LINKING IMPROVED SURGERY TACTICAL PLANS TO ELECTIVE AND EMERGENCY PATIENT SERVICE: ANALYTICAL METHODS TO COMPUTE EXACT DISTRIBUTIONS FOR WAITING TIME AND RESOURCES UTILIZATION

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1. Introduction
Tactical plans in the literature aim at optimizing the hospital efficiency by allocating at best the planned operations over the planning horizon to get a good spread of resources utilization. But hospitals claim that patient satisfaction also is important. The objective of this paper is therefore to assess the impact of any tactical plan on both patient service and resources utilization at the operational level. To this purpose, we develop analytical methods that derive from any stream of planned patients the exact probability distributions for the waiting time and for the resources utilization. We explore two strategies to improve tactical plans: slack planning and smooth allocation. Our framework of analysis relies on the functioning of the Thorax Center Rotterdam described in [1]. Patients are grouped in several categories of pathology. Operation durations can be assumed deterministic, whereas lengths of stay in both intensive and medium care units are probabilistic. The required nursing hours (NH) for each patient category only depend on the number of days since surgery. We thus consider 4 critical resources: operating theatre hours (OT), intensive care beds (IC), intensive care nursing hours (NH) and medium care beds (MC).

Section 2 describes the model to get the tactical plan and presents the two strategies of improvement (slack planning and smooth allocation). Section 3 provides the basic principles of the analytical methods. In Section 4 we give the results of a case study based on data from the Thorax Center. Results show that both slack planning and smooth allocation reduce the waiting time and smoother tactical plans lead to a better spread of resources consumption at the operational level.

2. Model description for the tactical plan and improvement strategies
The optimization program to get the tactical plan consists in assigning a given group of elective patients to operating slots, so as to minimize over the horizon the capacity excess and the deviations between the expected resources consumption and their target levels of utilization. In the consumption of each capacitated resource, we consider both the planned patients and the expected emergency patients. However such a tactical plan ignores the consequences on the patient service at the operational level: due to the randomness of arrivals and lengths of stay, the allocation of patients resulting from the optimization may lead to long waiting or lumpy resources use. In the next section, we show how to derive from any stream of planned patients the exact distributions for the waiting time and the resources utilization at the operational level where arrivals of emergency and elective patients are confronted to planned slots of operations.

Besides, we examine two strategies to improve tactical plans: slack planning and smooth allocation. The slack planning strategy consists in increasing the number of operating slots for allowing faster admission of queued patients (see [2]). Three options are considered: no slack planning, medium and large slack planning. The smooth allocation strategy forces the number of
operations to be equally allocated over the horizon. In this way we reduce the variance in the time between patient arrivals and the first possible operation slot; a smoother capacity resource use is also expected. Using the smooth allocation or not in combination with the 3 options for slack planning results in a set of 6 mixed integer programs leading to 6 different tactical plans, for which we will determine the operational performance in Section 4.

3. Distributions for the waiting time and for the resources utilization

Patient arrivals are assumed to follow a Poisson distribution, with a parameter depending on the day of the week for emergencies and a fixed weekday parameter for electives. As we assume that unused operation slots cannot be used by patients of other categories, the waiting time calculation can be done for each category separately. For electives, we consider the waiting time of patients to be composed of two parts: the average waiting time until the first possible operation day ($WT^{bo}$) and the average waiting time of patients who can not be operated on that first day ($WT^{no}$). Thus, $WT^{bo}$ does not depend on the actual queue length, but only on the distribution of the number of days between 2 operation days. The second element, $WT^{no}$, considers the probabilities there are more queued patients than planned patients so the surplus has to wait until the next operation day.

From the waiting time calculations, we obtained the steady state probabilities for the number of waiting and operated patients of each category on each day that we use to compute the exact distribution of the consumption of each of the 4 resources.

4. Case study

We assess the performance at the operational level of the 6 tactical plans described in Section 2 by using the analytical methods we developed to compute the exact distributions for the waiting time and resources utilization. Figure 1 summarizes the approach.

![Figure 1: Assessing the impact of tactical plans on patients service and resources consumption.](image)

The results show that increasing the number of planned patients (slack planning) reduces strongly the waiting time, but slightly increases the resource overutilization. Smooth allocation of patients also reduces the waiting time since operations are planned more frequently and more regularly. Smoother plans not only reduce the overutilization (defined as the deviation between exact resources utilization and their target values) but also the capacity excess since resources usages are better spread over the horizon.

References
