



# Robust nurse-to-patient assignment in home care services to minimize overtimes under continuity of care



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## ABSTRACT

Home Care (HC) providers are complex organizations that manage a large number of patients, different categories of operators, support staff and material resources in a context affected by high variability. Hence, robust resource planning is crucial for operations in HC organizations, in order to avoid process inefficiencies, treatment delays, and low quality of service. Under continuity of care, one of the main issues in HC planning is the assignment of a reference nurse to each assisted patient, because this decision has an impact on the workload assigned to the nurse for the entire patient's length of stay. In this paper, we derive an analytical structural policy for solving the nurse-to-patient assignment problem in the HC context under continuity of care. This policy accounts for randomness related to both the demands from patients already assigned to nurses and the demands from new patients who need assignments. The policy is compared to other previously developed approaches, and applied to a relevant real case.

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## 1. Introduction

### 1.1. Background

Home Care (HC) consists of delivering medical, paramedical and social services to patients at their domicile rather than in hospital. HC leads to a significant increase in the quality of life for patients, who are assisted at home, and to considerable cost savings for the entire health care system [1–3]. HC is a relevant sector of the health care domain in western countries: in the US, about 3.3 million beneficiaries received HC services from more than 11400 agencies in 2009, and Medicare spent 19 billion dollars on HC [4]. Moreover, these numbers are continuously growing because of the aging of population, the increase in chronic pathologies, the introduction of innovative technologies, and the continuous pressure of governments to contain health care costs [2,5].

Many resources are involved in HC service delivering, including different categories of operators (nurses, physicians, physiotherapists, social assistants and psychologists), support staff and material resources. Managing these resources is a difficult task because the HC provider has a large number of assisted patients, must synchronize the use of the resources at each patient's home, and delivers the service to an often vast territory [3,6,7]. Therefore, robust

resource planning is crucial for operating in HC organizations, to avoid process inefficiencies, treatment delays, and low quality of the provided service.

In addition, random events affect the service delivery and undermine the feasibility of plans, e.g., variations in patients' conditions, resource unavailabilities and longer durations of operators' transfers in the territory. The most critical and frequent events are sudden variations in patients' conditions, which make the service demand highly uncertain and the resource planning more complex. As example, Lanzarone et al. [8] show that the coefficient of variation (i.e., the ratio between the standard deviation and the expected value) of the weekly demand from HC patients ranges from 0.39 for medium-high care intensity patients to 1.29 for low care intensity patients. Finally, the existence of some constraints, such as the continuity of care and the risk of incurring operators' burnout [9], makes HC resource planning different from the planning problems encountered in other production and service systems, also within the health care domain.

In the HC context, continuity of care means that only one operator for each category is assigned to a patient, named the *reference* or *principal* operator, who is not changed for a long period, usually a semester [10], and preferably provides all of the visits required by the patient to the operator's category. Continuity is considered an important quality indicator of the HC service, because the potential loss of information among operators is avoided, and the patient receives care from the same operator rather than having to continuously develop new relationships [11].

Despite the complexity required for planning, in the majority of HC providers human resource planning is not supported by proper

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skills, methodologies and tools that are needed for managing the logistics and the organizational activities of care delivery. Hence, the possibility of implementing adequate planning models and tools for the HC context could improve the robustness of plans with a limited investment of support staff sustained by the HC providers.

The main issues of HC resource planning are the partitioning of a territory into a given number of districts, the human resource dimensioning, the assignment of visits to operators, and the scheduling and routing determinations [7,12]. These issues involve three planning levels:

- *Districing and resource dimensioning*: HC patients are grouped into categories, depending on the type of required service. Typically, the main distinction is between palliative and non palliative patients; in line, each nurse is characterized by a skill, i.e., the set of patient classes he/she can handle. This planning level consists of dividing the territory served by the provider into regions and the patients of each region into groups based on the skill requested to nurses. Each group represents a district, and a certain number of skilled nurses are assigned to the districts to satisfy the demand of their patients.
- *Operator assignment*: once allocated to a district, operators are chosen to provide each visit based on different criteria (e.g., the time of the day, the specific service requested during the visit, etc.). Under continuity of care, patients (and not single visits) are assigned to operators and the assignments are kept along with the time.
- *Scheduling, routing and control*: this is the definition of the weekly plans with the sequence of visits for each operator, taking into account the planned assignments. This level also includes the daily control of the activities to respond to unavailabilities or unexpected variations in service demand.

In this paper, we focus on the operator assignment under continuity of care, taking into account nurses.

### 1.2. The nurse-to-patient assignment problem in home care

Patients need to be assisted by different categories of operators: they are always in the charge of nurses and, depending on the case, they may involve one or more figures such as a physiotherapist, physician, or psychologist. Operators of each category are divided into districts depending on their skills and territory. Assignments are usually planned considering the districts as independent, meaning that each patient is cared for by an operator with a skill that is compatible to his/her pathology and who works in his/her geographical area. However, in the real practice of HC providers, after the assignments are set, an operator may also be assigned to care for patients who do not belong to his/her district, to compensate for infeasibilities of scheduling and routing, or to partially compensate for workload unbalancing among districts [7,12].

A key issue for the assignments is the continuity of care, particularly for nurses. A large number of HC providers pursue the continuity of care. However, some other HC organizations do not adopt reference operators to increase the operational efficiency, and each visit to a patient is provided by any appropriate operator who has sufficient available capacity in the required time period. In this way, at each planning period, no constraint deriving from previous assignments has to be included and no engaged workload of operators related to previous assignments has to be managed.

Nurse-to-patient assignment under continuity of care consists of assigning each newly admitted patient to his/her reference nurse, chosen among the compatible ones (i.e., belonging to new patient's district). The goals pursued by HC providers can be different depending on the provider. A widespread goal is the minimization of the overtime incurred by operators. This minimization is highly important mainly for two reasons: the provider

minimizes the operators' extra times to be paid and, consequently, the sustained variable costs. At the same time, such objective reduces the risk of burnout, which is related to the care volume exceeding the operator's contract capacity. Burnout is a syndrome that can affect a broad range of professions (including physicians, nurses and educators) as a prolonged response to chronic job-related stressors [9]; this phenomenon causes decreased job performance and reduced job commitment, bringing workers to stress-related health problems and low career satisfaction. Another objective usually adopted by providers is to obtain a fair and balanced workload among the operators [13,14].

### 1.3. Contribution

The main difficulty in solving the assignment problem is to face the random events that affect service delivery and give a high variability to the workloads charged to nurses and, consequently, to the overtime costs. This paper addresses the problem of assigning newly admitted patients to their reference nurse, while maintaining continuity of care. Specifically, this paper proposes an analytical policy for solving the nurse-to-patient assignment problem within the HC setting, taking into account the stochasticity of new patient's demand and nurses' workloads.

The problem is formalized as a minimization of nurses' maximum overtimes in a lexicographic way: firstly, we minimize the highest value, then the highest value of the remaining ones, and so forth. Operatively, the goal is analytically pursued by minimizing the maximum increase of a stochastic cost function, which depends on the time spent by nurses when providing visits in surplus to their capacity. This objective also leads to balance the workloads of the nurses within districts when the HC structure is not underutilized. The simplicity of the proposed policy makes easy its implementation in practice.

Because of the assumptions introduced, the policy requires validation in real cases. When applied to a significant real case, the approach presented in this paper guarantees lower overtimes and better workload balancing when compared to a numerical approach based on mathematical programming [14], to a policy which minimizes the expected value of the square overtimes [15], and to the usual practice of HC providers. Specifically, lower overtimes and better balancing are obtained with the policy for the majority of patients, whose demand is characterized by a high variability. Only for patients whose demand is characterized by a low variability (e.g., palliative patients), results among the approaches are similar and show that considering uncertainty in the nurse assignment problem does not add significant benefits and simpler approaches can be successfully applied.

### 1.4. Structure of the paper

A literature analysis of the assignment problem is firstly presented in Section 2. The formal statement of the nurse-to-patient assignment problem under continuity of care and the assumptions introduced are described in Section 3. The proposed policy is then derived starting from the single-patient assignment (Section 4) and extending to the multi-patient assignment (Section 5). Finally, Section 6 reports the application of the proposed approach to a relevant real case, and the final conclusions are reported in Section 7.

## 2. Literature review

The assignment problem is a very general problem with variety of applications, studied since 1952 [16]. In the most general

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