Engineering Applications of Artificial Intelligence 61 (2017) 21–34

Contents lists available at ScienceDirect

Engineering Applications of Artificial Intelligence

journal homepage: www.elsevier.com/locate/engappai

Multi-criteria assignment policies to improve global effectiveness of medico-social service sector

Geovanny Osorio[a,b], Thibaud Monteiro[a,*], Lorraine Trilling[a], Frédéric Albert[c]

[a] INSA Lyon, DISP (laboratoire de Décision et d'Information des Systèmes de Production), Bât. Jules Verne, 19 av. Jean Capelle, 69621 Villeurbanne, France
[b] Fondation OVE, 19 Rue Marius Grosso, 69120 Vaulx-en-Velin, France
[c] Ministère de santé, 14 Avenue Duquesne, 75007 Paris, France

ARTICLE INFO

Keywords:
Multidimensional assignment problem
Resources allocation
MILP
Resources utilization
Medico-social service sector
Simulated annealing

ABSTRACT

In this paper, we propose a multi-criteria approach in order to reduce the waiting time on the assignment of users to medico-social institutions. The main goal is to ascertain whether alternative assignment policies can improve global response to users' demands, and to assess the performances of each alternative (scenario) compared to the current practice. We propose a mathematical model of user assignment to medico-social structures and professionals, under constraints of resource capacity, professionals' skills and user requirements (formulated in an individual support project). With alternative assignment policies, users' needs could be covered partially. They also authorize the involvement of several structures and several professionals in the response to the request. A mixed integer linear programming solver is used to solve this assignment problem, following a lexicographic approach in case of partial coverage policy. For some assignment policies that have long calculation times, we propose a simulated annealing approach in order to speed up the resolution. In order to validate simulated annealing approach, we compared it with a greedy randomized adaptive search procedure. The problem is solved for instances where we have real size data for a set of institutions for disabled children and teenagers. We present and compare computational results over several scenarios, highlighting the improvement provided by each alternative assignment policy.

1. Introduction

The medico-social sector is composed of a wide range of services and institutions (also called medico-social structures or structures throughout the study) that support vulnerable people such as disabled children, teenagers or adults, people in precarious situations or in social difficulty such as situations of exclusion or dependency, and the elderly. Today, this sector faces a quantitative and qualitative supply deficit, manifested especially in the exclusion of frail and disabled people. When the need for an accompaniment (or support) is identified, a request for admission is sent to one or several medico-social institutions, which then accept or refuse the person, according to his or her particular needs as described in the ISP (Individual Support Project), the specialization of the structures and the availability of the healthcare practitioners and social workers (social educators, special needs teachers, nurses, physicians, psychologists, speech therapists, etc.), that we refer to as 'professionals' throughout the paper. This current assignment process is not satisfactory. A recent French national report (Piveteau et al., 2014) highlights the difficulty of finding support for a large number of people with heavy needs (called "zero solutions"). This causes a break in the person's life path, with consequences on both the person and his or her immediate environment (loneliness, risk of crisis, need for hospitalization, etc.). Apart from deteriorating living conditions, the lack of support can lead to situations involving high expenses (in case of hospitalization for example). The same report emphasizes the sense of solidarity: *"Contrary to rupture, it is not 'everything and immediately' but 'always something with an ever outstretched hand'"*. This report points out the multiple origins of the problem: (1) the medico-social offer is not qualitatively and quantitatively sufficient (Vachey et al., 2012); (2) there is a lack of coordination between the offer and users' needs; and (3) current assignment policy consists in finding a solution that covers all support needs in a single institution. In order to improve response to people's need for support, we have chosen to tackle the third point above. We explore the track consisting in the search for alternative assignment policies that are more flexible and that may, for example, partially cover the user's needs, or that authorize involvement of several structures and several professionals in meeting the need. The

* Corresponding author.
E-mail addresses: geovanny.osorio@fondation-ove.fr (G. Osorio), thibaud.monteiro@insa-lyon.fr (T. Monteiro), lorraine.trilling@insa-lyon.fr (L. Trilling), frederic.albert@sante.gouv.fr (F. Albert).

http://dx.doi.org/10.1016/j.engappai.2017.02.009
Received 12 July 2016; Received in revised form 10 February 2017; Accepted 14 February 2017
Available online 01 March 2017
0952-1976/

problem is to assign users to professionals and structures, according to their needs in several domains, while respecting constraints such as resource capacity, professionals' skills or need coverage. In this Multidimensional Assignment Problem (MAP), the number of admitted users (assigned to one single structure) is the main criterion to optimize, as it results in a total coverage of user needs. However, an alternative to this assignment policy could be to relax constraints related to the assignment of users to one single structure with one single professional for each domain requested by the user in his ISP. Another relaxed constraint could be to cover needs partially (i.e., we allow the admission of a user even if all their requirements for each area of the ISP are not completely covered). In this case, a secondary objective would aim to maximize the minimum coverage rate for all users.

In this paper, we evaluate alternative assignment policies compared to the current policy, in order to determine whether, under more flexible policies, we can achieve a better use of human resources and thus increase the number of users admitted. The main purpose is to decrease the waiting time for users to access services and thereby to reduce the risk of interrupting the support they receive. A previous work presented a first model and a first exact resolution method (Osorio et al., 2015a). In this paper, we propose an extended model of multi-criteria assignment policies and a metaheuristic-based approach to solve problems that have prohibitive calculation time.

The paper is organized as follows. The next section presents a review of the literature on the Multidimensional Assignment Problem, to which our problem is linked. In Section 3 we then present the formulation of the problem of assigning users to medico-social structures as a mathematical model. This model is designed to be able to translate each proposed alternative policy by changing only few parameters. In Section 4 the experimental approach is described. This section presents all the scenarios that are compared, along with how the input data have been generated and how each case is solved. It presents an algorithmic approach based on simulated annealing for reducing the computation time, especially for scenarios involving partial need coverage. Section 5 gives the results obtained, compares the performances of the assignment policies according to performance indicators, and gives some managerial assessments. Finally, Section 6 draws conclusions and defines some future research tracks.

2. Related works

In the literature, some studies have tackled the lack of response to persons with disabilities mentioned in (Piveteau et al., 2014). These researches related to the decision making enhancing the effectiveness of the medico-social networks are mainly oriented towards human resource assignment (Lin et al., 2016), towards the regulation of governmental social support (Kroneman et al., 2012) or towards the implementation of good professional practices (Crowley et al., 2011). We have not found researches focused specifically on the decision related to user assignment issues considering the multiple dimensions of the problem.

The user assignment in the medico-social sector is a Multidimensional Assignment Problem (MAP) because it involves several professionals, such as practitioners and social workers, several skill areas and possibly several structures, all in parallel. The MAP is a more complex problem than the linear assignment problem (Martello and Toth, 1987). In the latter, the objective is to match the elements of two data groups. The dimensions are then associated with the number of groups to match. Whereas the classic assignment problem is two-dimensional, the term "multidimensional assignments problem" refers to three or more dimensions. Accordingly, it affords a much larger range of possible combinations, where the goal is primarily associated with solution that minimizes a cost function. The MAP has a large number of applications as the combination of data or resources planning, such assigning n tasks to m workers or machines in order to minimize the delay (Burkard and Cela, 1999). In this section, we explain what a MAP is. We then show how this NP-hard problem has been solved in the literature using exact solving approaches or heuristics and metaheuristics when exact approaches have failed.

2.1. The multi-objective and multidimensional assignment problem

Since its original formulation, the linear assignment problem has been considered as one of the fundamental problems in the combinatorial optimization branch of optimization or operations research (Munkres, 1957). There are in fact several applications in the literature (McKeown and Workman, 1976) (Pentico, 2007) (Burkard, 2002). The existing assignment problems that allow n jobs to be matched to m resources are often limited to considerations of cost and benefit of each possible combination. However, the cost and the benefits may not be the only criteria to be considered. Chen and Lu (2007) propose an index of composite efficacy to represent the performance measure for a particular assignment.

Ten years after the onset of assignment problems, MAP emerged as a natural extension of the assignment problem (Pierskalla, 1967). The initial example was the three-Dimensional Allocation Problem (3DAP), which allowed for the minimization of the total assignment cost of n items to j places to m different periods time. The general idea of a MAP is that, apart from assigning an item to a location or a work machine, there are often additional dimensions, which can improve the quality of the allocation. These dimensions can be time, space, quality, etc. In the case of user assignment to the medico-social sector, beyond the assignment of users to medico-social structures, the assignment problem also affects several professionals in different fields of activity. The efficacy of this assignment can be evaluated primarily according to the number of assigned users (which can be linked either to a profit function or to the investment of operating characteristics), but also with some quality indicators of the mission (allocation rate of different resources used, coverage rate of expressed need). A recent work on the MAP shows that this problem remains difficult to solve (Haus, 2015).

Apart from the MAP, in this study, we focus on a multi-objective problem to assess more flexible policies and to analyse how these policies could potentially improve current response to user assignment. Two approaches could be considered: the case, where criteria assignment policies can be ranked, and the case, where criteria have a same weight. In the case of equivalent criteria, Multi-objective Harmony Search (MOHS) could be explored (Sheng et al., 2014). In this case, criteria are not contradictory and the optimal decision does not need to be taken in the presence of trade-offs between two or more conflicting objectives. In our problem, the first and main objective is to maximize the number of users admitted in one or several structures. Thus we chose Lexicographic Assignment Problem (LAP) which has been widely applied in various fields: strategic resources distribution (Brown, 1983), production of programming (Luss, 1991), emergency services (Ogryczak, 1997) or even in the design of communications networks (Cosares et al., 1995). The lexicographical approach requires the establishment of a planned order in the different objectives and according to the preferences of decision makers.

2.2. Exact solution methods

MAPs are considered as an NP-hard combination problem. Even the resolution of MAPs of a moderate size is a difficult task because a linear increase in the number of dimensions produces an exponential increase in the size of the problem. Despite its inherent difficulty, more accurate and heuristic algorithms (Aiex et al., 2005), (Pasiliao, 2003) have been proposed to solve this problem. In most of these algorithms, some form of local neighbourhood search is used, as in the case of Walteros et al. (2014) that introduced a non-continuous linear program, which was then compared with the traditional "Branch and Price" method. Following the same goal, Kuroki and Matsui (2009)