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Innovative Applications of O.R.

Different stakeholders' perspectives for a surgical case assignment problem: Deterministic and robust approaches

Inês Marques^{a,b,*}, M. Eugénia Captivo^{a,c}^a Centro de Matemática, Aplicações Fundamentais e Investigação Operacional, Faculdade de Ciências, Universidade de Lisboa, Lisboa 1749-016, Portugal^b Centre for Management Studies, Instituto Superior Técnico, Universidade de Lisboa, Avenida Rovisco Pais, Lisboa 1049-001, Portugal^c Departamento de Estatística e Investigação Operacional, Faculdade de Ciências, Universidade de Lisboa, 1749-016 Lisboa, Portugal

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ABSTRACT

Adequate access to health care is one of the main strategic axes considered in the Portuguese National Health Plan. This plan seeks to ensure the best performance and adequacy of care maximizing the use of resources, quality, equity and access. This work results from a close collaboration with a large and publicly funded Portuguese hospital. The aim is to propose a systematic approach to help the surgical planner in the scheduling of elective surgeries, in order to optimize the use of the available surgical resources, and improve equity and access to operated and waiting patients. The decisions to be taken by this surgical case assignment problem are twofold: select patients to be scheduled in the planning horizon from a large waiting list for surgery; and assign a day, an operating room, and a time block to the selected patients. Three versions are modeled in (mixed) integer linear programming: from the administration's intention up to the surgeons' current practice, and a halfway reflecting a negotiation with the surgeons. A robust approach is proposed to tackle the uncertain surgeries' duration without the need to assume a given distribution for these random parameters and allowing to control the level of conservatism in the solutions. Practical and real-sized problems from the hospital are solved providing very good optimization gaps within a short time limit, both for the deterministic and robust approaches. The schedules obtained are analyzed regarding quality and robustness, and are also compared with the surgical schedules performed by the hospital.

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1. Introduction

Adequate access to health care is one of the main strategic axes considered in the Portuguese National Health Plan (PNHP) (General Direction of Health, 2013). The strategic orientation of the PNHP seeks to ensure the best performance and adequacy of care while maximizing the use of resources, quality, equity and access. Concerning access to surgical care, the demand for surgical care in Portugal has increased ever since a systematic measurement was introduced (UCGIC, 2014). For example, surgical demand in 2014 was 43.7% higher than in 2006. In the public sector, the waiting list for surgery increased 4.5% in December 2014 when compared to the same period of the previous year, while the median waiting time of users who are waiting for a surgery presented a value of 3.0 months in December 2014. In December 2014, 12.0% of pa-

tients experienced waiting times for surgery in excess of the maximum waiting time clinically recommended according to the patient's priority level (maximum response time). In view of these figures, hospitals are forced to make the most appropriate use of the available resources in order to provide timely care to surgical requests. The System for Management of Patients Waiting for Surgery (SIGIC) defined the goal of 90.4% for the percentage of surgical patients operated within the maximum response time.

This work results from a close collaboration with the administration of a large and publicly funded Portuguese hospital. This hospital operated 16,203 patients in 2014. Official figures indicate that 90.1% of the patients were operated in a timely manner and thus this hospital almost achieved the goal defined by SIGIC. Nevertheless, the hospital presents an average waiting time of 118 days for the operated patients, which is below the target fixed on 120 days. However, problematic figures appear when looking to the waiting list for surgery. At January 2, 2015, the hospital under study had 5689 patients waiting for surgery: the median waiting time is almost three months; the average waiting time is 127 days, above the target of 120 days; 14.0% are already above the maximum response time by 88 days on average. These figures

* Corresponding author at: Departamento de Engenharia e Gestão, Instituto Superior Técnico, Universidade de Lisboa, Avenida Rovisco Pais, 1049-001 Lisboa, Portugal. Tel. +351-21-8419962.

E-mail addresses: ines.marques.p@tecnico.ulisboa.pt (I. Marques), mecaptivo@fc.ul.pt (M.E. Captivo).

Table 1
Hospital figures for operating and waiting patients (2014).

	Number of patients	% of patients above the maximum response time	Average waiting time (days)	Median waiting time (days)
Operated patients (2014)	16,203	9.9%	118	91
Waiting patients (at January 2, 2015)	5689	14.0% (by 88 days on average)	127	87

(summarized in Table 1) show that, in practice, patients waiting for less time are preferably scheduled, violating the equity objective of the PNHP. The aim of this work is to propose a new and systematic approach to help the hospital in the scheduling of elective surgeries, in order to optimize the use of the available surgical resources, improve the overall access (operated and waiting patients) and the equity in the access.

Operating room (OR) planning and scheduling problems are usually organized into three hierarchical decision levels (Guerriero & Guido, 2011): strategic and long term decisions (*case mix problems*); tactical and medium term decisions (*master surgery scheduling problems*); and operational and short term decisions (*elective surgery scheduling problems*). The operational level is often decomposed into two types of decisions (Cardoen, Demeulemeester, & Beliën, 2010a): *advance scheduling*, also referred to as the *surgical case assignment problem* (SCAP), assigns a day in the planning horizon and an OR to patients waiting for a surgery (elective patients); while *allocation scheduling* specifies starting times to each assigned surgery or defines the sequence of the assigned surgeries in each OR and day. In this work, two type of decisions must be taken: to specify, from a long waiting list, the elective patients to be scheduled in a weekly planning horizon, and to assign a day, an OR and a time block to the selected patients. These decisions fall in the SCAP using a block scheduling strategy. The administration of this hospital is only interested in the advance scheduling of elective patients, and it is not so concerned with starting times or in sequencing the selected surgeries.

This paper provides insights on the actual way of scheduling surgeries in the hospital, and proposes new strategies to schedule elective patients satisfying the interests of the administration and the government guidelines, but still acceptable for the surgeons that have a strong political force in the hospital. Three SCAP versions are thus proposed representing conflicting stakeholder viewpoints (and objectives): the administration's version privileges equity and timely surgical access; the surgeons' version approximates the hospital's current practice; the mixed version models an intermediate strategy. These versions are firstly tested using a deterministic approach which shows to be overbooked in a real case scenario. For all models a robust approach is then formulated considering uncertainty in the surgeries' duration. This approach allows to consider a degree of conservatism for the constraints subject to uncertainty. This paper combines an important real world problem with detailed explanation and results of mathematical and robust optimization models. The models are tested with real world and high dimension data sets.

The scientific contributions of this paper are as follows: to consider uncertainty in the surgery durations through a robust optimization approach and provide insights about the impact on the surgical suite's performance; to include surgeons' operating time limit in the SCAP; to assure non-overlapping of surgeons among different ORs (feasibility for the allocation scheduling phase); to consider different strategies for management the patients in the waiting list for surgery. The contributions of this work to the hospital include: a systematic approach, for different surgical suite

stakeholders, to select the patients to be scheduled in the planning week as well as assigning a day, a time block and an OR to the selected patients; a systematic approach to avoid the manually procedures currently in use at the hospital as well as to try to reduce the adverse influence exerted by the surgeons in the management of the patients in the waiting list and in the scheduling process; the possibility for the decision maker to reflect the attitude towards uncertainty by defining a degree of conservatism (budget of uncertainty) for the surgical plans to be obtained by the robust approach, with impact on the smooth running of the surgical suite and on the productivity level of the surgical suite. The proposed models are successfully applied to solve real-life instances provided by a major hospital in the region of Lisbon.

The remainder of this paper is organized as follows. Section 2 contains a focused literature review on related problems. Section 3 describes the SCAP and provides some insights on the hospital under study. Section 4 presents the deterministic (mixed) integer linear programming models while Section 5 proposes the robust approach. Section 6 applies the models to the empirical data from the hospital and discusses the results obtained. Conclusions of this research are provided in Section 7.

2. Literature review and problem's classification

Cardoen et al. (2010a), Guerriero and Guido (2011), Van Riet and Demeulemeester (2015) and Samudra et al. (2016) present the most current literature reviews on the application of operations research to OR planning and scheduling, and Cardoen, Demeulemeester, and Beliën (2010b) propose a classification scheme of the research in this domain. In order to clarify the scope of this particular problem, we classify this work according to the descriptive fields proposed in these papers. The SCAP is an advance scheduling problem that fits in an operational decision level. Concerning patient characteristics, only elective (inpatient and outpatient) cases are considered (el). The problem incorporates a single criterion in each version proposed (single), considering two main performance criteria relating to patient waiting time and throughput (wait and through). The decisions apply to the patient level since they are made for individual patients (pat); for each patient selected to be scheduled, decisions related to the assignment of a date, a time block and an OR have to be made (date, room, and other) using a block scheduling strategy. The surgical suite is studied isolated from other upstream or downstream facilities such as hospital wards, intensive care unit or post anesthesia care unit (iso). The three versions proposed for this SCAP are formulated as (mixed) integer linear programming models and solved exactly using a commercial general solver. Resource constraints considered include regular operating room time and surgeons' operating time limits. Due date constraints are also included. Although deterministic models are proposed, uncertainty is also incorporated (stoch) regarding the duration of the surgeries in the waiting list (dur) through a robust optimization approach. The models are tested using hospital's real data, however the procedures proposed in this paper were not implemented in practice up to the present

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