Aggregate Model-Based Performance Analysis of an Emergency Department

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ABSTRACT

In this paper the authors present an aggregate simulation model for a real-life emergency department, which is based on the concept of effective process times and which uses a token system to model patients claiming multiple resources simultaneously. Although it has been developed for a specific hospital, the model is flexible, and capable to describe different settings. The modeling steps, model specification and model validation are explained in detail. By using a process-based simulation language, the resulting model is transparent, intuitive and easy to use in quantitatively and efficiently evaluating the effect of proposed changes in the operational processes of the emergency department on patient service levels and resource utilizations.

Keywords: Aggregate Modeling, Effective Process Time, Health Care, Simulation, Simultaneous Resource Possession

1. INTRODUCTION

Due to rising costs, the health care sector is forced to work more efficiently and to better utilize their resources. Therefore, LEAN principles have been introduced in health care. Also at the Emergency Department (ED) of the Catharina Hospital in Eindhoven (CZE) the LEAN concept has been introduced to improve operational processes (Wolleswinkel, 2012). The aim is to streamline operational processes, i.e., to eliminate unnecessary operations to achieve better performance using existing resources.

To support decision making in process improvement programs, simulation has proved to be an effective tool (Brailsford, 2007; Duguay & Chetouane, 2007; Sinreich & Marmor, 2005). A literature review on the use of simula-
tion and modeling in the health care domain can be found in (Jun, Jacobson, & Swisher, 1999; Brailsford, Harper, Patel, & Pitt, 2009; Brailsford & Vissers, 2011), showing evidence that simulation and modeling are growing in popularity. This approach is also followed for the CZE: we develop a simulation model for the ED, based on actual data from the electronic hospital information system (EZIS), and exploit the concept of effective process time (EPT), cf. (Hopp & Spearman, 2008). The basic idea is that the various details of patient treatment times are not modeled in detail, but their contribution is aggregated into an EPT distribution, the parameters of which are directly estimated from the available data. This concept has been originally developed in semi-conductor manufacturing (Jacobs, Etman, Campen, & Rooda, 2003; Etman, Veeger, Lefeber, Adan, & Rooda, 2011). Its applicability in health care modeling, in particular for an MRI department, has recently been explored in (Jansen, Etman, Rooda, & Adan, 2012), and it is further investigated in the current paper. Characteristic features of the ED are that (i) patients simultaneously require multiple resources (e.g., treatment room, nurse, and physician) and (ii) nurses and physicians can spread their attention over multiple patients.

We propose a novel token system to model the above mentioned features of simultaneous resource possession and multi servicing, a concept which has also been instrumental in analyzing multi-server queueing systems with concurrency constraints (Berezner, Kriel, & Krzesinski, 1995; Krzesinski, 2010). This token system, in combination with EPTs, describes the ED at an aggregate level, which is suitable and sufficiently flexible to support the improvement program of CZE. Various details of patient treatment times are not modeled in detail, but aggregated into an EPT distribution whose parameters are directly estimated from data: a concept that originally has been developed in semi-conductor manufacturing and in this paper is successfully transferred to health care modeling. Furthermore we propose a novel token system to model patients requiring multiple resources (treatment room, nurse and physician) simultaneously and physicians and nurses participating in more than one activity simultaneously. A third contribution in our modeling approach is the usage of recursive partitioning to derive a reliably fitted treatment time distribution from data.

The resulting model, specified in the process-based simulation language Chi 3.0 (Hofkamp & Rooda, 2012), is transparent, flexible and intuitive, and hence, in the spirit of the principles set out in (Sinreich & Marmor, 2005).

The aim of this study is to investigate the capacity level needed to deliver the health care services within the target times set by the hospital management. The capacity consists of (ED-) physicians, (ED-) medical interns, (ED-) nurses and treatment rooms. Using the developed model, we are able to address questions such as:

- What capacity is at least required on a typical Monday to meet the target maximal waiting times?
- How much does the waiting time decrease if the number of nurses increases?
- How does the waiting time change if patients arriving by ambulance are treated with the same priority as other patients?

The contribution of this paper is in the modeling approach: instead of a detailed model we use an aggregate model, which is suitable and sufficiently flexible to support the improvement program of CZE. Various details of patient treatment times are not modeled in detail, but aggregated into an EPT distribution whose parameters are directly estimated from data: a concept that originally has been developed in semi-conductor manufacturing and in this paper is successfully transferred to health care modeling. Furthermore we propose a novel token system to model patients requiring multiple resources (treatment room, nurse and physician) simultaneously and physicians and nurses participating in more than one activity simultaneously. A third contribution in our modeling approach is the usage of recursive partitioning to derive a reliably fitted treatment time distribution from data.

Using this aggregate modeling approach we are able to obtain answers to the above mentioned questions, showing which improvement actions are most effective. In particular, these capacity questions and their effect on waiting times are also the only conclusions that can be drawn from the model. Clearly, for more detailed questions, a more detailed model is required.
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