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Scheduling of elective patients considering upstream and downstream units and emergency demand using robust optimization

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ABSTRACT

Surgery is a vital process in Healthcare Centers (HCs). The importance of a surgery department is not only due to its direct impact on the health but also due to its high impact on the income and costs of HCs. Considering the upward trend of population aging in societies, increasing demand for surgery, and limited resources of HCs, providing an efficient schedule for Operating Room (OR) is essential. In this paper, a multi-objective mathematical model is proposed considering upstream and downstream units. The proposed model consists of three objectives in which the first one minimizes the number of deferred patients to the next planning horizon. The second one minimizes the waiting cost of scheduled patients and the cost of extra beds acquired in the ward, and the last one minimizes the idleness and overtime of ORs, lateness in operating children and earliness in operating patients far from HC. Then, the robust counterpart is proposed to evaluate some uncertain parameters, such as surgery t, Length of Stay (LoS) in upstream and downstream units and emergency demand. Since this problem is NP-hard, a new Mixed Integer Programming based Local Search Neighborhood (MIP-based LNS) algorithm is applied. Afterward, the effect of increasing number of slots on the CPU time is studied using a sensitivity analysis. Finally, a real case study entitled 'Alborz Hospital' is investigated. The obtained results show that applying the proposed model and increasing two beds in the Intensive Care Unit (ICU) could potentially decrease the number of deferred patients by 58.33% as compared to the traditional schedule (i.e., a schedule based on trial and error). Furthermore, the average idleness of ORs could be reduced by 36.58% as compared to the traditional schedule.

1. Introduction

Surgery is a vital process in HCs. The importance of surgery department is not only due to its direct impact on the health but also due to its high impact on the income and costs of HCs (Xiang, Yin, & Lim, 2015). As stated by Van Essen, Hans, Hurink, and Oversberg (2012), more than 60% of patients visiting HCs require being serviced by ORs. The previous studies stated that more than 65% of HCs' revenue depends on this department (Cima et al., 2011; Jackson, 2002); likewise, this department accounts for a large portion of HCs' expenditure (Denton, Miller, Balasubramanian, & Huschka 2010).

According to the Organization for Economic Co-operation and Development[1] (OECD), the share of the healthcare industry has risen in the GDP of developed countries over past years. To be more precise, Fig. 1 illustrates the ascending trend of the share of this industry in the GDP of seven developed countries. Zhao and Li (2014) have predicted this upward trend will continue over the following years. Taking into account this ascending trend, it is clear that providing an efficient plan for different sections of this industry (especially surgery department) is worthwhile.

The problem of OR scheduling includes three decision-making levels, such as the strategic level (long-term), tactical level (mid-term), and operational level (short-term). These decision-making levels have been explained comprehensively in the literature. For the sake of brevity, we do not discuss those and refer interested readers to the previous studies (e.g., Hulshof, Kortbeek, Boucherie, Hans, & Bakker, 2012). In this paper, we aim to study the problem of OR scheduling (with respect to the operational decision-making level) for a real case study entitled 'Alborz Hospital' in Iran. This hospital uses the block scheduling policy. In this policy, all available time of each OR throughout a planning horizon is divided into a number of blocks; then, these blocks are assigned to specialties. Note that a block here refers to a fixed amount of time at a given day assigned to a specialty, e.g., if ORs are open for eight hours throughout a day and each day includes two blocks. Thus, the length of each block is equal to four hours. The length of a block has to be greater than the time unit for which an OR can be

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[1] https://data.oecd.org/health.htm.

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0360-8352/

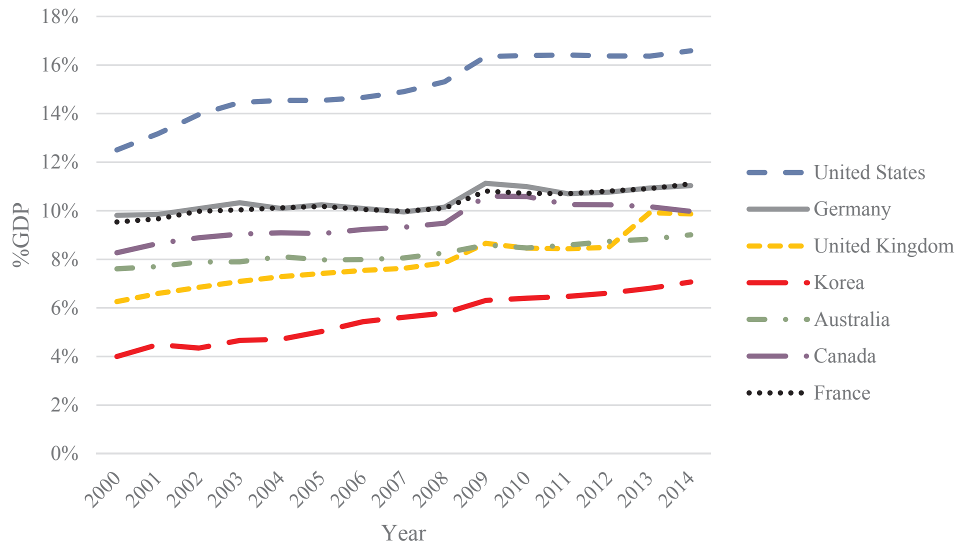

Fig. 1. The GDP share of health expenditure for seven developed countries.

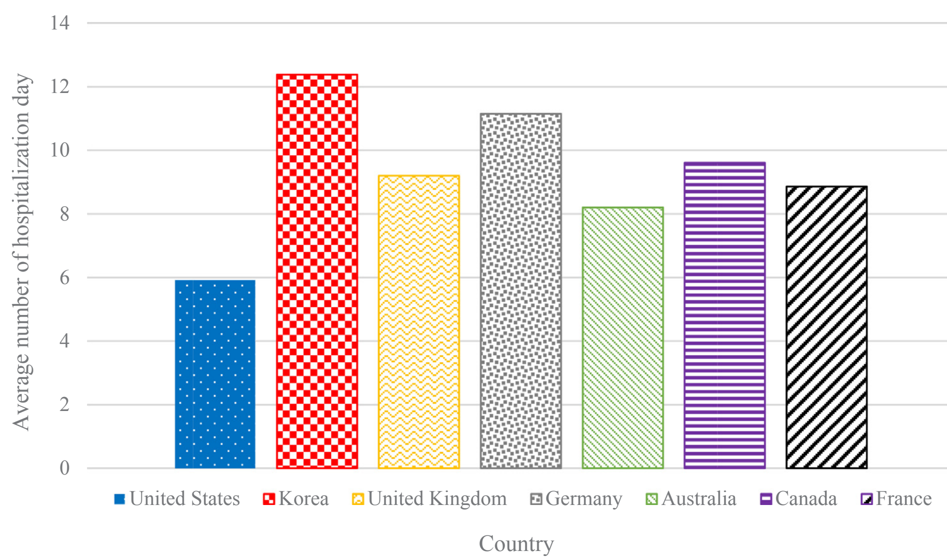

Fig. 2. Average number of hospitalization day in upstream and downstream units for inpatients (from 2000 to 2014).

reserved for a specialty in a day (Ceschia & Schaerf, 2016). To understand the importance of this problem, we can only pay attention to review papers published particularly for this problem. For instance, Gartner and Padman (2017) provided a comprehensive review of literature specifically for the problem of patient scheduling, i.e., operational decision-making level. First, they defined several taxonomies to clarify this problem. Then, they compared about 50 papers published recently regarding the resources they considered, their modeling and solution approaches, and the uncertainties they considered.

In this paper, a mathematical model is proposed. The proposed model studies both of the advanced and allocation scheduling, simultaneously. Unlike most of the previous investigations (e.g., Landa, Aringhieri, Soriano, Tànfani, & Testi, 2016; Min & Yih, 2010), this model determines surgeries' start time rather than surgeries' sequence in the allocation scheduling. It is almost impossible to precisely determine surgeries' start time due to the uncertainty of the surgeries duration; however, providing an efficient prediction for surgeries' start time not only determines the sequence of surgeries but also could decrease the waiting time of outpatients. Furthermore, it would regularize the transportation process of inpatients to ORs from upstream units.

In contrast to many of the previous investigations (e.g., Durán, Rey, & Wolff, 2016, Fei, Chu, & Meskens, 2009; Hashemi Doulabi, Rousseau, & Pesant, 2016; Turhan & Bilgen, 2017), the proposed model consists of three objectives that investigates the interests of all parties involved (including management, staff members, and patients). The first objective minimizes the number of deferred patients to the next planning horizon. The second one minimizes the waiting cost of scheduled patients and the cost of extra beds acquired in the ward. Eventually, the last objective minimizes the idleness and overtime of ORs, lateness in operating children (under five years old) and earliness in operating patients far from HC (with distance more than 100 km). The mentioned objectives are explained further in Section 2.

In the real world, patients may occupy resources of the upstream and downstream units. The upstream unit refers to resources that patients might occupy before being operated in ORs, such as ward. Moreover, the downstream unit denotes resources that patients would use after being operated in ORs, such as Post Anesthesia Care Unit (PACU), ICU, and ward. According to OECD, patients had been hospitalized in these units a considerable time on average. For more clarification, Fig. 2 illustrates the average LoS of patients in these units for seven developed countries from 2000 to 2014. Given that these resources are limited, the generation of impractical schedule would be