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A reusable simulation model to evaluate the effects of walk-in for diagnostic examinations

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ABSTRACT

Enabling patients to walk in for their diagnostic examination without an appointment has considerable potential in terms of quality of care, patient service, and system efficiency. We present a model to evaluate the effect of implementing a combined walk-in and appointment system, offering appointments to all patients preferring or strictly requiring these, while enabling all other patients to walk in. In a combined system, appointments can be scheduled in periods with low walk-in demand to counterbalance the possible high variability in walk-in arrival rates. We develop a discrete event simulation model, combined with an intelligent algorithmic methodology for appointment schedule optimization, for evaluating the implementation of a combined walk-in and appointment system for diagnostic examinations. Our simulation model is reusable: its component-based structure and generic underlying logic enable it to automatically represent any type of diagnostic facility, for which it can then evaluate the effect of implementing a combined walk-in and appointment system. Applying this approach, we quantitatively investigate the impact of implementing a combined walk-in and appointment system for CT-scans, performing a case study at the Academic Medical Center (AMC) Amsterdam. Inspired by the results, the AMC CT-facility has implemented a combined walk-in and appointment system, thereby shortening patients' diagnostic trajectories, and decreasing the number of required hospital visits for many patients.

1. Introduction

Diagnostic examinations play an important role in determining a patient's condition and deciding on the course of treatment. Enabling patients to walk in for their diagnostic examination without an appointment has considerable potential in terms of quality of care, patient service, and system efficiency. Access time, defined as the number of days between the request and the actual examination, may have a negative impact on the patient's condition and health outcomes when prolonged [1]. Walk-in eliminates access times completely. Consequently, the diagnostic trajectory is shortened which in turn shortens the period the patient and his relatives are in a state of suspense about the patient's condition. Further, walk-in

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provides patients with autonomy to choose their preferred moment for the examination. When walking in right after the consultation in which the necessity of the examination has been revealed, the patient saves one hospital visit. In terms of system efficiency, walk-in eliminates three downsides of an appointment system. First, no-shows are absent in a walk-in system, while these cause server idle time in an appointment system. Second, stochasticity of examination durations forces the inclusion of slack time in an appointment system, to guarantee acceptable patient waiting times (the time between a patient's arrival at the facility and the start of the examination). There is no need for inclusion of slack time in a walk-in system. A walk-in system thus facilitates a potentially higher system utilization. Third, a walk-in system eliminates the administrative work related to scheduling and possibly rescheduling appointments as well as reminding patients of their appointment times.

A disadvantage of a walk-in system is the possible high variability in patient arrivals, which results in a highly variable system utilization and high patient waiting times during busy periods. An appointment system, on the other hand, is ideal for spreading workload over time. Implementing a full walk-in system is not possible for most diagnostic examinations, because appointments are inevitable for certain patients (e.g., patients with high preparation times, examinations requiring the presence of a medical specialist from another department, or patients preferring an appointment over walking in). By employing a combined walk-in and appointment system, a diagnostic facility can have the best of both worlds: appointments can be scheduled in periods with low walk-in demand such that the overall daily arrivals are smoothed [2,3].

While walk-in is common practice for X-ray examinations, other diagnostic examinations, such as computed tomography (CT) and magnetic resonance imaging (MRI) scans, are appointment-based in most hospitals. In this paper, we present a computer simulation model to evaluate the effect of implementing a combined walk-in and appointment system for diagnostic examinations. The model is reusable: its component-based structure and generic underlying logic enable it to automatically represent any type of diagnostic facility (see Section 3.1 for a detailed explanation of reusable simulation modeling). Thus, our simulation model can be used to investigate the consequences of implementing a combined walk-in and appointment system for any type of diagnostic examination. In this paper, we apply it to evaluate the impact of implementing such a system for CT-scans.

This paper is organized as follows. Section 2 discusses relevant literature. Section 3 describes the reusable simulation model. Section 4 introduces our case study and presents the results, followed by a discussion and conclusions in Section 5.

2. Literature

The amount of literature on using computer simulation to study healthcare delivery is substantial [4–6], and also contains studies on CT-scan delivery (e.g., [7,8]). To the best of our knowledge, the impact of a walk-in system has only been quantitatively investigated before for nurse-led NHS walk-in centers, providing community-based ambulatory care [9], and for diagnostic clinics, treating non-emergent cases that would otherwise report to the emergency department [10]. Ashton et al. [9] developed a simulation model to advise a health center in Liverpool, consisting of an NHS walk-in center, a general practitioner's practice, and various primary and community healthcare services, on how to operate their services upon relocation to new premises. Because the various services were to share waiting areas and treatment rooms in the new situation, analyzing the interaction between the services and providing suggestions for limiting the number of patients simultaneously present in the central waiting room were important aspects of the simulation study. Reilly et al. [10] aimed to enhance performance of a diagnostic clinic employing a complete walk-in system, by adjusting physician staffing patterns and introducing so-called *delay scheduling*. In periods of congestion in the clinic, walk-in patients were assigned a *delay time*. Patients could decide to temporarily leave the clinic and return after the delay time (i.e., later on the same day), in which case the delay time was not counted as clinic-accountable waiting time. Upon returning to the clinic, such patients were treated with priority. Reilly et al. [10] employed simulation modeling to evaluate the delay scheduling and staffing changes, and concluded that these resulted in reduction of manpower by 10% while significantly reducing the clinic-accountable waiting time. While both these studies aimed at improving the performance of existing complete walk-in systems, we develop a methodology for evaluating the impact of implementing a combined walk-in and appointment system.

In combined walk-in and appointment systems, the appointment schedule naturally affects system performance. Although a review on outpatient appointment scheduling in 2003 concluded that the presence of walk-in was neglected in most studies [11], several authors have recently studied the question which slots to reserve for appointments and which slots to leave open for walk-in in combined systems. This has been investigated for a single consultation session [12–14] or for a multi-day cycle [3,15]. Aiming to find the optimal moments at which to schedule appointments, authors either assume the number of appointments to schedule to be pre-specified [12,15], or optimize this number simultaneously [3,13,14]. All studies focus on schedule performance from a walk-in patient's and a system perspective by optimizing some combination of patient waiting times, provider idle time, provider overtime, and a revenue for each patient seen. [3] is the only study additionally considering access times for scheduled patients. Because access time is an essential performance indicator in a combined walk-in and appointment system, we combine our simulation study with optimization of the appointment schedule based on the methodology by Kortbeek et al. [3].

While scheduling appointments in periods with low walk-in demand has been demonstrated to effectively counterbalance high variability in patient arrivals [2,3], the concept of call-in has been shown to achieve similar effects [16]. The literature defines *call-in* patients as those who (i) do not require immediate service – as emergency patients do, (ii) have a medical urgency that prohibits them from being scheduled as regular elective patients, and (iii) are available to be served