



Scheduling elective surgeries in a Portuguese hospital using a genetic heuristic



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ABSTRACT

The Portuguese National Health Plan outlines two main guidelines for hospital units: improve the efficient use of the available resources and reduce the waiting list for surgery. The aim of this work is to provide a contribution in the field of operations research to achieve these guidelines. The operating theater is a hospital unit that represents a great proportion of the hospital budget. Furthermore, it is a central service with connections and implications in the service of many other hospital units. Therefore, this work is dedicated to a case study of an elective surgery scheduling problem arising in a Portuguese public hospital. The problem consists of assigning an intervention date, an operating room and a starting time for elective surgeries that remain in the hospital waiting list, thus combining simultaneously advance and allocation scheduling. Two conflicting optimization criteria are independently considered: maximize the surgical suite occupation and maximize the number of surgeries scheduled. Two versions of a single objective genetic heuristic are developed and applied to real data from the studied hospital. The results show that this approach improves the quality of the hospital surgical plans in light of the objectives considered, requiring much fewer resources to construct the surgical plans. Real instances with 508–2306 elective surgeries are successfully solved in less than 240 s. These are better results than authors' previous approaches to the same problem.

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1. Introduction

The health care sector has undergone major changes over the last decade. The increase in life expectancy coupled with a great technological development has boosted the demand for health care (e.g. on external consultations, treatments and surgery applications). This increased demand forces an effective provision of health services. Nevertheless, similar to other economic sectors, the health sector has been suffering from successively more restrictive budgets, forcing a resource rationalization practice among health care providers and also a more efficient usage of these resources. Thus, public hospitals have been enduring increasing difficulties in fulfilling their mission and contractual responsibilities with the successive budget cuts that have been occurring in Portugal.

The operating theater is a hospital unit with extremely high costs (mainly staff and equipment costs) representing a great proportion of the hospital's budget [1,2]. In addition, the surgical suite is a central service with connections and direct implications in many other hospital units, such as wards and recovery units. These factors require the development of operating room planning practices that enable an efficient use of the operating theater. Moreover, improving the efficient use of a hospital's available resources as well as reducing the waiting list for surgery are two main guidelines which are outlined in the Portuguese National Health Plan [3]. Waiting lists for surgery result from a mismatch between the demand for surgery and the health system supply capacity. The latter is defined by the number of installed and available surgical suites and by the efficiency of the organization providing health care. Therefore, optimizing the operating room's installed capacity, as well as the human and technological resources available, also reflects on the balance of the waiting list for surgery.

This work presents a case study of an elective surgery scheduling problem arising in a Portuguese hospital. The aim is to contribute to increase the efficiency of the hospital surgical supply's installed capacity and to reduce the hospital's waiting list for

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surgery. At the beginning of this study, the surgical suite of this hospital had a regular time occupancy rate of about 42% with a waiting list reduction rate of nearly 5.5%. These indicators reveal a clearly inefficient use of the operating theater representing a significant opportunity cost, both social and economic.

The elective surgery planning problem tackled in this paper consists of scheduling elective surgeries for a day, an operating room and a starting time, within a weekly planning horizon. This problem arises at an operational level of decisions for operating room planning, combining advance and allocation scheduling within the same problem. Marques [4] proved that this problem is NP-hard. Few papers in the literature consider a combination of these two components within a unique problem and all of these papers deal with short planning horizons, e.g. a day or a week (see e.g. Roland et al. [1] and Riise and Burke [5]). Due to the high complexity of these two components, the problem is very difficult to solve for real size instances, as pointed out in Riise and Burke [5]. The computational difficulty inherent to the surgeries' scheduling problem has encouraged the development of heuristic approaches (see e.g. Hans et al. [6], Fei et al. [2], Roland et al. [1], Liu et al. [7], Riise and Burke [5] and Marques et al. [8]). Notwithstanding, in the literature there are some integer programming approaches to the problem (see e.g. Guinet and Chaabane [9], Velásquez and Melo [10], Cardoen et al. [11,12] and Marques et al. [13]). The specificities of the different cases under study as well as the different national realities are the most relevant factors contributing to the diversity of the work in this area. This makes difficult the comparisons between the various approaches and also the application of existing approaches in distinct realities. Recently, Cardoen et al. [14] and Guerriero and Guido [15] presented literature reviews on the contribution of operations research to operating room planning and scheduling. Cardoen et al. [16] proposed a classification scheme of the research in this domain.

In previous approaches to the same problem, the authors presented an integer linear programming model [13], and specially designed constructive and improvement heuristics [8]. The model was solved with CPLEX 11.0 and we obtained good quality surgical plans for the smaller real instances. However, this exact methodology has consumed much computational time and was unable to build a single feasible solution for high dimension instances. The heuristics presented in [8] were adapted to be embedded in the genetic algorithm (GA) that is now presented. As we will see in Section 4, the results obtained with this approach are very competitive (in terms of solutions quality and computational time) even in the larger real instances.

Roland et al. [1] also present a GA to the elective case scheduling problem. However, the problem studied is different in its specifications and in the objective considered. In addition, the characteristics of the designed GA are rather different and the codification structure does not guarantee feasible solutions. When considering small instances (only one operating day and 19 elective surgeries), the GA computing times never exceeded 322 s, but on a real life weekly instance (composed of 80 surgeries) the computational time increased significantly (more than 1.6 h if considering a population containing 20 individuals and 5000 generations, as emphasized by the authors, or a population with 100 individuals and 500 generations).

This paper proceeds in Section 2 with a description of the elective case scheduling problem for the hospital under study and some hospital specifications. Section 3 presents the GA developed for this problem and Section 4 reports on the results of the computational experiments performed using real data obtained from the hospital. Finally, conclusions and future research directions are outlined in Section 5.

2. Problem description and case study

The present case study focuses on a general, central and university hospital located in Lisbon, incorporated within the Portuguese National Health Service (public hospital). The hospital performs nearly 5000 surgeries per year and the waiting list for surgery had about 2200 surgeries at the time of the beginning of this study. It has no emergency service so the problem is exclusively dedicated to elective surgeries. Elective surgeries can be either *conventional* (inpatient surgeries) or *ambulatory* (outpatient surgeries). For an ambulatory surgery both the hospital admission and the discharge of the patient occur on the same day and therefore the patient is not in hospital overnight. According to Portuguese legislation [17], elective surgeries are classified in four levels of priority defining the due date in which they must be performed: *deferred urgency* surgeries must be completed in three days; *high priority* surgeries within 15 days; *priority* surgeries must be completed within two months; and *normal* surgeries in one year.

The hospital has one central surgical suite with six identical operating rooms. One of these operating rooms is exclusively devoted to ambulatory surgeries while the remaining operating rooms are reserved for conventional surgeries. The surgical suite is open in regular time between 8.30 am and 8 pm, from Monday to Friday. The surgery schedule should respect this regular time and no surgery should be planned using extra time. Five surgical specialties compete for the operating rooms' time. The practice of this hospital is to assign rooms to surgical specialties throughout the day. Two main reasons are pointed out for this: the fragile nature of the mobile specialized equipment usually specific to each specialty; and the required downtime of about an hour to exchange a surgical specialty in a room during the day which would represent a major inefficiency in the surgical service. Nevertheless, scheduling is performed in open scheduling strategy and there is not a defined pre-allocation of operating room time to specialties in a master surgery schedule. Between two surgeries performed in the same room, cleaning and disinfecting protocols, performed by auxiliary staff and taking about 30 m, must take place. Each operating room is staffed with fixed and permanent nursing teams throughout the surgical suite's regular time. Each patient is assigned to a surgeon at waiting list booking time and, therefore, when planning, patients and surgeons are already assigned, which thus constitutes an input for the planning problem. This is a cultural practice commonly used in Portugal. Surgeons can operate at any time of the day within the operating theater's regular time and also in any operating room provided that the surgical specialties match. Practical experience in this hospital shows that other resources do not limit the activity of the surgical suite, namely beds (in the recovery units and wards), staff (nurses and auxiliary staff), equipment and materials.

In the hospital under study, surgical planning is weekly and is finalized on Friday for the following week. It is a manual procedure that requires the contribution of several human resources. Each surgical ward collects the proposed surgeries for the following week and sends the corresponding planning maps to the head nurse of the surgical suite. The head nurse confers and verifies the possibility of combining the planning maps of all surgical wards and finalizes the surgical plan. This task requires too much staff time and the result achieved is far from contributing to the efficient use of the operating theater. It is still possible to make online changes to the surgical plan during the course of the week until noon of the day before the surgery. This turns to a re-scheduling problem that does not fall in the scope of this work.

As a result, scheduling is performed in open strategy but it must assign up to one surgical specialty to each room and day.

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