Duty Rostering for Physicians at a Department of Orthopedics and Trauma Surgery: Decision Support using Mathematical Optimization

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Motivation

- Duty rosters have large impact on efficient hospital operation and employee satisfaction
- Various conflicting, often incommensurable objectives
- Complex requirements on duty rosters make manual roster generation hard or even impossible for large hospitals / departments

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Large potential for optimization models in physician scheduling

However: "Final implementation of advanced mathematical models in physician scheduling is still very limited" [Erhard et al. 2018]

M. Erhard, J. Schoenfelder, A. Fügener, J. O. Brunner, State of the art in physician scheduling, *European Journal of Operational Research 256 (1)*, pp. 1–18 (2018).

This Talk

Integer programming based duty rostering model for physicians at a department of orthopedics and trauma surgery

- Model used in practice since 2016
- Decision support for handling of unplanned absences of physicians using substitute lists

- Comparison to manually generated duty roster
- Long-term analysis of model rosters on real input data

Problem Definition

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- About 50 physicians (residents and fellows)
- Planning period of two months
- 5 night duties (16:00 - 08:00) and one late duty (15:00 - 23:00) each day
- Considered duties are emergency duties (performed in addition to normal working hours)
- During normal working hours (07:15 – 16:00 from Monday to Friday), physicians work in 12 surgical teams

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Staffing of surgical teams and physician preferences need to be respected when creating duty rosters

Requirements and Objectives

Staffing of surgical teams:

- 2–9 residents / fellows per surgical team
- For each team:
  - Max. allowed number of physicians that are absent on the same day
  - Max. allowed number of fellows that are absent on the same day

Requirements and Objectives

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Mandatory rest times:

- Day off after a night duty
- Not present in surgical team on day of a late duty

Consequences:

- Staffing requirements of teams need to be respected when assigning duties
- No two night duties of the same physician on consecutive days
- But: Late duties of the same physician on consecutive days are possible

Requirements and Objectives

Different experience levels:

- Duties require different experience levels
- Each physician is eligible for two of the six different duties

Consequence:

- Duties should be assigned to physicians from the corresponding duty group (set of physicians eligible for this duty)

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Physician preferences:

- Physicians can request (specific) duty on each day
- Physicians can mark days as undesired for being on duty

Consequences:

- As many duty requests as possible should be fulfilled
- Duties on days marked as undesired ("undesired duties") should be avoided

Requirements and Objectives

Fair distribution of duties among physicians:

- Fair distribution separately for duties during the week and on weekends
- In each duty group:
  Each physician should be assigned the same number of duties per day present (not on vacation)
- In total:
  Each physician should be assigned a fair number of duties in total (in both duty groups together) per day present
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Consequences:

- Fair distribution is essential requirement in the model
- Fair distribution in each duty group during the week / on weekends
- Fair distribution in total during the week / on weekends

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- Duty created manually by an experienced physician
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Problems with resulting duty rosters:

- Staffing requirements of surgical teams often violated
- No fair distribution of duties among physicians
- Duties often assigned to physicians from wrong duty groups

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- Input data (absences and preferences of physicians, surgical teams, duty groups, ...) entered via a dedicated web interface

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  - Fair distribution of duties:
    - in total / in each duty group
    - during the week / on weekends
  - Avoid undesired duties
  - Fulfill as many duty requests as possible

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  $\rightsquigarrow$ Weights determined in iterative process with practice partner
- $\approx$ 18.000 variables and 28.000 constraints
- Solved using CBC (open-source MIP solver, https://projects.coin-or.org/Cbc)

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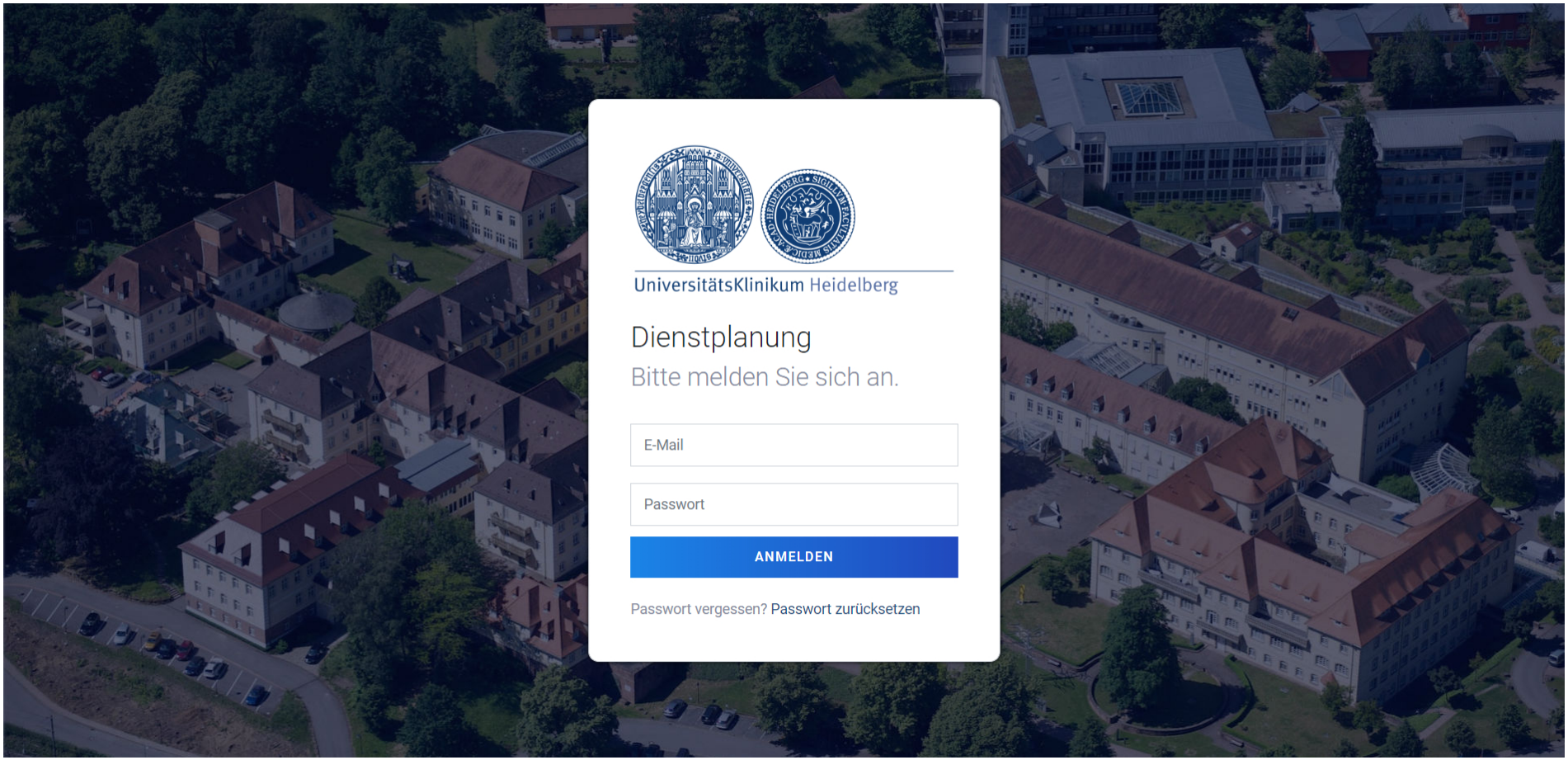

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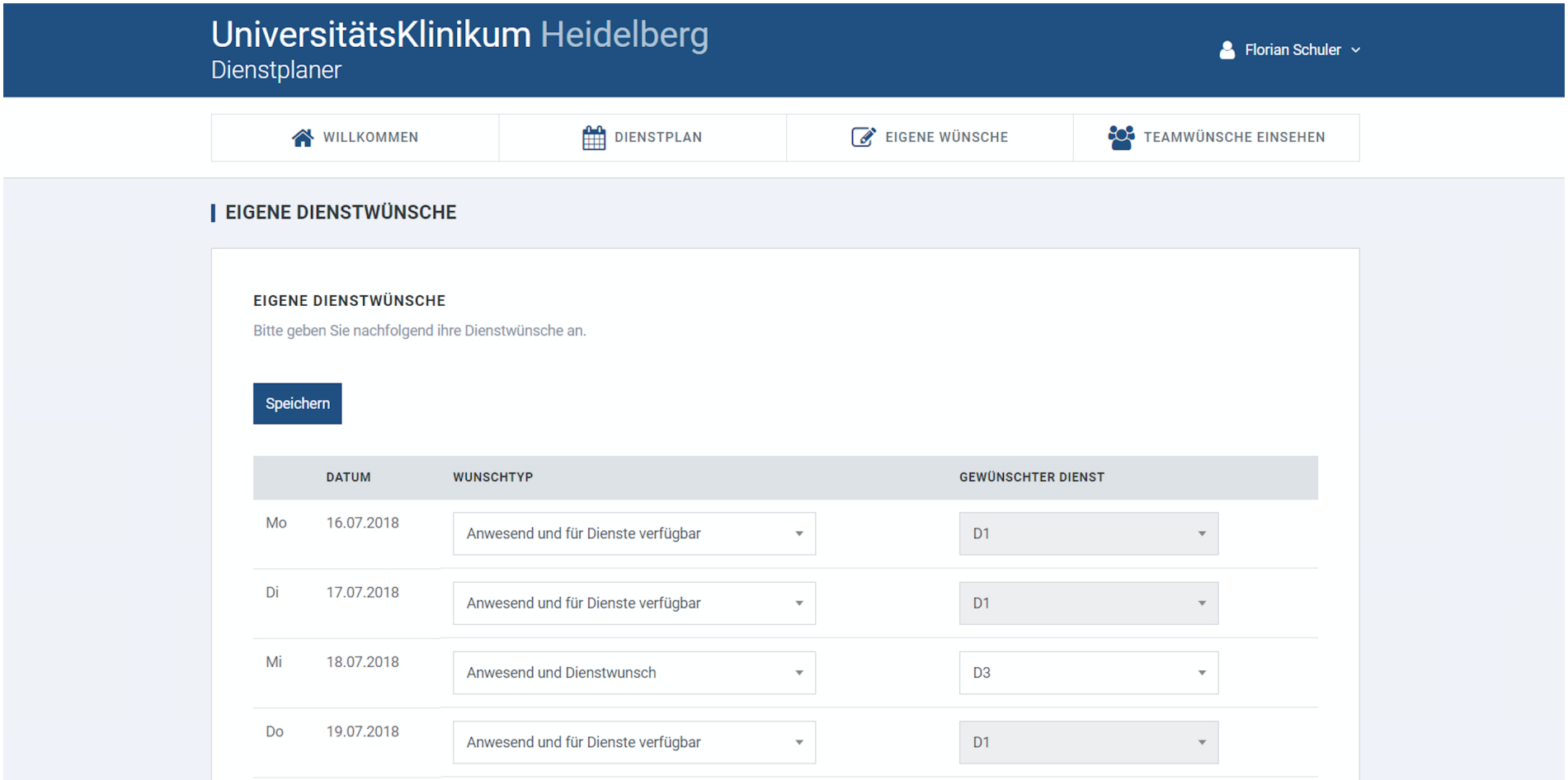

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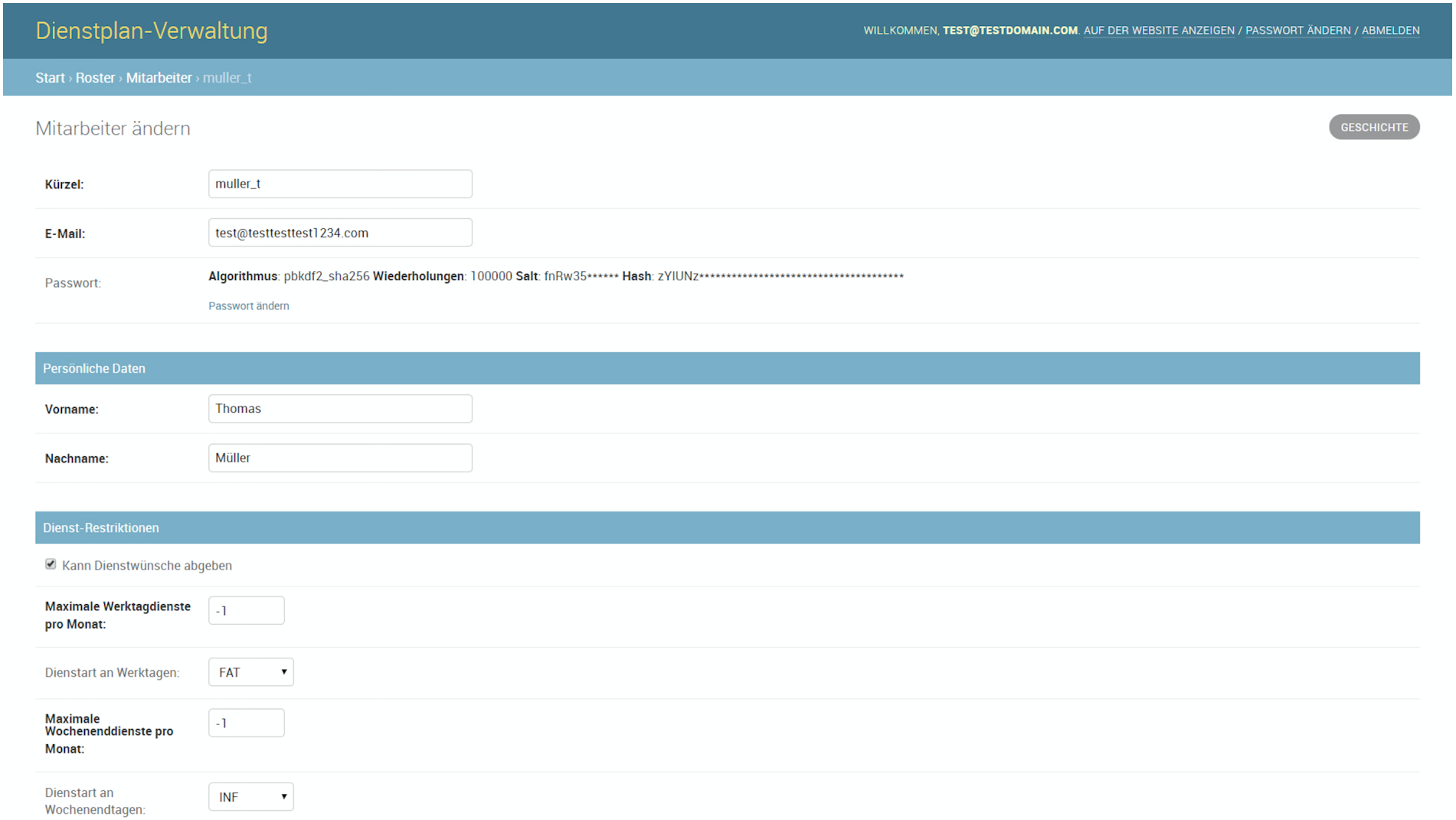

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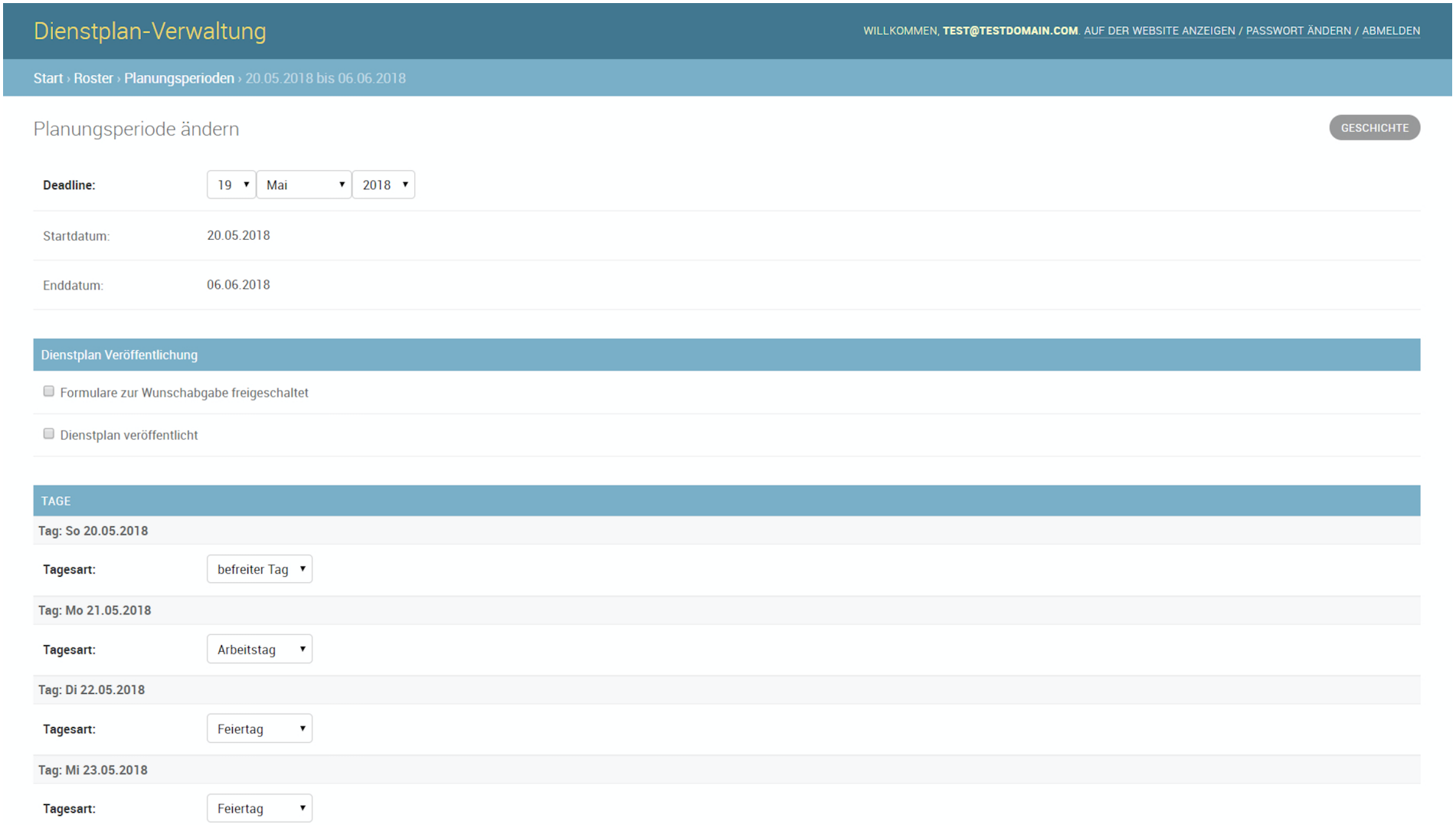

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Output consists of:

- Duty roster
- List of possible substitutes for each duty on each day
  $\rightarrow$ Decision support for handling of unplanned absences (e.g., sick leave)

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Day	Date		Current	Staffing of Surgical Teams				Substitutes	
Wednesday	10-Jan-18	D1	Müller	T1	T2	T3	T4	Krüger	Lange
		D2	Schmidt	2/3 (67%)	1/2 (50%)	2/4 (50%)	3/5 (60%)	Schmitt	Klein
		D3	Schneider	T5	T6	T7	T8	Schröder	Richter
		D4	Fischer	2/3 (67%)	1/2 (50%)	2/3 (67%)	2/2 (100%)	Schröder	Hofmann
		D5	Weber	T9	T10	T11	T12	Schmitt	Klein
		Late	Meyer	2/4 (50%)	1/2 (50%)	6/7 (86%)	6/9 (67%)	Krüger	Lange
Thursday	11-Jan-18	D1	Wagner	T1	T2	T3	T4	Lange	
		D2	Becker	2/3 (67%)	1/2 (50%)	3/4 (75%)	3/5 (60%)	Schmitt	
		D3	Schulz	T5	T6	T7	T8	Schröder	Braun
		D4	Hoffmann	2/3 (67%)	1/2 (50%)	2/3 (67%)	2/2 (100%)	Schröder	Hofmann
		D5	Schäfer	T9	T10	T11	T12	Schmitt	
		Late	Meyer	3/4 (75%)	1/2 (50%)	6/7 (86%)	6/9 (67%)	Lange	
Friday	12-Jan-18	D1	Koch	T1	T2	T3	T4		
		D2	Weber	2/3 (67%)	1/2 (50%)	2/4 (50%)	3/5 (60%)	Maier	Schmidt
		D3	Bauer	T5	T6	T7	T8		
		D4	Richter	3/3 (100%)	2/2 (100%)	2/3 (67%)	2/2 (100%)	Braun	Schröder
		D5	Klein	T9	T10	T11	T12	Maier	Schmidt
		Late	Meyer	2/4 (50%)	1/2 (50%)	5/7 (71%)	6/9 (67%)		

Comparison of Solutions

Obj. coeff.		Manual	Model
Team staffing requirements			
-	Violations of team staffings **before** duty asgmt.	9	9
-	Violations of fellow staffings **before** duty asgmt.	10	10
−1000	**Additional** violations of team staffings after duty asgmt.	11	0
−1000	**Additional** violations of fellow staffings after duty asgmt.	5	0
Physician preferences			
-	Submitted duty requests	112	112
+2	Fulfilled duty requests	57	68
−25	Undesired duties assigned (entry 3 not respected)	1	0
Fair distribution of duties			
-	Phys. with fewer duties than desired in duty groups on work days	21	0
-	Phys. with more duties than desired in duty groups on work days	23	0
-	Phys. with fewer duties than desired in duty groups on weekends	15	0
-	Phys. with more duties than desired in duty groups on weekends	12	0
-	Phys. with fewer duties than desired in total on work days	7	0
-	Phys. with more duties than desired in total on work days	9	0
-	Phys. with fewer duties than desired in total on weekends	6	0
-	Phys. with more duties than desired in total on weekends	10	0
-	Phys. with more than two duties on Saturdays	1	0
Duty assignment according to duty groups			
-	Duties assigned to physicians from wrong duty groups	20	0

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-	Phys. with more than two duties on Saturdays	1	0
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Long-Term Results

- Analysis of duty rosters generated by the model on real input data
- Four planning periods of two months each
- Optimality gap set to 3%
- Computation times include time for reading the input and preprocessing

	Period 1	Period 2	Period 3	Period 4
Team staffing requirements				
Violations of team staffings **before** duty asgmt.	13	12	9	22
Violations of fellow staffings **before** duty asgmt.	10	1	12	22
Add. violations of team staffings after duty asgmt.	0	1	0	6
Add. violations of fellow staffings after duty asgmt.	0	0	0	2
Physician preferences				
Submitted duty requests	291	304	294	229
Fulfilled duty requests	146	134	128	82
Undesired duties assigned	7	12	0	16
Total computation time (in minutes)	2:06	2:29	5:59	2:26

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Add. violations of team staffings after duty asgmt.	**0**	**1**	**0**	**6**
Add. violations of fellow staffings after duty asgmt.	**0**	**0**	**0**	**2**
Physician preferences				
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Conclusion

- Model used by the practice partner since 2016
- Time requirement for generating duty rosters drastically reduced (several days $\rightarrow$ several hours)
- Low cost of implementation due to use of open-source solver

- Roster quality greatly improved with respect to all objectives:
  - Staffing requirements of surgical teams respected whenever possible
  - Much fairer distribution of duties among physicians
  - Better adherence to physician preferences
  - (No more duties assigned to physicians with wrong experience level)

- Substitute lists very useful in practice to handle unplanned absences

Thank you for your attention!