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Flexible bed allocation and performance in the intensive care unit

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Abstract

The beds of an intensive care unit (ICU) are a scarce resource. Stochastic patient demands for these beds and stochastic service times in their utilization make managing that resource a complex problem lacking an easy solution. The current practice in one Hong Kong hospital is for the ICU administrator to exploit the fact that there are some patients whose admission to the unit can be postponed. These are patients scheduled for an elective surgery that can be cancelled. One way to minimize the number of cancelled surgeries is to reserve some of the unit's beds for the exclusive use of the elective-surgery patients. We evaluate various bed-reservation schemes via a simulation model that is based on this ICU's historical data, and demonstrate the tradeoffs that each requires among various relevant system-performance measures. We further show how this information can be summarized in a classic efficient frontier. This frontier provides a useful medium through which the ICU administrator can communicate the rationale behind the chosen bed-allocation system to the surgeons and the ICU physicians, in an attempt to resolve the potential conflicts between them.

Keywords: Operations strategy; Computer simulations; Facility layout; Scheduling

1. Introduction

Operations managers make repetitive decisions subject to capacity constraints that are not readily relaxed. Thus, utilizing the extant capacity optimally is an operational imperative. Nowhere is this imperative better exemplified than in a hospital's intensive care unit (ICU) where the lives of the hospital's most critically ill patients are at stake.

We focus on the ICU in a not atypical Hong Kong public hospital whose administrator, acting as a triage officer, determines admissions priorities so as to enhance the number of surviving patients. Expanding capacity, the number of beds in the unit, is not an option, as ICU care is an unusually expensive therapy. Reducing capacity is not an option either, as

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this would risk deserving patients being denied admission to the unit or released prematurely. Thus, the ICU administrator's problem is how to better utilize the existing capacity so as to relieve what upon occasion is a bed shortage and better serve the patients without incurring additional cost. Patients, however, are only one of several constituencies to which the administrator is accountable, and the preferences of those constituencies in the prioritization process often conflict. One especially prominent conflict in our sample hospital is between the operating surgeons and the ICU physicians. This is a potential conflict in any hospital that has an ICU.

The basis for the conflict is that the surgeons must schedule elective surgeries and the operating theater well in advance, and assume there will be an empty bed in the ICU, whereas the ICU physicians set their admissions priorities based upon *all* the applicants' needs. In this setting, the administrator often must deny admission to an elective-surgery (ES) patient, ex ante, thereby forcing the surgeon to cancel and reschedule the surgery, which can have several negative consequences. First, this can wreak havoc with both the surgeons' schedules and those of the supporting staff, and waste the time of some highly skilled people. Second, the cancellations require changes in the operating theater's schedule. Last, they can cause great psychological stress on patients, few of whom view their own surgeries as being ''minor''.

To resolve the conflict, the surgeons have proposed reserving some ICU beds exclusively for ES patients. Though blatantly self-serving, this is not necessarily a bad idea. Indeed, some form of reservation strategy might be a very good idea that offers the administrator a way out of a very ticklish managerial situation. But lives rather than personal sensibilities are involved in the bed-reallocation process. Therefore, in lieu of tinkering with the actual bed arrangements, we use a simulation model to explore the implications of a bed-reservation strategy. The model generates the data that are relevant to evaluating the effects of two specific forms of reservation strategy: a classic dependency unit (DICU) attached to the surgery department, and a novel flexible bed allocation (FBA) scheme that reserves beds for ES patients. The strategies are evaluated on various performance criteria both for ICU patients as a group and for patients delineated by each of four distinct sources from which the unit receives its referrals. The model's parameters are determined empirically from historical data.

An earlier version of the model, which was expressly built to analyse this ICU's operations, is described in detail in Kim et al. (1999), where we confirm its validity for the unit. Our simulations alone led us to infer that ''insofar as there are serious issues relating to the managerial aspects of this particular ICU, these emanate solely from elective surgery'', and that ''the current ICU capacity of 14 beds is sufficient to handle patients at the current arrival rates'' (Kim et al., 1999, p. 45). These inferences and the expressed concerns of the protagonists have prompted the present extension of that earlier work. In this extension, we first refine the basic model by introducing and verifying a new assumption as to the distribution of service times for the ES patients. Second, we explore the implications of various FBA strategies in a multiple-objective setting. Third, we introduce the administrator to the concept of an efficient frontier both as an immediate decision aid and as a visual means to help explain to the physicians and surgeons the preferred choice among those strategies and the status quo.

There is a considerable literature on hospital capacity and bed allocation. Some of this literature relies on queuing theory (Bailey, 1954; Cooper and Corcoran, 1974). Elsewhere, simulation is preferred (Goldman et al., 1968; Blewett et al., 1972; Kuzdrall et al., 1974; Kwak et al., 1975; Kao and Tung, 1981; Williams, 1983; Dumas, 1984; Dumas, 1985; Hashimoto et al., 1987; Rakich et al., 1991; Parry and Petroda, 1992; Ridge et al., 1998). Simulation has also been widely used in attempts to improve other aspects of hospital performance. Some recent studies in point are McAleer et al. (1995), Wharton (1996), Klassen and Rohleder (1996) and Gonzalez et al. (1997).Butler et al. (1996) contains a survey of the literature on operations management in the strategic planning process in hospitals. The present paper adds to that specific literature directed at bed allocation and scheduling in the ICU.

Previous research specific to ICUs focused primarily on the clinical aspects of their operations (Teres et al., 1991; Zussman, 1992; Oh et al., 1993; Bein et al., 1995), or used the data from ICU log