Configuration of health pathway networks for patients with chronic diseases

El Hassan Laaziz [1,2*]

[1]ESITH, Casablanca, Morocco
[2] LISAD/ ENSA-UIZ, Agadir, Morocco

Abstract. Chronic and long-term diseases, particularly neurodegenerative diseases and polymorbidity, are increasingly occupying the medical and socio-medical landscape and are a concern for government policies. These diseases are of particular concern because the care function (waiting for a patient) is complex and does not have the same utility. The objective of this article is to propose a modeling framework for optimizing patient flows through these care centers with the aim of minimizing the overall cost of the care system (i.e. the total cost of consuming these resources) while maximizing utility for patients. Utility (utility matrix) is defined in our article as a matrix valuing each type of care pathway by its utility for a specific category of patient or for their stage of illness. The model is an integer linear program.

1 Introduction

Chronic and long-term diseases, particularly neurodegenerative diseases and polymorbidity, increasingly occupy the medical and socio-medical landscape and are a concern for government policies. These diseases are particularly worrying because the care function (waiting for a patient) is complex and does not have the same utility.

It is a concern at the operational management level. At this level, many contributions to modeling and optimization in hospital engineering have been produced. It is less of a concern at the tactical and strategic level, particularly in countries like France where health is under the control of the state and public management. Indeed, in this context, the implementation of health networks is well guided by studies and forecasts at the definition and sizing phase. On the other hand, the configuration of services (and the resources required for services) often remains on the initial estimates (or a little less under the pressure of rationalization imperatives, ... state) or falls squarely into operational management seeking to adapt as best as possible by using short-term synergies between network establishments.

The objective of this article is to propose a modeling framework for optimizing patient flows through these care centers with the aim of minimizing the overall cost of the care system (i.e. the total cost of consuming these resources) while maximizing utility for patients. Utility (utility matrix) is defined in our article as a matrix valuing each type of care pathway by its utility for a specific category of patient or for their stage of disease. The model is a linear integer program, containing a penalty term that penalizes wastage (non-care of patients). The program is tested and numerical results are produced. This article is organized into three sections. The first contains the definition of the problem, the second is devoted to the definition of the parameters and variables of the model and the third contains the mathematical model.

2 Problem definition

The network of care centers considered contains:

- a set G composed of care centers admitting patients (beds) for more than one day (see hospitalization: CHU and EPAHD and others)
- a set C of patient areas (or cities or cantons) in a territory (patients' homes)
- a set K of medico-social or assistance care centers (different types, with specialties, and able to recommend transfer to a matrix of possible care centers).

A possible health pathway base (pathways) will be defined. Each pathway is characterized by 1 to 3 intermediate care centers and may or may not lead to a long-term admission. The classes of patients must favor this or that pathway according to the treatment

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* Corresponding author: laaziz02@gmail.com

recommended either by the treating physician or the hotline.

Figure 1 gives a synopsis of such a system of care centers:

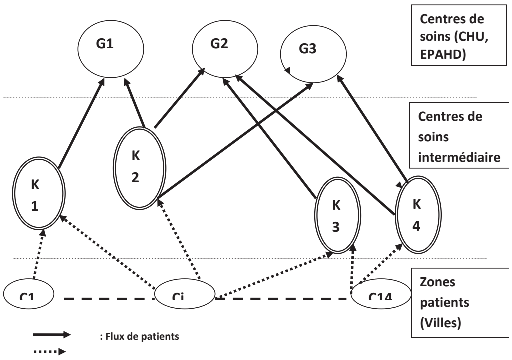

Fig. 1. Health center network**.**

The possibilities are defined in the data given their non-deterministic characteristics, and resulting from medical experience and the recommendation of the treating physician. All possibilities will be defined as an inference basis (which itself will be deduced from machine learning based on history). Here the medical information that would allow classifying patients according to the stages of the disease, and the basis of the most appropriate treatments is necessary

The model that will be produced is a tactical planning model that

Any path p in P, connecting the pair of nodes (i, j) of GxCxKxQ has as attributes (i,j,k,,F_p,s_p^q,u_p^q,) where:

i: origins of the path (home)

j: all care centers including hotline and treating physician, which are also obligatory passages

We will use the following definitions in our formulation of the model:

3 Notations and parameters

In formulating the model, the following notations will be considered:

G: Set of hospitalization centers, indexed by j
K: Set of intermediate care centers, indexed by k
C: Set of patients, indexed by i
Q: Set of patient segments according to the stage of the disease (, indexed by q
P: Set of feasible and recommended health pathways by geriatric medicine according to medical progress, indexed by p (i, j, k, F_p s_p,u_p)
s_p: the average (estimated) time of care at the final node of pathway p
u_p: utility (estimated, to be defined) of care at the final node of pathway p.
F_p: Average fixed cost relative to the pathway per patient at pathway p.
O_p: Node of origin of the service relative to pathway p.
D_p: Node of destination of the service relative to pathway p.
E_j^i (q): Number of patients/Demand for care (medical services) from patient area i to Care Center j, (i,j) in GxC.
δ_i^j : Capacity of the destination care center (node) j during the planning period, from admitting patients from area i. Decision variables
y_p: Number/flow of patients served/treated on pathway p
x_p^q : Number/Flow d of class (stage) q on pathway p.

4 Model formulation

In the region we will consider 5 cities (zones). We will assume that each of the cities has at least one center of each type and that it is incapacitating. The model will allow to define the load plan of the center of this city (and therefore its capacities and resources to be provided) if necessary. Otherwise it will be the capacity and additional resources of the nearest center.

The assignments resulting in the Eij(q) are a priori defined by the treating physicians and the Hotline.

The model is a fixed-load, path-based Integer Linear Program (ILLP). Its formulation is as follows:

$$\mathbf{Min}\ \left(\sum_p F_p y_p + \quad + \sum_p \sum_q \left(s_p^q / u_p^q\right) * x_p^q\right)\ ) \tag{1.1}$$

$$\sum_{q \in Q^*} x_p^q = y_p \forall\, p \in P \tag{1.1}$$

$$\sum_p \sum_q = \sum_p y_p \tag{1.2}$$

$$\sum_{p \in P, D_p = j, t_p = k} \sum_q \left(s_p^q\right) * x_p^q) \ \leq \delta_k^j \ \forall\, q \in Q, j \in G, k \in K \tag{1 .4}$$

$$\sum_{i \in C} \sum_{p \in P, O_p = i, t_p = k,} y_p \ = \ \sum_{j \in G} \sum_{p \in P, D_p = i, t_p = k,} y_p \ \forall \ \ k \in K \tag{1.5}$$

$$\sum_{p \in P, O_p = i} \sum_{q \in Q} x_p^q \ \geq \ \sum_{j \in G} \sum_{q \in Q} E_j^i(q) \ \forall\, i \in C \tag{1.6}$$

$$x_p^q \ \mathit{entiers\ non\ negatifs}, \forall\, p \in P, q \in Q \tag{1.7}$$

$$y_p \ \mathit{entiers\ non\ negatifs}, \forall\, p \ \mathit{in}\ P \tag{1.8}$$

In the formulation, the objective (1.1) is to minimize the total service time of the Care Center while increasing the utility 〖(s〗 _p/u_p^). In the Path/Patient Class matrix (indexed on the stages), a utility coefficient is assigned to each path (which is also the utility of the destination node).

Constraints (1.2-1.3) ensure that on each path, the total number of patients assigned to path p, are all taken care of regardless of the stage by the path, and thus prevent the loss of patients passing through the hotline or doctor and who would not be referred to any care center.

Constraints (1.4) define the capacity limitations of the care centers and territorial logistics modules allowing the routing, orientation and assistance of patients until their admission to the care center. Constraint (1.5) represents the design balance: ensuring that all incoming and outgoing flows of each CSMS are equal.

Constraint (1.6) represents satisfaction of the overall demand for each patient area for all stages and by all types of care centers.

Constraint (1.7) represents satisfaction of the demand by patient area i, disease stage q transiting by CSMS k.

5 Conclusion

The subject and objective of the article are of great importance when we know that what hurts the health journey the most is not necessarily an absolute lack of resources but rather their judicious allocation in space and time. In space it is a question of statistics and forecasting but in time it is a question of tactical planning.

The model is part of a work in progress. It is being improved with the addition of other valid inequalities representing specific constraints, a penalty term to the objective functioning and the finalization of the conceptual data model.

In future work, we will improve the model and the data model and we will produce numerical analyses to test the model.

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