend on the form policy: they are over 200 for automatic promotion and above 100 for non-automatic promotion.
- The highest values of consultants leaving due turnover does not always happen with high levels in general and additional turnover. It is more related to the demand profile: more than 2000 in increasing trend during at least half of the horizon and around 1300 or less in decreasing trend during at least half of the horizon.

For the 30 different scenarios, the profit, the gap between the value obtained and the best bound and solving time (in seconds) are given in Table 7. The profits range between more than 500 million (in absolute values), in case of increasing demand and non-automatic promotion, and less than 100, in case of decreasing demand and automatic promotion. The gaps are limited to 0.1% and the mean value is 0.064%. The solving times vary from 56 to 2078 s, with a mean value of 920 s.

If a deeper analysis on any of the instances is developed, we can plot the evolution for each year of all these groups of consultants (the workforce, the hired ones...). In Fig. 3, the results are graphically shown for the instance 20. Moreover, the workforce capacity can be compared respect to the demand (Fig. 4).

Summarizing, results show that the adaptation of the workforce size to the demand is based mostly on hiring. Comparing the two promotion policies, the model

Table 7 Profit, gap (%) and solving time (s) in the 30 defined scenarios

#	PRP	G Turn	A Turn	Dem.	Profit	Gap (%)	Solving time (s)
1	0	L	L	C	432,409,470	0.10	353
2	0	L	L	I	527,185,330	0.10	1128
3	0	L	L	D	358,895,030	0.08	1284
4	0	L	L	ID	457,666,580	0.05	1768
5	0	L	L	DI	409,932,220	0.09	1101
6	0	L	H	C	431,736,550	0.10	863
7	0	L	H	I	526,738,170	0.10	751
8	0	L	H	D	358,520,950	0.10	491
9	0	L	H	ID	456,954,180	0.10	767
10	0	L	H	DI	409,545,540	0.09	1263
11	0	H	L	C	431,397,320	0.09	81
12	0	H	L	I	526,345,290	0.10	1007
13	0	H	L	D	358,465,810	0.08	819
14	0	H	L	ID	456,940,740	0.04	731
15	0	H	L	DI	409,266,810	0.09	920
16	0	H	H	C	431,017,110	0.09	788
17	0	H	H	I	525,809,700	0.10	628
18	0	H	H	D	358,042,930	0.08	1255
19	0	H	H	ID	456,393,800	0.07	1136
20	0	H	H	DI	408,694,140	0.10	410
21	1	L	N/A	C	179,154,700	0.05	69
22	1	L	N/A	I	279,309,230	0.00	1623
23	1	L	N/A	D	97,237,740	0.00	2078
24	1	L	N/A	ID	194,563,620	0.00	1973
25	1	L	N/A	DI	163,213,250	0.03	1268
26	1	H	N/A	C	179,154,700	0.05	69
27	1	H	N/A	I	288,914,850	0.00	56
28	1	H	N/A	D	115,540,690	0.00	858
29	1	H	N/A	ID	207,467,440	0.00	779
30	1	H	N/A	DI	163,213,250	0.03	1281

with automatic promotion entails an oversized staff as a consequence of a higher hiring, and consequently a lower profit for the company.

7 Conclusions

Undoubtedly, the management of staff in the consultancies is a key point. This paper presents a support decision system, based on a new mathematical optimization model, to help consulting firms in the strategic planning of their capacity.

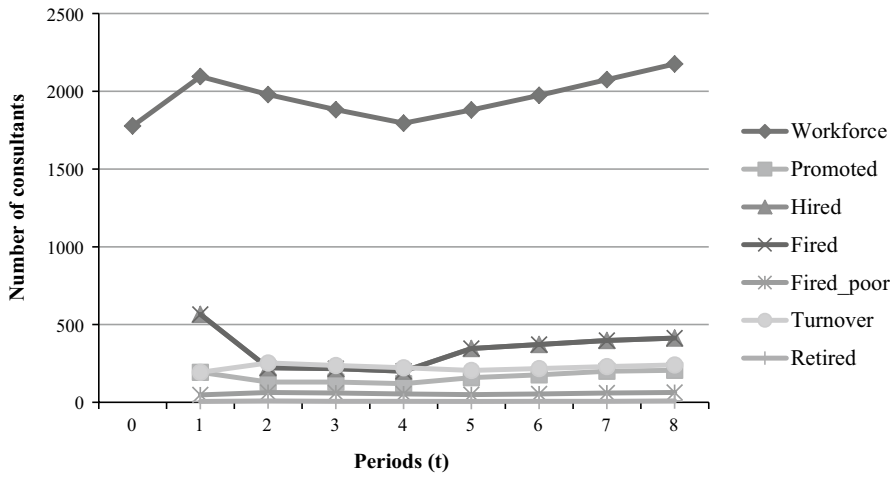


Fig. 3 Evolution of workforce, promotions, hiring, firing, firing due poor performance, turnovers and retirements (instance 20)

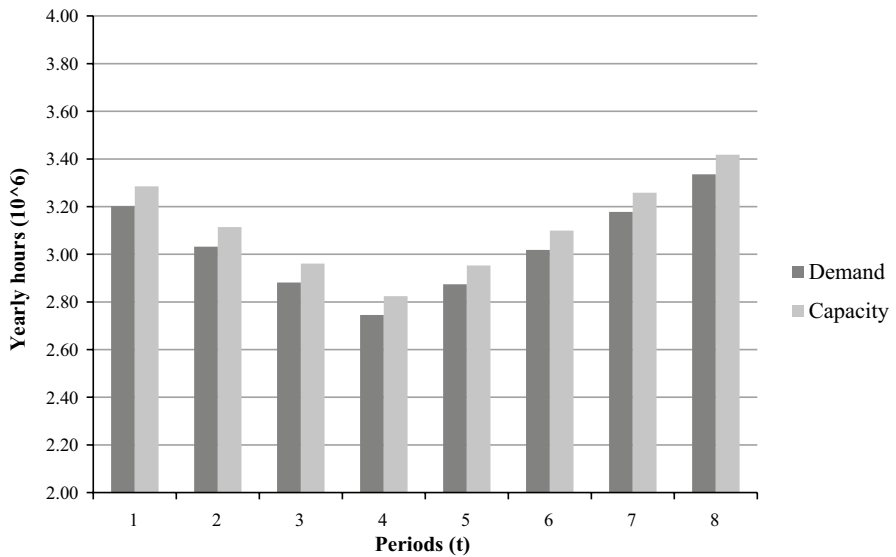


Fig. 4 Evolution of total demand and total capacity (instance 20)

As mentioned, the long-term planning favours the internal promotion, as future requirements are anticipated and consultants are hired in time.

Two promotion policies for consultants who have achieved their objectives and are able to reach the upper category are analysed and considered within the tool: automatic promotion (once the worker has attained the goals) and restricted promotion (not all promotable workers are assigned to the upper category). Some

demand scenarios are analysed: from optimistic (demand always increasing) to pessimistic (demand always decreasing) through another with variable demand (which combines increasing and decreasing demand).

Additionally, staff turnover is an important problem for these companies, mainly because of the lack of promotion. Hence, the model includes a relationship between the number of promotable consultants who are not promoted and the turnover. Planning capacity with a strategic vision (as the proposed system allows) can reduce the turnover and, consequently, the recruitment costs. At the same time, flexibility in the company is considered, as the tool allows adjusting the capacity to face changes in the amount and composition of the demand. In addition, this allows internal talent to be retained, one of the main challenges of consulting firms.

The decision support system was tested in an international consulting firm and, according to the results, it is considered a valid and an efficient tool for dealing with workforce (and capacity) strategic planning. The results sounded reasonable for the human resources managers in the company (no great differences between the results given after applying this decision support system and those usual in the company applying the automatic promotion). A more extensive experimentation has been developed to analyse the influence of factors like the demand, the turnover ratios and the promotion policy in the consultancy firm.

Finally, there are some future lines of work. The first is to include the uncertainty in some data (such as: demand, turnover, absenteeism). Including uncertainty in the mathematical model is not too hard (for example, it can be done through scenario analysis), but an accurate data analysis should first be performed to generate the different scenarios, and many companies lack the required information. The second research line is to include more elements in the model, such as firings of underperforming consultants who have not achieved the annual goals. Finally, it would be interesting to explore how to adapt the system to other companies similar to consultancies (other knowledge intensive organizations).

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