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Worker assignment models for hiring people with disabilities in service organizations *

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Abstract

A diverse workforce is one of the most important assets for modern organizations. In this sense, the integration of workers with disabilities is both an opportunity in terms of staff diversity and of corporate social responsibility, and, in many cases, a legal duty. Successfully achieving this integration can nevertheless be challenging, and requires taking into account different aspects, one of which is achieving a fair and efficient task distribution. In the literature, many task assignment models have been proposed for distributing and managing tasks within a work team, usually aiming to optimize productivity and efficiency. These models take into account workers' abilities, experience and work charge, as well as the characteristics of the tasks, to assign each worker the most appropriate task. When the workforce includes people with disabilities, the assignment models must be adaptable enough to guarantee the full integration of all the team members.

In this paper, we develop a mathematical programming model for task assignment in the context of hiring people with disabilities in service organizations. We discuss a practical case study at the Intendencia de Montevideo (IdeM), as part of a project for improving the integration of people with disabilities in its staff (currently, the IdeM staff only includes about 1.5% of employees with disabilities; while applicable laws state that this percentage should be at least 4%). The mathematical programming model developed includes four alternative objective functions, taking into account the goals of different stakeholders. We analyze the solutions found by applying the model, comparing the results against manual assignments. We also discuss the solutions obtained when the objective functions are integrated using a weighted sum method, and the sensitivity with regard to the coefficients. We also study how the results vary when the number of available positions is changed. The main conclusion is that mathematical programming models are an effective tool to support decision making and improve the integration of workers with disabilities in a service organization.

Keywords: Work assignment problem, task assignment, mathematical programming, people with disabilities, production engineering.

1 Introduction

The inclusion of people with disabilities in the workplace is both a challenge and an opportunity for organizations in terms of diversity and social responsibility. In this context, finding an efficient and fair task assignment is key to achieving the full and effective participation of all the workers, independently of their physical and cognitive abilities.

A task assignment model is a way to systematically assign and manage tasks within a team, organization or group of people, to achieve efficiency in resource usage. The main goal is to ensure that the tasks are assigned to the most appropriate persons, taking into account their abilities, experience, and workload. When including people with disabilities in the workplace, it is particularly relevant to take into account that the models must be efficient from a productive viewpoint, but also they must be flexible and adaptable to ensure the effective integration of all the team.

The present paper was motivated by an Internship program for persons with disabilities, put in place by the the Intendencia de Montevideo (IdeM), which is the local government of the city of Montevideo. The program was supported by a cooperation project with the Facultad de Ingeniería, Universidad de la República. The project included different steps. Foremost, a revision of the related bibliography and preparation of a state of the art was performed, to identify, analyze and summarize the previous research results in this field. The second step was to help IdeM determine the requirements for each existing job position and to identify the main aspects to be considered during the assignment. The third step was the development of mathematical programming models for performing workplace task assignment, with a focus in the inclusion of people with disabilities; and performing experiments over these models, showing that they can support decision making. Finally, the results were applied in real life, validating their usefulness and leading to further recommendations for the future.

The structure of the paper is as follows. Section 2 discusses the related literature. Section 3 presents the context of the work. Section 4 presents a mathematical programming model for the task assignment problem. Section 5 presents the data for the application example, and Section 6 the computational results. Section 7 discusses the sensitivity of the model with respect to objective function weights and with respect to available positions. Finally, Section 9 presents conclusions and future work.

This paper is an extended version of a work presented at the CLEI 2024 conference, [1]. In the present version, we add an extended state of the art revision (Subsection 2.1). We also perform a more thorough discussion of the weighted objective function (final part of Section 6), and we include new experiments for exploring the sensitivity of the model with respect to these weights, and with respect to the number of work positions available (Section 7). Complementarily, we add a new section about the real life application of the assignment proposal (Section 8).

2 Literature review

The literature search was focused on the inclusion of persons with disabilities in work contexts. We found papers discussing more general aspects linked with this inclusion process, and some specific papers for actual task assignment optimization models, but focused on industrial contexts. We discuss in the following subsections the different works found.

2.1 Articles regarding work inclusion

Corporate social responsibility (CSR) is a term usually employed regarding the active participation of organizations to positively impact society and the environment. Alcantara, Miralles and Garcia [2] discuss how work inclusion can be a factor in CSR activities, and how, even when governments must promote public policies for inclusion of persons with disabilities, it is necessary that companies also take an active role in this regard. Integrating persons with disabilities also contributes to a more diverse work environment, and promotes attitude changes in the non disabled workers, which can also translate to better task assignments taking into account the different abilities and capacities of the workforce.

Frequently, that persons with disabilities face different discriminations when trying to participate in the work market, both in the quality of the jobs offered (usually less well paid or half-time jobs), and with few professional development opportunities [3]. These difficulties may start from the formal education phases [4].

The work [5] performs a survey regarding job crafting, which is the redesign of tasks by a worker taking into account their capacity and the needs of the company (and can take into account the task itself, the relations with other workers, and the cognitive aspects). The authors perform a statistical analysis of the results, showing that workers with a greater disposition to accept colleagues with disabilities are also more prone to have positive behaviors to benefit the work environment. This shows that the positive aspects of inclusion spill over to the general performance of the company [5].

Other authors as Brucker and Sundar [6] also discuss the potential of job crafting, analyzing a survey of persons between 18 and 64 years old, with some disability and working for a year or more. Their results show that this population participates in fewer task crafting and relational crafting activities but in more cognitive crafting activities.

Discrimination against workers is analyzed in the work [7]. A survey of 459 persons with disabilities who were working in the five years before the survey measured the perception of inequity, discrimination and dissatisfaction. The results showed that this population perceived a clear discrimination, based on the inequity of job attribution. This also results in dissatisfaction values. The recommendation is to increase autonomy, complexity and variety of jobs assigned to this population. Some years later, the same authors [3] develop a model which relates the inequity perceived with the work dissatisfaction, and the intersectional aspects of this situation.

Barclay and Markel [4] performed a qualitative analysis based on work inclusion success cases. They interviewed workers with auto-perceived disabilities, and searched for patterns, concluding that job crafting was an important aspect to reach this success; and that the company must help in this sense by giving more independency for decision making to their workers, delegating decision making to lower levels and taking into account the opinions and suggestions from the workers with disabilities to improve the work environment and the organzation of the tasks.

Many works which discuss job crafting [4–6] are relatively recent (2020 or later), and in general mention that there is little research on the application of the technique for work inclusion of persons with disabilities.

The work [8] discussed the Blue Ocean Strategy to incorporate workers with disabilities in distribution centers. These strategies try to find new growth opportunities in less explored/competitive environments, by using innovation and value creation. The paper shows that several companies have successfully used this strategy to include workers with disabilities, and with proactive policies have reached a more diverse workforce, which helped in their growth processes.

2.2 Task assignment models considering persons with disabilities

We performed an exhaustive literature search, looking for task assignment models that considered persons with disabilities. Most of the papers were focused on assembly line models; to the best of our efforts, we did not find publications concerning task assignment with a focus on inclusion in the area of services or administrative tasks.

An assembly line is a manufacturing production system organized in stations. The work pieces, which can be raw materials, components or intermediate products, are processed in the stations, adding value, until the last station where the final product is assembled. The workers are assigned to one or many stations (depending on the work times), where they perform some specific tasks.

Costa and Miralles [9] classify assembly line task assignment problems in three categories of increasing complexity:

- **SALBP**: Single Assembly Line Balancing Problem. These models take into account precedencies among tasks, task execution times, and number of available workers (which are considered as equally proficient), and the objective is to assign every task to a workstation in order either to minimize the number of stations or to minimize the cycle time.
- **ALDP**: Assembly Line Design Problem. These models are more general and integrate constraints in the number and type of resources, costs, and task execution times.
- **ALWABP**: Assembly Line Worker Assignment and Balancing Problem. This model was proposed by Miralles et al. [10], and takes into account workers with different abilities, which results in different execution times for each task. We can distinguish the problem **ALWABP-1** when the objective is to minimize the number of workstations, and **ALWABP-2** when the objective is to minimize the cycle time; the second one is usually more applicable in the context of labor integration of people with disabilities [10].

The ALWABP has been applied in the Centros Especiales de Empleo (CEE) in Spain. These are sheltered work centers aiming at the employment and societal integration of people with disabilities. The CEE are at the same time places of training and adaptation and productive units, as they try to be competitive in the market; these objectives are usually thought of as conflicting, but they can be managed using multi-objective or multi-criteria decision tools [9].

The ALWABP-2 does not try to minimize the number of workers; it takes as input a fixed number of workers with certain abilities that can perform (or not) the given tasks with some known durations. The model is applicable not only in the case of people with disabilities, but also for any type of workforce, as in practice there are not two identical people with the same performance and possibilities. Some factors that can be taken into account include: preferences, medical recommendations, abilities, limitations, etc, as discussed in [10].

There is a wide literature discussing the solution, both exact and heuristic, of the ALWABP model. It is out of the scope of this work to present all these papers; we just mention the Branch and Bound and Remember (BBR) method proposed by Vilá and Pereira [11]; a reformulation for the ALWABP-F proposed by Borba and Ritt [12] applying relaxation methods and heuristics to improve a Branch and Bound procedure; and a VNS metaheuristic proposed in [13].

From the ALWABP model different variants were developed, taking into account different objectives or new constraints added to the original formulation in order to improve its applicability in real life. Below, we summarize some of these variants.

In [9] the goal is to integrate work rotations and to take into account production efficiency, in order to promote worker learning, while maintaining high productivity levels.

Araujo, Costa and Miralles [14] propose two new variants for the cases where the number of people with and without disabilities is very different. In that context, they propose to parallelize the workstations and to perform collaborative assignments, where two or more workers can work on the same task or workstation, complementing their capacities and collaborating to perform the same activity.

Moreira, Miralles and Costa [15] define another problem, the Assembly Line Worker Integration and Balancing Problem (ALWIBP), where the objective is to keep a given productivity level, while minimizing the number of workstations and assigning a given number of workers with disabilities, in the context where only a small percentage of the staff has some disability.

The paper [16] is based on the premise that the uncertainty in task execution times must be taken into account to obtain more realistic results, and especially so when there is a heterogeneous staff. Following the same line, Jordi Pereira [17] developed an ALWABP version considering time intervals for task execution times. Taking into account the variations in the number of workers, an extension to the problem is developed in [18] to minimize the cycle time under uncertain worker availability. This line is continued in paper [19] considering the case where there are not enough workers to operate all the workstations.

Other extensions include considering balancing the workload, to avoid overcharges that can lead to fatigue and efficiency losses, as well as an increased rate of work accidents [20]; and to consider integrating ergonometric risks in the task assignment decision [21].

In 2021, Yilmaz [22] proposed the AWALBPS model, adding sequence dependent setup times to the original AWALBP formulation.

The paper [23] studies U-shaped assembly lines and presents non-linear and linear models for the UALWABP-E (U-shaped line assembly line worker assignment and balancing type-E) problem. Chutima and Khotsaenlee [24] also study U-shaped assembly lines and discuss the participation of workers with disabilities as well as robots in these production settings.

In summary, we found a number of papers related to assembly line task assignment including workers with disabilities, specifically to the ALWABP problem and many variants. Most of the models take into account task precedencies, task execution times and number of available workers. We did not find examples of task or job assignments in service industries taking into account workers with disabilities. Nevertheless, some of the aspects of the models found in the literature review are related to our case study: taking into account different worker capacities or efficiency levels; tackling multi-objective problems; and integrating a given number of workers instead of minimizing the number of workstations.

Other general worker assignment models with personnel constraints are discussed in literature, see for instance [25] and [26]. In order to adapt these models to the case of persons with disabilities, it is necessary to include different aspects we mentioned above, that can be extracted from the assembly line models. In particular, it is important to notice that the model should not aim to minimize the number of workers or of workstations; an important constraint is that there is a number of persons that must be assigned to perform the tasks (in order to include them), and that they should not be excluded based on lower efficiency levels or lower speed in processing the assigned tasks.

3 Case study

The Uruguayan legislation implies that all the government organizations (at local and national levels) should integrate at least 4% of their staff with workers with disabilities. Nevertheless, this objective is far from being achieved. Our case study concerns the Intendencia de Montevideo (IdeM), which is the local government of the city of Montevideo. At IdeM, only about 1.5% of the staff have some type of disability. The reasons for not achieving the stated percentage are varied, from lack of accessibility in the workplace to lack of opportunities for people with disabilities to even have the required studies to apply for vacant places, generating a vicious circle between poverty and disability.

The IdeM is applying policies to improve this situation; there is a Disabilities Secretary (Secretaría de Discapacidad), which works to promote inclusion policies both internally at the IdeM and externally in private organizations in Montevideo. This office promoted an internship project within the Citizenship Attention Service (Servicio de Atención a la Ciudadanía -SAC), which is an office of the IdeM. The goal was to incorporate 16 interns, chosen by five organizations devoted to people with disabilities, within the following five services of the SAC:

- Administration.
- Call Center (Unidad Central de Atención Telefónica - UCAT) .
- Citizens' mailbox (Atención No Presencial - ANP), which receives complaints, queries or comments via website.
- In-person attention (Atención Presencial), which gives help to initiate online procedures both at the IdeM or central government sites.
- Information module (Módulo de Informes), which manages the different reception stations in the IdeM buildings, managing the access and providing a first-level information and orientation.

The partners for this project were five Uruguayan NGOs devoted to people with disabilities: the National Union of Blind Persons of Uruguay (Unión Nacional de Ciegos de Uruguay), the Sur Palermo Association (Asociación Sur Palermo), the Federation of Family Members Organizations for Mental Health (Federación Caminantes - Federación de Organizaciones de Familiares por la Salud Mental), the Uruguayan Down Association (Asociación Down del Uruguay) and the Uruguayan Association of Deaf Persons (Asociación de Sordos del Uruguay). These NGOs agreed with IdeM to provide a list of people (with at least three years of secondary studies completed) to perform internships at the SAC offices.

To perform the selection, the IdeM gave the NGOs a detailed description of the job positions with their requirements and an explanation of the activities that the workers should perform. Taking this information into account, the NGOs gave a list of profiles of interested persons who were apt to perform those tasks. The profiles included previous experience, studies completed and other comments. The applicants also had to state their preferences for the available positions (stated as a number from 1, the highest preference, to 5, the lowest one - positions not ranked meant that the applicant could not/did not want to work in that area).

In parallel, the team from FIng (Facultad de Ingeniería) performed a catalog of the aspects of physical accessibility for the workspaces, of the tools available to perform the work tasks, of possible barriers for the interns and of the work ambient in general. The workplaces were evaluated in person by the FIng team, who wrote a report indicating the different aspects to consider, both for and against, when including workers with disabilities at each workplace.

To create the catalog, the FIng team visited the five SAC offices and interviewed the managers for each one.

These interviews and assessments covered three key aspects: physical space at each office and adjacent spaces; furniture state; and human resource needs as perceived by the managers of each area.

Regarding the physical space, some key aspects measured included the width of the corridors, height and number of doors, turn radius, space between desks, space for moving within the offices, etc. Also, adjoint spaces such as bathrooms and dining areas were visited to ensure their accessibility. In addition, the access to the office was evaluated, which involved determining if lifts arrived to each floor of the building and their frequency, as well as ramp accesses and general mobility aspects.

Some tasks imply that the worker must employ some particular tools or technological devices, which needs special consideration particularly for blind or deaf people. In particular, we inquired about the use of screen readers in computers, as well as assistive applications for blind people, and the adaptability of chat and phone support activities.

Another relevant aspect was to determine which offices had previous experience in the inclusion of people with disabilities, and in the affirmative case, which kind of adaptations had to be performed, and what was the integration experience with the team and the environment.

About the available positions, the main aspects that were taken into account were whether the task required interaction with the users, and whether it was direct or indirect interaction; whether the task could lead to stress situations and how these situations were managed. Also, it was important to know what type of interaction with other colleagues the tasks required, the size of the work team, the variability of the tasks and the training required.

As the NGOs were selected previously, it was possible to know in advance what kind of disabilities the interns could have; this led to more specific questions regarding the workplace and the tasks, which were useful later when performing the assignment.

After completing the surveys, a manual preliminary assignment of the applicants to the available positions was performed, taking into account the information sent by the NGOs, the applicants' preferences, as well as the conditions of the positions and tasks to be performed.

The final assignment was performed in a meeting involving all the SAC area managers, staff from the Disabilities Secretary and from the FIng team. The starting point was the preliminary assignment, and all participants also received the printed profiles of the applicants. During the meeting, some doubts arose about the internship modalities, the integration of the interns, and the positions' workplace conditions, which were solved by interaction among the participants.

The number of work positions made available by the SAC services was smaller than the number of interns to recruit; also, some of the tasks generated interest from a large number of applicants, and other ones generated little interest. During the meeting, it was decided to cover all the initially available positions and to make more available so that all interns could be recruited, while trying to take into account the applicants' preferences. To increase the number of positions, the participants considered expected future increased workloads in some areas, the existence of different shifts, and the feasibility of dividing/sharing a task among different workers. At the end of the meeting, each area manager knew exactly how many positions would be covered in their area and the actual list of interns.

This process was completed between May and August 2023 and involved multiple meetings among the different actors.

4 Mathematical Programming model

In this section, we present a mathematical programming model for performing task assignments to persons with disabilities, based on the lessons learned in the Internship project described in the previous section.

The goal of the model is to take into account all the information employed in the manual assignment process, systematize the process and develop a tool for facilitating the pre-assignment step, as a help for decision making. We do not aim to replace the in-person meeting for performing the final assignment, as we understand that the managers' involvement in the decision is fundamental to the success of the assignment and the integration of the interns, but to help them by presenting a good quality solution.

We present the sets and parameters of the model, the decision variables, the constraints and several different objective functions.

4.1 Sets and parameters

The following sets represent the entities in the problem under study:

- **J:** Set of tasks, which represent the different activities that can be assigned to the interns. A task may have one or more positions available (i.e, there may be more than one intern needed to perform the same task).
- **I:** Set of interns, which represents all the persons who applied to the internship positions.
- **K:** Set of workplace requirements. These requirements may be for instance: accessibility constraints; availability of accessible toilets; availability of screen readers; requirements of physical efforts for the tasks, etc.
- **H:** Set of desired aspects for the workplaces. These are characteristics that are desirable but do not represent a hard limitation for assigning an intern to a task. For instance, knowledge of some technological tools, previous experience in dealing with users, and previous participation of people with disabilities in that task. Also, there are other aspects related to the desirability for the interns, for instance teamwork, well-defined and repetitive tasks, or ambient conditions in the workplace, such as well-lit desks. This set is defined taking into account the needs of the particular setting where the assignment must be performed.

The following parameters correspond to the main data of the problem:

- $\mathbf{NAP_j}$: number of available positions for each task $j \in J$. This is the number of interns that ideally are required to perform task j, taking into account the workload, the training capacities and the physical space in the office.
- $\mathbf{NEP_j}$: number of extra positions that can be occupied for each task $j \in J$. In most of the offices, by performing some small adaptations (changes in work shifts, desk disposition or task division), it would be possible to incorporate some additional interns in excess of the number originally dimensioned/desired; this is the number of extra positions allowed.
- $\mathbf{P_{ij}}$: preference of intern $i \in I$ for task $j \in J$. The applicants are asked to give their preferences for the different available tasks/positions. Their most preferred options are labeled by number 1, and lower preferences have numbers 2, 3, etc. (in this case study, the lowest preference available was 5 - the applicants could also choose to leave some tasks without preferences, meaning they did not want to perform that task at all- this was coded as preference 10).
- $\mathbf{R_{jk}}$: requirements for the tasks. This parameter takes the value 1 when requirement k applies to task j (i.e, when an applicant must comply with requirement k to perform the task j); and takes the value 0 when requirement k does not apply to task j.
- $\mathbf{C_{ik}}$: applicants' capacities in relation to the task requirements. This parameter takes the value 1 when applicant i complies with requirement k (he/she can perform a task requiring constraint k), and 0 when the applicant doesn´t have this capacity.
- $\mathbf{QE_j}$: cost associated to creating an extra position for task j. This is a penalty associated with generating more positions than desired for a given task, which is related to the adjustments to be performed.
- $\mathbf{QU_j}$: cost associated with not occupying a position for task j. This is a penalty related to leaving unassigned some of the desired/available positions, as this means that there will be workload that will not be covered at one office/task.
- $\mathbf{D_{jh}}$: Desirable aspects for a task. This parameter takes the value 1 when task j would benefit when performed by a person complying with some characteristics h; and 0 when this characteristics is irrelevant.
- $\mathbf{EC_{ih}}$: Experience and characteristics of the applicants in relation to the desirable aspects. This parameter takes the value 1 when applicant i complies with desirable aspect h and 0 if not.

4.2 Decision variables

A solution for the assignment problem is given by defining which task is assigned to each applicant, and how many positions are occupied for each task. The following are the corresponding decision variables:

- $\mathbf{x_{ij}}$: this binary variable takes value 1 when applicant i is assigned to task j and 0 otherwise.
- $\mathbf{nu_j}$: this integer variable corresponds to the number of unassigned positions for a task j; i.e, the places below the desired number.
- $\mathbf{ne_j}$: this integer variable corresponds to the number of extra positions assigned for task j, i.e, the places occupied over the desired number.

4.3 Constraints

The model constraints represent the conditions that a solution must comply with in order to be feasible. We define five constraint families; the first three are related to the feasibility of the solution, and the last two are auxiliary definitions needed for some objective function. A sixth constraint family regards the domain constraints for the decision variables.

1. **Requirements compliance:**

$$x_{ij} \times R_{jk} \leq Cik; \qquad \forall i \in I, j \in J, k \in K$$

This constraint ensures that an applicant i can only be assigned to a task j if the applicant complies with all requirements relevant to this task.

2. **Assignment constraints:**

$$\sum_{j \in J} x_{ij} = 1; \qquad \forall i \in I$$

Each applicant i must be assigned to one and only one task.

3. **Number of positions available:**

$$\sum_{i \in I} x_{ij} \leq NAP_j + NEP_j; \qquad \forall j \in J$$

It is not possible to assign more interns than the sum of available and extra positions for a given task. It is possible to assign less than this number (and even less than the available/desired number), but never more.

4. **Number of extra positions actually assigned:**

$$\sum_{i \in I} x_{ij} - NAP_j \leq ne_j; \qquad \forall j \in J$$

The number of extra positions actually assigned for a task is a decision variable. Its value is the total number of positions assigned minus the number of available/desired positions; except when the number of positions assigned is less than the number of desired positions, in which case it is zero. As a result of the previous constraint, it can be seen that the decision variable number of extra positions actually assigned must always be smaller than or equal to the number of extra positions available parameter, i.e, that:

$$ne_j \leq NEP_j; \qquad \forall j \in J.$$

5. **Unassigned positions variable:**

$$NAP_j - \sum_{i \in I} x_{ij} \leq nu_j; \qquad \forall j \in J$$

The number of unassigned positions for a task is a decision variable, which is equal to the number of available/desired positions minus the number of positions assigned (or zero if the number of positions assigned is larger than the number of available positions). As in the previous case, the constraint is written as an inequality.

6. **Domain constraints :** The following constraints correspond to the decision variables´ domains:

$$x_ij \in \{0, 1\}, \qquad \forall i \in I, \forall j \in J,$$
$$nu_j \geq 0, \qquad \forall j \in J,$$
$$ne_j \geq 0, \qquad \forall j \in J.$$

4.4 Objetive functions

We define four different objective functions. Each one gives priority to a particular aspect of the task assignment, in some cases related to the interns, in other cases related to the offices where they will work. We present the four functions:

1. **OptPref: Optimize interns' preferences**

$$Min \quad \sum_{j \in J} \sum_{i \in I} (x_{ij} \times P_{ij})$$

This function corresponds to searching for solutions where the interns are assigned to tasks taking into account their preferences (lower values of P_{ij} correspond to higher preferences, that's why the sum is minimized).

2. **MinQE: Minimize cost due to extra positions**

$$Min \quad \sum_{j \in J} (ne_j \times QE_j)$$

This function corresponds to searching for solutions with the least cost due to generating additional ("extra") positions over the available/desired ones. The cost per additional position may vary for the different tasks, so that we are not just minimizing the number of extra positions. The function is built by adding the values of the decision variables ne_j, weighted by the parameters QE_j.

3. **MinQU: Minimize cost due to unassigned positions**

$$Min \quad \sum_{j \in J} (nu_j \times QU_j)$$

This function corresponds to searching for solutions where the goal is to assign all the available/desired positions. The function is also weighted, so that assigning the positions may have different importance for each task. The function is built by adding the values of the decision variables nu_j, weighted by the parameters QU_j.

4. **MaxFit: Maximize fit**

$$Max \quad \sum_{j \in J} \sum_{i \in I} \sum_{h \in H} (x_{ij} \times EC_{ih} \times D_{jh})$$

This function corresponds to maximizing the fit of the interns with respect to the desired characteristics to perform the assignment tasks.

4.5 Complete model

We present here the complete formulation of the mathematical programming model, with a weighted objective function, where the minimization objectives are added and the maximization objectives are subtracted, with the following weights:

- $\boldsymbol{\alpha_1}$: weight for the optimizing preferences objective;
- $\boldsymbol{\alpha_2}$: weight for the minimizing cost of unassigned positions objective;
- $\boldsymbol{\alpha_3}$: weight for the minimizing cost of extra positions objective;
- $\boldsymbol{\alpha_4}$: weight for the maximizing fit objective.

The complete model is as follows:

$$
\begin{aligned}
Min \quad & \alpha_1 \sum_{j\in J}\sum_{i\in I}(x_{ij} \times p_{ji}) + \alpha_2 \sum_{j\in J}(ne_j \times QE_j) \\
& + \alpha_3 \sum_{j\in J}(nu_j \times QU_j) \\
& - \alpha_4 \sum_{j\in J}\sum_{i\in I}\sum_{h\in H}(x_{ij} \times EC_{ih} \times D_{jh})
\end{aligned} \tag{1}
$$

$s.a.$

$$x_{ij} \times R_{jk} \leq Cik; \qquad \forall i \in I, j \in J, k \in K \tag{2}$$

$$\sum_{j\in J} x_{ij} \leq 1; \qquad \forall i \in I \tag{3}$$

$$\sum_{i\in I} x_{ij} \leq NAP_j + NEP_j; \qquad \forall j \in J \tag{4}$$

$$\sum_{i\in I} x_{ij} - NAP_j \leq ne_j; \qquad \forall j \in J \tag{5}$$

$$NAP_j - \sum_{i\in I} x_{ij} \leq nu_j; \qquad \forall j \in J \tag{6}$$

$$ne_j, nu_j \geq 0 \qquad \forall j \in J \tag{7}$$

$$x_{ij} \in [0,1] \qquad \forall i \in I, j \in J \tag{8}$$

This model shares some similarities to the ALWALBP model [10], for assembly line task assignment considering workers with disabilities(discussed in Section 2), in that it considers binary variables for the assignment of tasks to workers, and in that it also includes a number of constraints regarding the ability of a worker to perform a given task. One difference is that in the ALWALBP model this last aspect is given by means of an explicit set A including all possible assignments; in our model, this is given implicitly by the parameters $\mathbf{R_{jk}}$, the requirements for the tasks, and parameters $\mathbf{C_{ik}}$, the applicants' capacities. For a pair (i, j) to be included in the set A of possible assignments, it is necessary that $\mathbf{R_{jk}} \leq \mathbf{C_{ik}}$ for every k. Our model extends to other aspects, as it also considers desirable characteristics, which are part of an objective function but are not mandatory (i.e., do not appear as part of a constraint family).

5 Application example

The application example was built using the real data gathered from the case study discussed in Section 3. There are five different tasks, each corresponding to one of the SAC offices.

Table 1 shows the parameters related to the tasks. The number of available/desired positions was the one provided by the managers of each of the SAC offices when the accessibility study was performed. The number of feasible extra positions was taken by the value agreed on when performing the manual assignment. In the case of the Administration and Citizens' mailbox, extra positions were set to 0, as there was no available desk space for more workers. The QE values, related to the cost of generating extra positions, was higher for the Call Center, where adding more interns implied re-coordinating work shifts as well as adding extra desks; and lower for the Modules and for the In-person attention, where there was enough available space and adding more interns only implied distributing the work among them (as no extra positions were feasible for Administration and Citizens' mailbox, the parameter is not relevant for these offices). The costs for leaving a position unassigned were the same for all the offices (as in this example, there was not enough information to make a difference among the tasks).

Table 2 shows the preferences of the applicants for the different tasks. This information was provided by the applicants, as they were asked to indicate their preferences, marking the tasks from 1 to 5 (tasks which an applicant did not want to perform were marked with a value of 10).

The most complex part of data preparation concerned the requirements and desirable aspects. After several meetings and information from the SAC offices, the requirements (marked in red) and desirable aspects (marked in yellow) shown in Table 3 were agreed upon.

The first three requirements regard physical, visual and auditive accessibility. During the situation inventory, we checked whether each office complied with the minimal requisites for ensuring that a person with each type of special needs could perform the required activities in this task. Physical accessibility requirements regard the need for displacements and to perform tasks involving movements and physical

Table 1: Task related parameters

Id	Task	NAP	NEP	QE	QU
1	Call Center	4	2	5	10
2	Administration	1	0	5	10
3	Modules	3	2	2	10
4	In-person attention	2	1	2	10
5	Citizens' mailbox	3	0	5	10

Table 2: Applicants' preferences

Id.	Name	Call Center	Admin.	Modules	In-person attention	Mailbox
1	N.L	10	2	1	10	10
2	S.A	10	2	1	10	10
3	J.L	5	1	3	2	4
4	L.G	5	1	2	3	4
5	F.M	2	1	4	5	3
6	S.I	2	3	4	1	5
7	A.N	4	1	5	3	2
8	S.D	10	2	10	10	1
9	L.M	1	10	10	10	10
10	M.P	1	10	2	3	10
11	L.D	2	3	10	10	1
12	L.G	2	1	10	10	3
13	C.D	2	1	10	10	3
14	D.V	1	2	10	10	3
15	F.D	2	2	4	2	1
16	L.F	2	4	1	2	5

efforts. Direct attention regards the need at this workplace to interact directly with the public. While these requirements were defined as they are similar to the ones applied in the manual assignment, it is difficult to ensure that they cover all relevant situations. In this sense, we recommend that when employing the model in another context, the requirements should be defined as objectively and clearly as possible to avoid conflicts when evaluating their compliance.

As the model definition is quite flexible, the desirable aspects can be interpreted in two complementary ways:

1. They may relate to some desirable aspect/characteristic in the profile of an applicant, that may benefit the sector or office.

2. They may relate to some desirable aspect of the task, which can take into account a need or capacity of the applicant.

Table 3: Requirements and desirable aspects for the different tasks

requirements/ Desirable aspects	Tasks				
	Call center	Adm.	Modules	In-person attention	Mailbox
Physical accessibility	1	1	0	1	1
Visual accessibility	0	1	1	1	0
Auditive accessibility	0	0	1	1	0
Movements	0	1	0	0	0
Direct attention	1	0	1	1	0
Stressful situations	0	1	0	0	1
Computers	1	1	0	1	1
Previous experience	1	0	0	0	1

In one case, the focus is on the employer, and in the other one, the applicant, but in both situations, the two parties accrue some benefits, directly or indirectly, from the benefit of the other party.

In our application example, we considered the following desirable aspects:

- For tasks that may lead to stressful situations: the desirable aspect is the capacity of the applicant to manage situations that require making fast decisions under stress. This aspect was first considered as a requirement, but as some profiles mentioned explicitly this capacity (or absence thereof), and other profiles did not have the information, it was agreed that it was better to consider it as a desirable aspect, as the least restrictive option.
- Knowledge and experience in computer use: in many tasks, using a a computer is necessary, so it was deemed to be useful if an applicant had previous experience with using some software tools.
- Office/position where a blind person has previously been employed: this is not a requirement, because the idea is that every office should integrate interns with any disability. Nevertheless, when an office has previous experience in integrating a blind person, a certain accessibility level has already been achieved, and this will be an advantage for a new intern with this disability. For instance, in our case, offices where a blind person had already worked had visual assistance/screen readers software available and configured, and persons with experience for training (this was the case for the Citizen's Mailbox service).

As a last step, the applicants' profiles were read again to assign the values of the C_{ik} and EC_{ih} parameters (capacities and characteristics) as discussed above. Some difficulties arose due to ambiguities in the profiles or in the interpretation of the requirements; the values were always taken as binary ones, even in some cases where a degree of compliance could have been defined.

6 Numerical results

The computational experiments were performed using the GLPK 4.65 solver, on a computer with an Intel(R) Core(TM) i5-8250U CPU @ 1.60GHz (8 cores), 1.8GHz, 8192MB RAM, running under Windows 11 Home 64-bit. Execution times were negligible (well under 1 second) for all the instances computed.

The model was validated using several test instances with a priori known optimal solutions. This verified that there were no obvious formulation problems and that the results when optimizing each of the four objective functions individually agreed with the ones expected based on intuition.

After the model was validated, the experiments were performed using the parameters from the application example case corresponding to the real IdeM instance. The model was solved four times, each for one of the objective functions (as stated above, execution times were always very short, less than one second). Table 4 shows the assignments obtained for each of the scenarios as well as a comparison with the manual assignment. For each scenario (labeled with the objective functions: OptPref, MinQE, MinQU, MaxFit), there are two columns; one labeled A, showing the task that each intern has been assigned to; and one labeled with a V, which show a value 1 if the solution computed with each objective function is equal to the manual one, and 0 otherwise. The last file of the table (highlighted in yellow) shows the number of agreements for each scenario.

As it is clear from the results, the manual assignment was very similar to the one based on the applicants' preferences, with thirteen coincidences (out of sixteen cases). Three of the sixteen applicants had the same assignment for the four scenarios as well as in the manual assignment. On the other hand, two applicants did not receive the same task in any of the scenarios as in the manual assignment. Looking more closely, in these two cases, the applicants' first preference was the Administration section/task, which was the most popular and only had one available position.

Table 5 shows the values of the different functions for each of the five solutions considered (the ones corresponding to the different objective functions and the manual one). The best function values over all the scenarios are highlighted (in green). As expected, the smallest values for Priorities, Extra Positions Cost and Unassigned positions costs are reached by the solutions obtained with the corresponding objective values; and the largest Fit value is reached when optimizing that objective. In the case of Unassigned positions, all solutions reach the best value (0), as no positions are left unassigned (due to the particular data of this case study). The manual assignment does not reach the best value for any of other the functions.

This table reinforces the conclusion that the manual assignment was very close to the optimal preferences solution. The manual assignment reached the value 22 for the preferences function, while minimizing it (OptPref solution) reached value 21; the values of the other goal functions for these two solutions were also very close (identical extra positions cost, and slightly worse Fit benefits). On the other side, the manual

Table 4: Comparison of results for different objective functions against manual assignment

Intern	OptPref		MinQE		MinQU		MaxFit		Assignment manual
	A	V	A	V	A	V	A	V	
1	3	1	4	0	4	0	4	0	3
2	3	1	4	0	4	0	4	0	3
3	4	1	4	1	1	0	1	0	4
4	3	0	3	0	1	0	3	0	4
5	1	0	3	0	2	1	1	0	2
6	4	1	3	0	3	0	1	0	4
7	5	1	1	0	1	0	5	1	5
8	5	1	1	0	1	0	5	1	5
9	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1
11	5	1	2	0	5	1	2	0	5
12	2	0	5	0	5	0	5	0	1
13	1	1	5	0	5	0	5	0	1
14	1	1	5	0	5	0	1	1	1
15	5	1	3	0	3	0	3	0	5
16	3	1	3	1	3	1	3	1	3
		13		4		5		6	

Table 5: Function values for the different considered solutions

Function	OptPref	MinQE	MinQU	MaxFit	Manual assignment
Preferences	21	65	66	51	22
ExtraPositionsCost	17	11	20	20	17
UnassignedPositionsCost	0	0	0	0	0
Fit	14	10	13	17	13

assignment solution has quite larger Extra Positions Cost in relation to the solution minimizing this goal; and quite lower Fit in relation to the solution maximizing this goal.

To better compare the tradeoffs among the five different solutions being analyzed, we normalized the solutions' values to the 0-1 interval, where 1 is the most desirable value. The functions were normalized using these formulas:

1. minimization functions: $\frac{MAX-value}{MAX-MIN}$;
2. maximization functions: $\frac{value-MIN}{MAX-MIN}$;

where MAX and MIN are the highest and lowest values among the ones shown in Table 5. The normalized values are shown in Table 6.

Table 6: Normalized function values

Function	OptPref	MinQE	MinQU	MaxFit	Manual assignment
Preferences	1.00	0.02	0.00	0.33	0.98
ExtraPositionsCost	0.33	1.00	0.00	0.00	0.33
UnassignmedPositionsCost	1.00	1.00	1.00	1.00	1.00
Fit	0.57	0.00	0.43	1.00	0.43

Figure 1 presents a radar graph where the footprint of each of the five solutions considered is shown in four dimensions. The manual assignment solution and the OptPref solution are quite similar (with the Opt Pref solution still dominating the manual one, which can be seen as the manual one is included within the OptPref one). The MinQU solution is dominated by the MaxFit solution. The three undominated solutions are the OptPref, MinQE and MaxFit ones, which all represent different tradeoffs between the different functions.

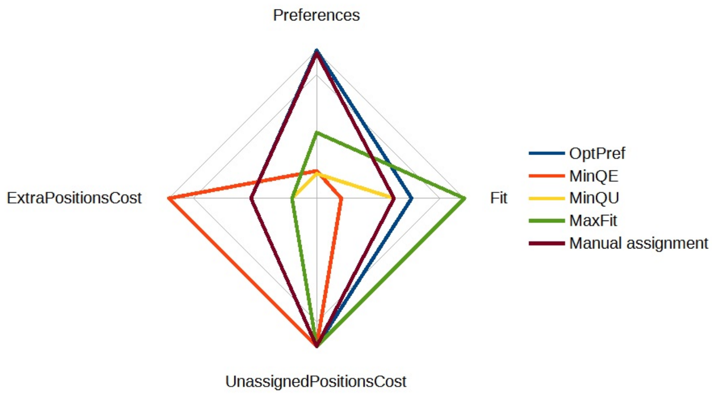

Figure 1: Radar graph comparison of the considered solutions

7 Sensitivity analysis

Once the mathematical programming model has been developed, it is important to perform a sensitivity analysis to understand how the results of the model depend on the values of some key parameters.

In this section, we will perform a sensitivity analysis of the task assignment model in relation to two aspects: the weights of the objective functions and the number of positions available. We will explore how changes in these parameters impact the solutions found, and the benefits obtained.

7.1 Objective function weights

As we discussed, the model includes four objective functions: optimize preferences, minimize the cost of unassigned positions, minimize the cost of extra positions, and maximize the assignment fit. When applying the model with a single objective computed as a weighted sum of these four functions, the values assigned to the weights will impact the relative importance of each function. The weights then represent the relative importance of each objective for the organization in the context of task assignment, and can vary in different contexts. We now show how the changes in these weights impact the model results.

To perform this analysis, in Table 7 we show again the best values for each of the four objective functions (we remind that it is not possible to attain all the values simultaneously; if one solution reaches the best value for one of the objectives, it will have worse values for at least another objective function).

Table 7: Best values for each objective function (evaluated individually)

Preferences	ExtraPositionsCost	UnassignedPositionsCost	Fit
21	11	0	17

We also remind the definition of the weights α:

- $\boldsymbol{\alpha_1}$: weight for the optimizing preferences objective;
- $\boldsymbol{\alpha_2}$: weight for the minimizing cost of unassigned positions objective;
- $\boldsymbol{\alpha_3}$: weight for the minimizing cost of extra positions objective;
- $\boldsymbol{\alpha_4}$: weight for the maximizing fit objective.

We show in Table 8 the different values for α considered, jointly with the values achieved for each of the objectives. The cases where an objective function achieves its best possible value are highlighted (in blue).

It is interesting to note that for every combination of the α weights, the cost of unassigned positions is always 0; this reinforces the conclusion that for the instance under consideration, it is possible to find optimal solutions for the other objective functions while assigning all existing positions.

We first observe the result where all functions have equal weights (first line in the table). We can see that (except the unassigned positions cost, which is always 0), all the other objective functions have slightly

Table 8: Evaluation of solutions obtained for different weight values

#	Weights	Preferences	ExtraPositionsCost	UnassignedPositionCosts	Fit
1	$\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0.25$	23	14	0	14
2	$\alpha_1 = 0.7, \alpha_2 = \alpha_3 = \alpha_4 = 0.1$	21	17	0	14
3	$\alpha_2 = 0.7, \alpha_1 = \alpha_3 = \alpha_4 = 0.1$	24	11	0	11
4	$\alpha_3 = 0.7, \alpha_1 = \alpha_2 = \alpha_4 = 0.1$	23	14	0	14
5	$\alpha_4 = 0.7, \alpha_1 = \alpha_2 = \alpha_3 = 0.1$	32	20	0	17
6	$\alpha_1 = \alpha_4 = 0.4, \alpha_2 = \alpha_3 = 0.1$	21	17	0	14
7	$\alpha_2 = \alpha_3 = 0.4, \alpha_1 = \alpha_4 = 0.1$	24	11	0	11
8	$\alpha_1 = 0.3, \alpha_4 = 0.5, \alpha_2 = \alpha_3 = 0.1$	21	17	0	14
9	$\alpha_4 = 0.6, \alpha_1 = 0.2, \alpha_2 = \alpha_3 = 0.1$	24	17	0	15
10	$\alpha_2 = 0.6, \alpha_3 = 0.2, \alpha_1 = \alpha_4 = 0.1$	24	11	0	11

worse values than the ideal ones. This shows a balanced importance for all functions, allowing to reach a compromise solution.

The results in lines 2, 3, 4 and 5 correspond to cases where one of the objectives has a much larger importance than the other three. In these four scenarios, the solutions reach the ideal value for the objective with the larger weight. The solution of line 2, obtained with the larger weight for the Preferences function, attains identical values to the solution obtained by taking into account just the same function. The solution of line 3, obtained with the larger weight for the Extra Positions Cost function, attains the best possible value for this function, and also improves on the Preferences (24 against 65) and Fit (11 against 10) function values in relation to the solution obtained considering only the Extra Positions Cost. The solution of line 4 is identical to the one of line 2; this makes sense, as the Unassigned Positions Cost has no impact in this instance, and the other three functions have equal weights (as was the case for line 2). The solution of line 5 corresponds to giving the higher weight to the Fit function; it has worse values for the Preferences and Extra Positions Cost functions, showing that these are highly conflicting objectives. The solution still dominates the one obtained considering only the Unassigned Positions Cost objective, as the Preferences function improves from 51 to 32.

We now consider other cases. In lines 6, 8 and 9, the Preferences and Fit have larger weights than the other two functions (together, their weights sum 0.8, but with different relations). The results are as expected; these solutions show good values for the prioritized functions, with slightly different trade-offs. In lines 7 and 10, the Extra Positions Cost and Unassigned Positions Cost are more important (also summing 0.8, with different relative importance); this leads to obtaining the best possible values for these functions, with some worsening of the other two functions.

7.2 Sensitivity with respect to the number of positions

The main goal of this section is to evaluate the impact of the NAP_j (number of available positions) and NEP_j (number of extra positions) parameters in the results of the model, to understand its robustness and flexibility under different scenarios.

To perform this analysis, we start from the case base described in Section 5, and we examine four different variations in the parameter values, comparing the results obtained by optimizing the different objective functions in the instances with the new parameters against the original results (note that while there is a coincidence in number, the fact that we consider four variations in parameters is not related to the fact that there are four different objective functions).

The four scenarios considered are the following ones. In the first case, we increase the number of available positions so that the total number is equal to the number of applicants (but not necessarily in the tasks they prefer). A second scenario considers that the total number of available positions is equal to the number of applicants, and distributes the available positions following the preferences of the applicants. A third scenario starts from the original number of positions and adds an extra position to each task. The fourth scenario starts from the original number of positions and adds both an available and an extra position to each task.

As discussed in Section 5, in Table 1 we can see the number of available positions (in total: 13) and extra positions (in total: 5) for the original (base) case. The number of applicants for the case study is 16. Table 5 shows the values of the four evaluation functions for the different solutions found applying the different objective functions over the original case.

As mentioned, in the first additional scenario, we increase the number of available posts to 16, without changing the extra positions. Table 9 presents the results obtained, highlighting (in blue) the best values achieved.

Table 9: Results for the scenario with available positions equal to the number of applicants

Function	OptPref	MinQE	MinQU	MaxFit
Preferences	21	55	55	61
ExtraPositionsCost	5	0	0	20
UnassignedPositionsCost	10	0	0	40
Fit	14	12	12	20

When comparing the results in Tables 5 and 9, it is possible to see that the Extra Positions Cost goes down in most cases. This is as expected, as the number of available positions has increased, it is less necessary to occupy extra positions. In the case of objective functions MinQE and MinQU, this cost is zero; the functions are related in this instance, as leaving unassigned positions directly implies using extra positions.

It is interesting to see that when the objective functions used are OptPref and MaxFit, we still have Extra Positions Cost and Unassigned Positions Cost larger than zero; as for these objective functions, the focus is not on the positions' availability, but on the preferences and characteristics of the interns. When optimizing these functions, this implies that some available positions will not be occupied, and for other tasks, some extra positions will be needed.

The second experiment is based on an instance where the total number of available positions is also equal to the number of applicants (16), and additionally, the number of available positions for each task is exactly equal to the number of applicants who prefer it (priority 1). This should be a scenario even more favorable than the previous one. The results for this scenario are shown in Table 10.

Table 10: Results for the scenario with available positions equal to the applicants' preferences

Function	OptPref	MinQE	MinQU	MaxFit
Preferences	17	81	81	50
ExtraPositionsCost	10	0	0	20
PuestosLibres	20	0	0	40
Fit	15	13	13	22

When taking the number of available positions for each task equal to the number of applicants' desired positions, and using the objective function OptPref, the value of the preferences function improves, as expected. Nevertheless, the best number theoretically possible (16, equal to the number of applicants, which would be attained if everyone was assigned to a task with the highest preference, 1) is not reached. Looking at the solution found in that case, we find that one of the applicants had marked as first preference a task for which he/she did not comply with all the requirements, so it is not possible to perform this assignment; this person is assigned to an extra position in another task, and one position is left unassigned. When optimizing the functions MinQE and MinQU we obtain similar results to the previous scenario (where the lowest cost, 0, is reached). In the case of the MaxFit objective, we can reach better values than in the previous scenario.

A third scenario corresponds to the original instance, adding an extra position to each task. The results are shown in Table 11. The extra positions result in solutions where more applicants are assigned following their preferences (with corresponding increasing values of the Extra Positions Cost function). When applying the OptPref objective function, some positions are left unassigned to take advantage of the extra positions in desired tasks and improve the Preferences value. The same happens with the MaxFit objective function, as the extra positions can be taken advantage of to reach a better fit in the assignment (while leaving some available positions free).

Table 11: Results for the scenario adding an extra position to the base instance

Function	OptPref	MinQE	MinQU	MaxFit
Preferences	20	66	86	51
ExtraPositionsCost	22	11	20	35
UnassignedPositionsCost	10	0	0	30
Fit	15	9	13	22

The fourth (and last) scenario starts from the original number of positions and adds both an available and an extra position to each task (i.e, it is similar to the third one, but adding a position for each task). The results obtained for this case for the four different objective functions are shown in Table 12.

Table 12: Results for the scenario adding an available position and an extra position to the base instance

Function	OptPref	MinQE	MinQU	MaxFit
Preferences	19	64	64	48
ExtraPositionsCost	10	0	0	25
UnassignedPositionsCost	30	10	10	60
Fit	15	13	13	23

In this case, we have more available positions than applicants, which means that in every solution, there will be some cost due to unassigned positions, for every objective function. In this scenario, the MinQE and MinQU solutions do not need to use extra positions, so this cost will be 0. As in previous scenarios, we can see that those objective functions are highly correlated (in this case, they obtain exactly the same results). When considering the MaxFit objective function, we reach the best fit with respect to all the previous scenarios, showing that the higher number of positions result in solutions with better agreement between applicants and task requirements. Also, the OptPref objective function obtains good agreements.

8 Hiring process and survey

After the interns were hired and assigned to their corresponding work positions, we performed a survey with the IdeM in order to analyze the assignment results. At the same time, we obtained a list of the different activities performed to complete the hiring process.

After the assignment, several meetings were arranged between the SAC and the NGOs to answer any queries or doubts about the hiring process, which was performed in two steps; half of the interns were hired in November and half in February.

The first group included eight interns, who were hired on 20 November 2023. During their first week of work, the interns participated in six workshops as part of a general induction process. The workshops discussed subjects such as the functions of the organization, gender roles, and other general aspects. Some of the interns could not participate in the workshop dynamics due to some barriers, showing that the induction process must be improved to take this into account.

Regarding the job assignment, the process was in general successful. Nevertheless, some difficulties arose. One of the interns was not comfortable with her task in the Information Module. While she was comfortable in general with interaction with the public, in her post she had a large and diverse public, leading to a high stress level. After a short initial time, she was finally re-assigned to another task. Another one of the interns had some difficulties with his assigned tasks, particularly as there was no direct supervision from a qualified technician. This led to better induction activities for the next interns to be assigned to that particular task. A third intern, who was assigned to the Call Center, had no previous experience working with computers, which was a requirement for his task. As he had experience in using intelligent mobile phones, he received specific training, which allowed him to work on this task afterwards.

Regarding the NGOs, some of them did not provide company to the interns after the initial assignment. One of the NGOs had a more active attitude, following the adaptation process of the interns, which was very helpful to improve their ability to tackle the different difficulties during the initial weeks.

In most cases, both the area leaders and the interns were satisfied with the tasks assigned. The area leaders commented that the inclusion of the new interns was an occasion for learning and growth of the whole area, improving the links and relationships within the work teams.

The second group of eight interns started work on 19 February 2024. The previous assignment was modified to cover a post in the Information Module, which was vacant after the situation mentioned in the previous group. Taking advantage of the experience generated with the first group, several improvements were introduced. A first general induction was performed so that the interns got familiarized with their workplace and their teammates, and only later with the organization in general. The induction workshops were organized taking into account a larger number of shorter sessions, as the previous ones had been too tiring for the participants.

It was stressed that the technical counterparts had to follow/actively help the new interns in their work experience in the first weeks, and this led to much better results. There was also a sign language interpreter hired by the IdeM during the first weeks.

In general, the Disabilities Secretary was satisfied with the project results, and the IdeM is discussing how to employ these models in other job assignment tasks. The Secretary looks forward to including persons with disabilities in more general contexts, and to continuing to improve the induction and capacitation materials and workshops.

9 Conclusions

The main conclusion is that the model developed is simple and at the same time very applicable. Its value lies in its simplicity, validity and relevance to the IdeM. With very low computational times, it found better assignments than the ones built manually. It also included the possibility of weighting different objective functions and of taking into account more globally the needs and preferences of the involved parties.

The model is very general, and even if it was motivated by the work inclusion of persons with disabilities, it is a general tool that can be used in other contexts to take into account the different capacities of workers, characteristics of tasks, and inclusion aspects in a wider context. As discussed at the end of Section 2, the model also extends other other worker assignment models with personnel constraints, by adding some particular characteristics, such as not excluding workers who may have lower speeds or efficiency levels, and considering different objective functions which take into account social objectives.

One relevant aspect would be to apply the model for larger scenarios, with more interns, work positions, and additional constraints. The computational time for solving the problem was very short, but it is possible that in more complex instances the computational complexity grows and that the effort for solving the problems can become a limitation for practical applications. For the AWALBP problem, the literature includes many works developing and exploring different methods for solving realistic instances more efficiently and quickly; this kind of effort may also be needed for our problem. a Another line is to perform a more in-depth exploration of the multiple objective formulation, which was considered in the present work by using a weighted sum with parameters α. While the results obtained were interesting, other methodologies can be suitable for supporting decision making, and could be applied; one is goal programming; a second one is interactive methods, where the decision maker can specify preferences to further refine the solution search; the third one is finding the full Pareto set or an approximation to the Pareto front, to better understand trade-offs among the objectives.

Some aspects of the real-life problem were not taken into account in the model developed in this work. We now mention some that can also be added in future developments of the tool.

One of these aspects is to take into account more detailed information about the educational achievements of the applicants, both the level completed, but also additional courses and knowledge of languages. Another aspect is more detailed information about previous work experience, both related and unrelated to the positions to be provided. Even if these aspects are not requirements/requirements, they can be influential when performing the assignment.

Also, it would be interesting to consider non-linear cost functions for unassigned positions and for extra positions; as the impact in one case, and adaptations in the second one, can lead to cost growths higher than linear.

Another information to be taken into account is the weekly availability of the applicants (in relation to the task shifts). This information can help to take into account the desired number of positions per shift, cover the necessities in different turns and have more flexibility with the interns. In some positions, it may be possible to include remote work on some days of the week. This option was not available for the case study discussed in this paper, but for some future scenario, it could be a possibility to be taken into account.

It is interesting to take into account that the interns were incorporated in two stages, separated by two months, to have a more gradual integration in the offices. The agreement with the sponsoring NGOs included the presence of a person from each NGO to act as an articulator and to accompany the interns during their first weeks at work. This could be taken into account in the model so that the assignment of interns to each office during each stage takes into account the availability of the articulators and their load. The same criteria could be helpful to consider inductions, trainings and other activities for ensuring the success of the integration process.

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