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Designing cyclic appointment schedules for outpatient clinics with scheduled and unscheduled patient arrivals

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ABSTRACT

We present a methodology to design appointment systems for outpatient clinics and diagnostic facilities that offer both walk-in and scheduled service. The developed blueprint for the appointment schedule prescribes the number of appointments to plan per day and the moment on the day to schedule the appointments. The method consists of two models; one for the day process that governs scheduled and unscheduled arrivals on the day and one for the access process of scheduled arrivals. Appointment schedules that balance the waiting time at the facility for unscheduled patients and the access time for scheduled patients are calculated iteratively using the outcomes of the two models. Two methods to calculate appointment schedules, complete enumeration and a heuristic procedure, are compared in various numerical experiments. Furthermore, an appointment schedule for the CT-scan facility at the Academic Medical Center Amsterdam, The Netherlands, is developed to demonstrate the practical merits of the methodology. The method is of general nature and can therefore also be applied to scheduling problems in other sectors than health care.

1. Introduction

Developing appointment schedules for service facilities that process both scheduled and unscheduled arrivals is challenging, as it requires planning and scheduling on different time scales. A well-designed appointment system comprises an efficient day appointment schedule and provides timely access. This article is motivated by challenges faced by hospital outpatient clinics that serve patients on a walk-in basis. Most of these clinics also have a limited number of appointment slots. There are various organizational (e.g., fixed slots for patients in a care pathway, patients with long travel time to the hospital, children) and medical (e.g., local anesthesia or contrast fluid required) reasons to give a patient an appointment. In this article, we introduce a method to design appointment schedules for such facilities. To illustrate the method, we also design an appointment schedule for the Computed Tomography (CT) scan facility at the radiology department of the Academic Medical Center (AMC) in Amsterdam, a Dutch teaching hospital. At the CT-scan facility, where approximately 11,000

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diagnostic examinations per year are performed, currently an appointment system is employed. Management considers the implementation of a mixed walk-in and appointment system.

Advantages of a walk-in system are a higher level of accessibility and more freedom for patients to choose the date and time of their hospital visit. Disadvantages are a possible highly variable demand, and as a consequence low utilization and high waiting time (the time between the physical arrival at the facility and the start of consultation and/or treatment). The advantage of an appointment system is that workload can be dispersed, while it has the disadvantage of a potentially long access time (the time between the day of the appointment request and the appointment date). Since prolonged access times result in a delay of treatment, deterioration of health condition is a serious risk [1]. Allowing patients to walk in effectively reduces access times to zero, and thus increases quality of care. In addition, health care facilities typically aim to guarantee a certain service level with respect to the access time for patients with an appointment.

The challenge in a mixed system is thus to balance access time (for appointment patients) and waiting time (on the day of service). To achieve this, we develop a methodology that schedules appointments when the expected walk-in demand is low. To smoothen the system, in periods of high demand part of the walk-in patients is offered an appointment at a later moment. Walk-in demand [2,3] and demand for appointments requests [4] are often cyclic; therefore, we develop a cyclic appointment schedule. Appointment scheduling has received considerable attention in the literature (see Section 2), in contrary to models that relate access and waiting time [5].

Our contribution is a methodology that incorporates unscheduled and scheduled arrivals and maximizes the number of unscheduled patients served on the day of arrival, while satisfying a pre-specified access time norm for scheduled patients. We model the unscheduled arrivals with a stochastic non-stationary arrival process and incorporate balking behavior. The scheduled patients have priority, may not show up, and appointment requests are assumed to arrive according to a cyclic pattern. To account for the cyclic arrivals, the appointment schemes we develop are also cyclic, where the cycle is a repeating sequence of days. The cycle length can, for instance, be a week or a month. The Cyclic Appointment Schedule (CAS) specifies a capacity cycle (the maximum number of patients that can be scheduled on each day of the cycle) and a day schedule (the maximum number of patients to be scheduled per time slot on each day). Access time and waiting time are measured on different time scales, since access time is counted between days and waiting time during a day.

To facilitate the two time scales, our approach consists of decomposing the appointment planning process and the service process during the day. For both processes we propose an analytical evaluation model. The first model determines the access time for scheduled patients for any given capacity cycle. The second model determines the expected number of unscheduled patients that cannot be seen on the day of arrival. Two methods to calculate appointment schedules, complete enumeration and a heuristic procedure, are compared in various numerical experiments. Furthermore, an appointment schedule for the CT-scan facility at the AMC is developed to demonstrate the practical merits of the methodology.

This article is organized as follows. Section 2 provides a literature review. In Section 3, we give an introduction to the methodology and provide a formal problem description. Sections 4–6 present the access and day process evaluation models and the iterative procedure. Section 7 describes the numerical experiments, followed by the discussion and conclusions in Section 8.

2. Literature

In many service facilities customers are requested to make an appointment. There is a substantial body of literature focusing on the design of appointment systems. Health care is the most prevalent application area and hence most prevalent in the literature (see the surveys [6,5,7]). Appointment systems can be regarded as a combination of two distinct queuing systems. The first queuing system concerns customers making an appointment and waiting until the day the appointment takes place. The second queuing system concerns the process of a service session during a particular day. We denote these two queuing processes as the 'access process' and the 'day process'. The remainder of this section provides an overview of the literature relevant for the present work and is structured as follows: (1) appointment scheduling, (2) access time models, and (3) integrating the access process and the day process.

2.1. Appointment scheduling

Appointment scheduling concerns designing blueprints for day-appointment schedules with typical objectives such as minimizing customer waiting time, and maximizing resource utilization or minimizing resource idle time. A large part of the literature focuses on scheduling a given number of appointments on a particular day (e.g., [8–12]). The extent to which various aspects that impact the performance of an appointment schedule are incorporated varies, such as customer punctuality (e.g., [13]), customers not showing up ('no-shows') (e.g., [14,8]), lateness of the server at the start of a service session (e.g., [11]), service interruptions (e.g., [13]) and the variance of service duration (e.g., [14]).

Research techniques employed in appointment scheduling can be divided into analytical and simulation-based approaches, of which the latter is most widely applied [6]. In the day process we aim for an analytical approach, namely finite-time Markov chain analysis. Related examples with health care applications are [15,16,8,10,17,12], although these references do not consider unscheduled customers.

Often, a homogeneous customer population is assumed [18]. Some studies however, focus on service systems with various customer types. Differentiation between customer types is identified as a consequence of distinct service requirements