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S.P.J. van Brummelen, W.L. de Kort, N.M. van Dijk

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# Queue length Computation of Time-Dependent Queueing Networks and its Application to Blood Collection

S.P.J. van Brummelen[a,b,c,*], W.L. de Kort[b,d], N.M. van Dijk[a,c]

[a]Centre for Healthcare Operations Improvement and Research, University of Twente, Enschede, The Netherlands
[b]Donorstudies, Sanquin Research, Amsterdam, The Netherlands
[c]Stochastic Operations Research, University of Twente, Enschede, The Netherlands
[d]Department of Public Health, Acedemic Medical Center, Amsterdam, The Netherlands

**Abstract**

Service systems often experience time-dependent aspects, typically due to time-dependent arrivals and capacities. Easy and quick to use queueing expressions generally do not apply to these situations, but are still used. At the same time a large number of computational papers exist that deal with queue length distributions for time-dependent queues. Most of these are fairly theoretical and based on single queues. Real-life service systems, however, might resemble a queueing network structure. With this paper we aim to bring both worlds together. It presents a computational method for time-dependent queueing networks based on uniformization.

Although uniformization is generally perceived to be too computationally prohibitive, we show that our method is very effective for practical instances, as shown with a Dutch blood collection site. The results shown in this paper take a matter of seconds to compute. The objective of the results is twofold: (1) to show that the time-dependent queueing network approach is imperative for some queueing networks, including this application and (2) to evaluate possible improvement scenarios for Dutch blood collection sites that can only be properly assessed with a time-dependent queueing method.

*Keywords:* Uniformization; Markov Chains; Time dependent; Blood collection sites; Queueing; Queueing networks.

## 1. Introduction

### 1.1. Background

Service systems with free walk-in arrivals rarely have a steady number of arrivals during business hours. Some time intervals will have a high average number of arrivals, and others a low number of arrivals. This happens because people (jobs) usually have preferences for certain time intervals. These preferences usually depend on the type of systems. Systems with a short service and sojourn time usually experience peaks in arrivals just before or after standard office working hours and during lunchtime (e.g. checkout at supermarkets). Systems with longer service and sojourn times usually see preferences for certain days of the week (e.g. hospitals). Due to breaks and part-time employees (servers), service capacity also is not uniform throughout a day. If queueing methods are applied to these kinds of situations, often general queueing expressions are used like product forms and Little's law. However, these methods assume a steady-state situation. This means that the method will give an average distribution of jobs in an infinite horizon situation. A time independent system will usually tend to this average, which is the reason a steady-state approach can work well in systems that are time independent or change very slowly. However, if system changes occur relatively often compared

*Corresponding author
*Email address:* `s.p.j.vanbrummelen@utwente.nl` (S.P.J. van Brummelen)