A SIMULATION-BASED APPRAOCH FOR OPTIMAL PHYSICIAN SCHEDULING IN THE EMERGENCY DEPARTMENT

Wilhelm Behringer, Anika Johlke, Christian Pigorsch

MOTIVATION

- Minimize patient waiting times and health risks associated with overcrowding
- Address the uncertainty of the patient flow into the emergency department (ED)

➡ Design of a physician duty roster that is adapted to the stochastic patient flow

➡ Develop a flexible simulation model that can easily be updated with new data

RESEARCH QUESTIONS

- Does the arrvial of patients vary significantly during a day, week or month?
- How can the arrival of patients be described?
- By which probability distribution can the distribution of treatment times be characterized?
- How can optimal duty rosters be identified?
- Do the optimized duty rosters comply with legal requirements (ESI)?
- **To what extent does an optimized roster, as opposed to the current roster, help minimize patient waiting times?**

RESULTS

Key Statistics of Waiting Time			
Distribution of Treatment Times	**Mean**	**Median**	**90% Q**
	CURRENT DUTY ROSTER		
Empirical	29.46 min	0.00 min	72.07 min
Gamma	20.12 min	0.00 min	62.23 min
Log-Normal	22.86 min	0.33 min	70.10 min
	OPTIMIZED DUTY ROSTER		
Empirical	15.08 min	0.00 min	48.00 min
Gamma	14.29 min	0.00 min	45.63 min
Log-Normal	16.36 min	0.00 min	51.07 min

Table 1: Simulation Results
Key Statistics of Waiting Times

- Improvement of the 90% quantile of waiting time (> 25%)
- Compliance with ESI regulations
- Applicable with new data

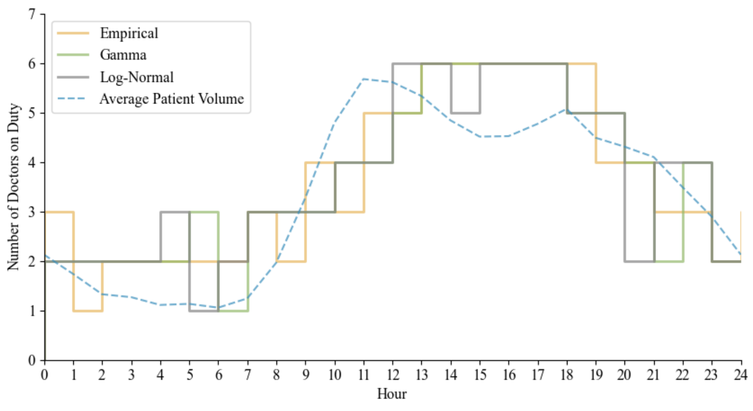
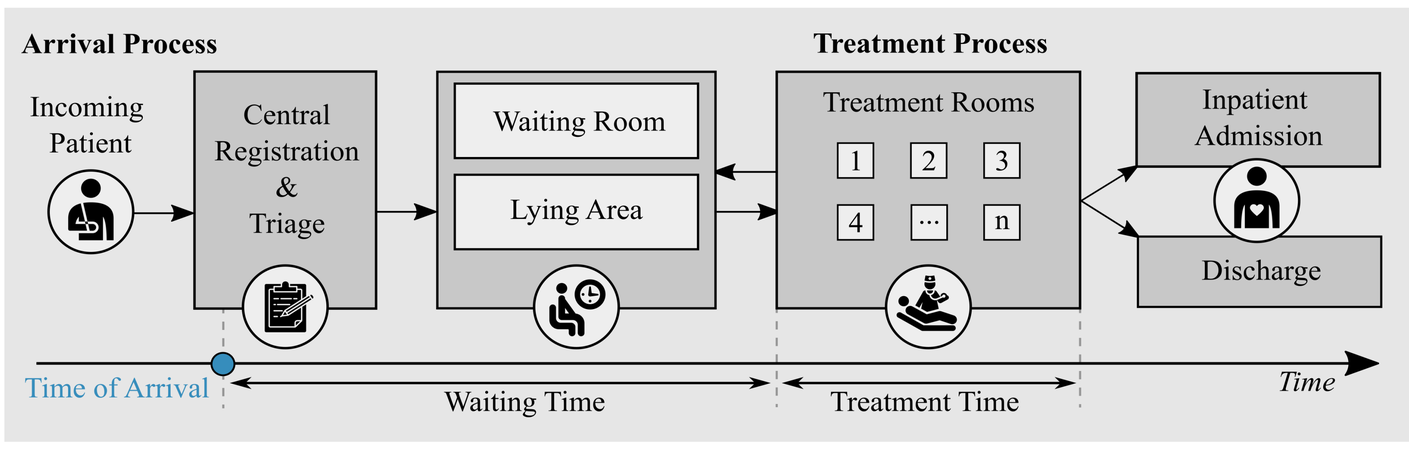


Figure 6
Number of Physicians during a Day vs. Average Patient Volume during a Day

REFERENCES

- Kuo, Y.-H., et al. (2016). "Improving the efficiency of a hospital emergency department: a simulation study with indirectly imputed service-time distributions." Flexible Services and Manufacturing Journal **28**(1-2): 120-147.
- Kuo, Y. H. (2014). "Integrating simulation with simulated annealing for scheduling physicians in an understaffed emergency department." HKIE Transactions **21**(4): 253-261.

ED PROCESSES



➡ Only bottleneck to be considered:

number of physicians

Figure 1
Aggregated Process Flow in the Emergency Department of Jena

ARRIVAL PROCESS

. Time of arrival

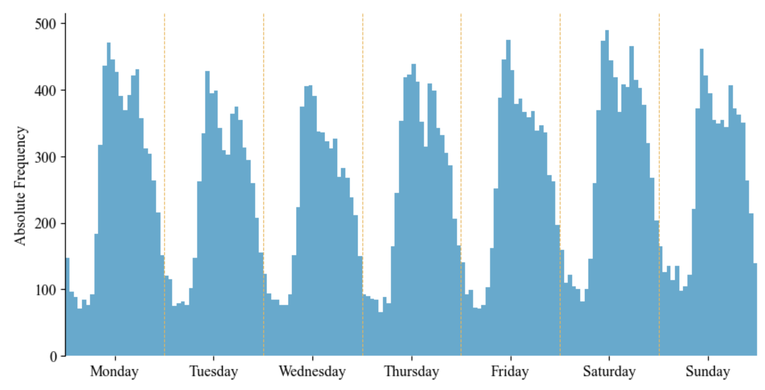


Figure 2
Average Weekly Patient Volume

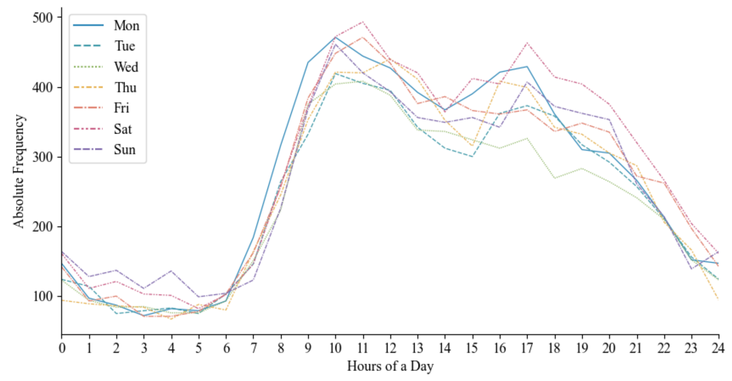


Figure 3
Average Daily Patient Volume per Weekday

- No significant monthly fluctuations, but weekly and daily

➡ Modeling the arrival process as **nonhomogeneous Poisson Process** with intensity function Λ for the expected number of incoming patients until time *t*

$$\Lambda(t) = \mathbb{E}[N(t)] = \int_0^t \lambda(u)du,$$

- Modeling of λ(u) as exponential Fourier series to take the daily and weekly fluctuations into account

➡ $\tilde{\lambda}_t(x) = exp[\theta_0 + \theta_1 sin(2\pi\frac{x}{T}\theta_2) + \theta_3 cos(2\pi\frac{x}{T}\theta_2) + \theta_4 sin(2\pi\frac{x}{T}\theta_5) + \theta_6 cos(2\pi\frac{x}{T}\theta_5)]$

- Parameter Estimation by Maximum Likelihood Method

TREATMENT PROCESS

. Treatment duration
. Triage level according to ESI
. Treated by Resident or Specialist
. Leading symptom category
. Patient arrival type

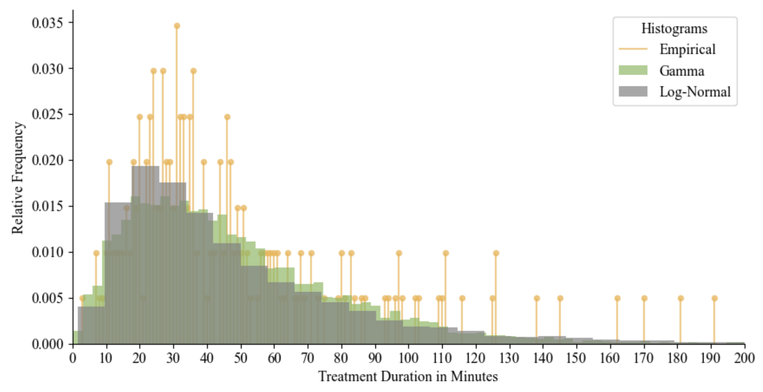


Figure 4
Three Distributions of Treatment Time

- Derivation of an empirical multivariate distribution based on real treatment times

➡ new sampled data is limited to the range of the real data

- Estimation of the parameters of two continuous distributions: the gamma and the log-normal distribution

➡ Three distributions to sample treatment times

- Determining the waiting time of a patient from the time of arrival to the start of treatment
- Simulation of any duty roster based on the distributions of arrival and treatment time

OPTIMIZATION

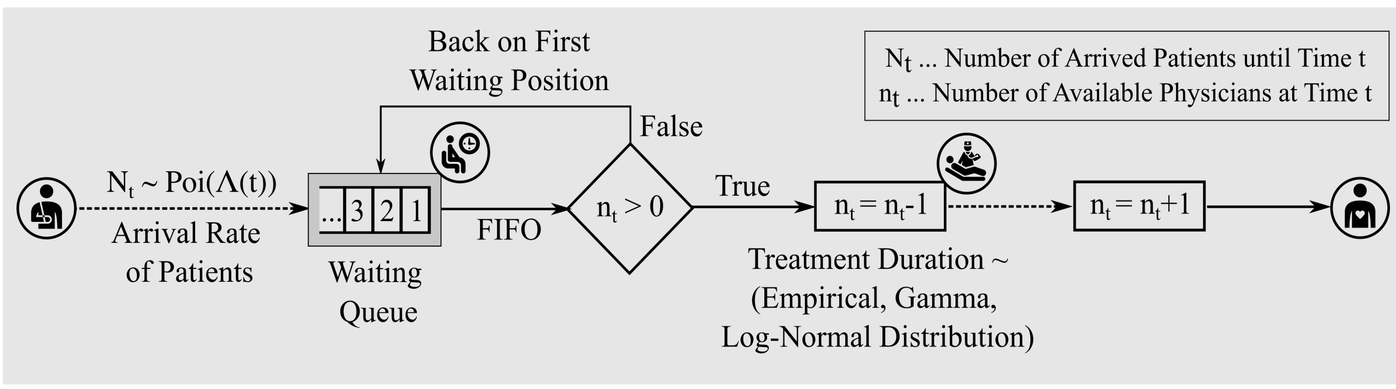
Simulated Annealing

Structure of a duty roster as input for the algorithm:

`[0,0,1,0,0,0,2,0,0,0,2,0,1,1,0,0,0,2,0,1,1,0,0,0]`

index: amount of physicians starting their duty and work for 8 hours

SIMULATION SETUP



➡ Waiting times of all simulated patients

➡ Calculation of key statistics

Figure 5
Aggregated Process Flow in the Emergency Department of Jena

Contact:
wilhelm.behringer@med.uni-jena.de,
anika.johlke@uni-jena.de,
christian.pigorsch@uni-jena.de

UNIVERSITÄTS KLINIKUM Jena

JSEC Schumpeter Center for Research on Socio-Economic Change

FRIEDRICH-SCHILLER-UNIVERSITÄT JENA