Appointment-driven queueing systems
EURO: Bonn 2009

Stefan Creemers & Marc Lambrecht
Research Center for Operations Management
Katholieke Universiteit Leuven

July 7, 2009
Introduction

• Introduction & problem setting
• Optimization
• Methodology
• Questions
Problem description: Setting

January 15

- January
- February
- March
- April
- May
- June
Problem description: Setting

January 15

April 15
Problem description: Setting

January 15

April 15

8AM | 10AM | 12PM | 2PM | 4PM | 6PM

LUNCH

Appointment-driven queueing systems
Problem description: Setting

Waiting time at waiting list

Stefan Creemers  Appointment-driven queueing systems
Problem description: Setting

- January 15
- April 15

Waiting time at waiting list
Waiting time at service facility
Problem description: Setting

- January 15
- April 15
- Server idle time
- Waiting time at waiting list
- Waiting time at service facility

Stefan Creemers
Appointment-driven queueing systems
Problem description: Setting

Waiting time at waiting list

Server idle time

Waiting time at service facility

Server overtime
Problem description: Performance measures

Waiting time at the waiting list
Waiting time at the service facility
Server idle time
Server overtime
Problem description: Strategic questions

- Waiting time at the waiting list
- Waiting time at the service facility
- Server idle time
- Server overtime

- How many service sessions should be installed
- When should a service session be installed
- How many customers should be served during each session
- How should customers be scheduled during a session

...
Problem description: Strategic questions

- Waiting time at the waiting list
- Waiting time at the service facility
- Server idle time
- Server overtime

- How many service sessions should be installed
- When should a service session be installed
- How many customers should be served during each session
- How should customers be scheduled during a session
- ...

Stefan Creemers
Appointment-driven queueing systems
Optimization: Insights

Number of customers allowed during a session

Performance
Optimization: Insights

Performance

Waiting time at the waiting list

Number of customers allowed during a session
Optimization: Insights

Waiting time at the waiting list vs. Number of customers allowed during a session.

Stefan Creemers
Appointment-driven queueing systems
Optimization: Insights

Waiting time at the waiting list

Number of customers allowed during a session

Performance

MON TUE WED THU FRI SAT

Stefan Creemers
Appointment-driven queueing systems
Optimization: Insights

- Waiting time at the waiting list
- Number of customers allowed during a session

Stefan Creemers
Appointment-driven queueing systems
Optimization: Insights

Waiting time at the waiting list

Performance vs. Number of customers allowed during a session

MON | TUE | WED | THU | FRI | SAT

Time

Appointment-driven queueing systems
Optimization: Insights

Performance vs. Number of customers allowed during a session

Waiting time at the waiting list

MON | TUE | WED | THU | FRI | SAT | Time

Stefan Creemers | Appointment-driven queueing systems
Optimization: Insights

- Waiting time at the waiting list
- Number of customers allowed during a session

Stefan Creemers
Appointment-driven queueing systems
Optimization: Insights

Waiting time at the waiting list

Number of customers allowed during a session

Performance

MON TUE WED THU FRI SAT Time

Appointment-driven queueing systems
Optimization: Insights

- Waiting time at the waiting list

Number of customers allowed during a session

Time

MON TUE WED THU FRI SAT
Optimization: Insights

Waiting time at the waiting list

Number of customers allowed during a session

Performance

MON | TUE | WED | THU | FRI | SAT | Time

Appointment-driven queueing systems
Optimization: Insights

- Waiting time at the waiting list
- Number of customers allowed during a session
- Performance

Stefan Creemers  Appointment-driven queueing systems
Optimization: Insights

Waiting time at the waiting list

Number of customers allowed during a session

Performance

MON TUE WED THU FRI SAT

Time

Appointment-driven queueing systems
Optimization: Insights

Waiting time at the waiting list

Number of customers allowed during a session

Performance

MON TUE WED THU FRI SAT Time

Areas of application
Cost Function
Methodology
Optimization
Problem description
Questions

Stefan Creemers
Appointment-driven queueing systems
Optimization: Insights

- Waiting time at the service facility
- Number of customers allowed during a session

Stefan Creemers
Appointment-driven queueing systems
Optimization: Insights

- Server idle time
- Number of customers allowed during a session

Stefan Creemers
Appointment-driven queueing systems
Optimization: Insights

- Performance
- Server idle time
- Number of customers allowed during a session

- MON
- TUE
- WED
- THU
- FRI
- SAT

Server idle time: 

Stefan Creemers
Appointment-driven queueing systems
Optimization: Insights

- Server overtime

Number of customers allowed during a session

MON | TUE | WED | THU | FRI | SAT | Time

Appointment-driven queueing systems
Optimization: Insights

Server overtime: 

Number of customers allowed during a session
Optimization: Insights

Server overtime

Performance

Number of customers allowed during a session

MON TUE WED THU FRI SAT

Server overtime: Versus

Stefan Creemers
Appointment-driven queueing systems
Optimization: Cost function

Costs vs. Number of customers allowed during a session

- Waiting at list
- Waiting at facility
- Server overtime
- Server idle time
Optimization: Cost function

- Waiting at list
- Waiting at facility
- Server overtime
- Server idle time

Number of customers allowed during a session

Total cost function

Costs
Optimization: Cost function

- Total cost function
- Optimum
- Waiting at list
- Waiting at facility
- Server overtime
- Server idle time
- Number of customers allowed during a session

Stefan Creemers
Appointment-driven queueing systems
Areas of application

- Health care and services in general (e.g. Cayirli & Veral 2003)
- Manufacturing systems (e.g. Biskup, Herrmann & Gupta 2008)
- Transportation (e.g. Namboothiri & Erera 2008)
- Telecommunications and computing (e.g. van Leeuwaarden, Denteneer & Resing 2006)
- Open Access appointment systems (e.g. Liu, Ziya & Kulkarni 2009)
- ...
Modeling approach

An appointment-driven system is a combination of two distinct queueing systems:

- **Service Allocation Model (SAM):** observes the queueing behavior of customers from the making of an appointment until the start of the service session in which service is administered.
- **Customer Appointment System (CAS):** observes the queueing behavior of customers during a service session itself.
Modeling approach

From the SAM we obtain:

- The expected waiting time of a customer from the making of an appointment until the start of the service session in which service is administered
- The distribution of the number of customers to be served during a given service session

This latter parameter is used to weigh the performance measures resulting from the analysis of the CAS:

- Customer waiting time at the service facility
- Server idle time
- Server overtime
Link between SAM and CAS

SAM

<table>
<thead>
<tr>
<th>SUN</th>
<th>MON</th>
<th>TUE</th>
<th>WED</th>
<th>THU</th>
<th>FRI</th>
<th>SAT</th>
<th>SUN</th>
</tr>
</thead>
</table>

CAS₁

CAS₂

CAS₃

CAS₄

CAS₅

CAS₆

CAS₇

CAS₈

P[Q=0]

P[Q=1]

P[Q=2]

P[Q=3]

P[Q>3]

P[Q=0]

P[Q=1]

P[Q>1]

SERVICE SESSIONS

Stefan Creemers
Appointment-driven queueing systems
Service Allocation Model (SAM)

- Model: set of two-dimensional DTMC
- Methodology: matrix-analytical techniques and efficient algorithms implemented in Visual C++
- Results: Numerically exact results, limited computational requirements allow the study of complex, real-life problems

Queueing models for appointment-driven systems
Accepted for publication in Annals of OR

An advanced queueing model to analyze appointment-driven service systems
Computers & operations research, 36(10), 2773-2785
Customer Appointment System (CAS)

- Model: Four- to five-dimensional DTMC depending on the assumptions imposed
- Methodology: efficient algorithms implemented in Visual C++
- Results: Depending on the granularity used in the algorithms near exact results may be obtained

Appointment-driven queueing systems
Creemers S. (2009)
PhD Thesis
Time for questions