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Fairness-driven mid term scheduling of medical staff at a hospital network

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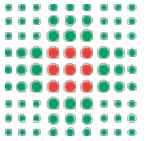
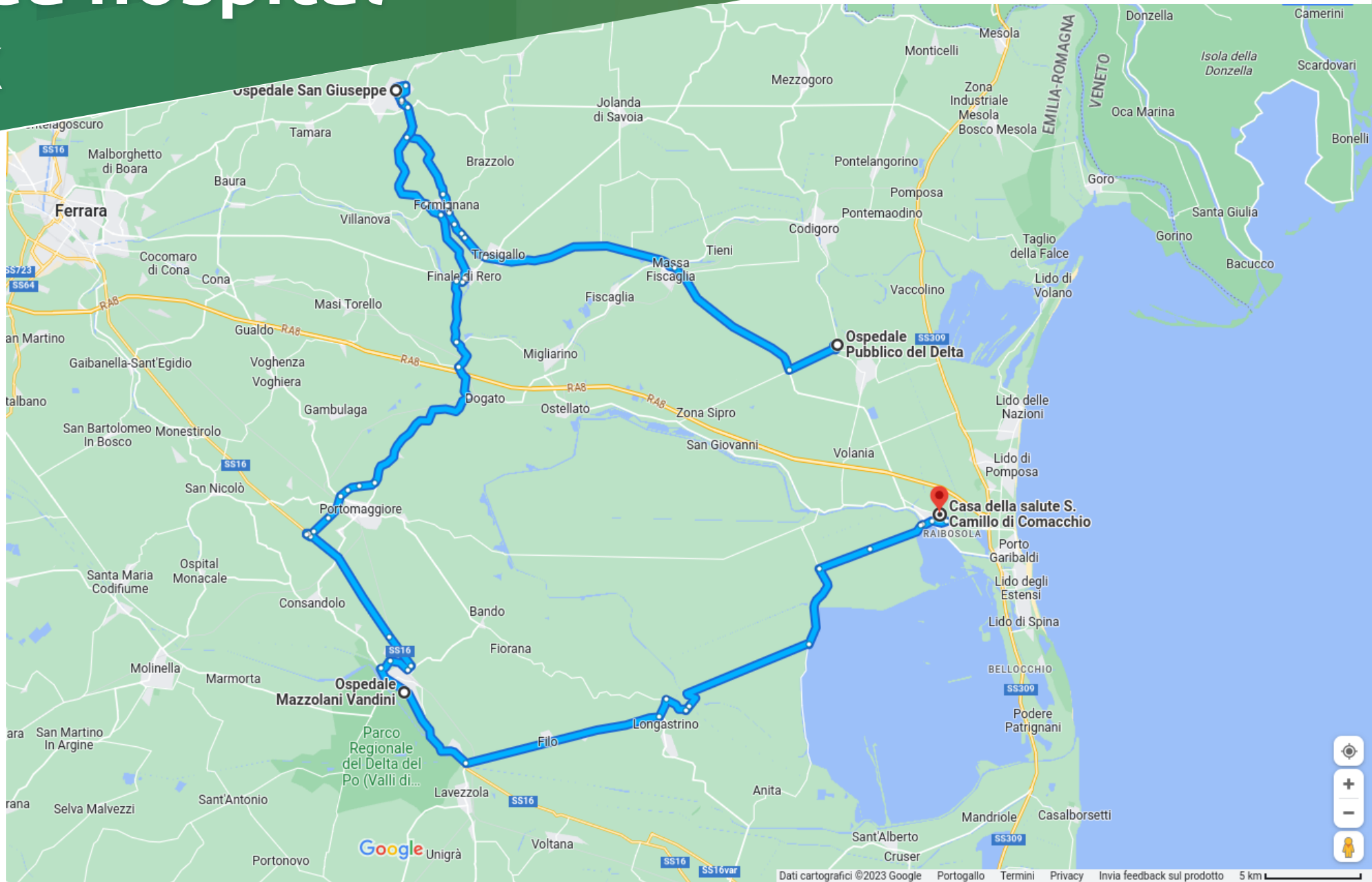


SERVIZIO SANITARIO REGIONALE EMILIA-ROMAGNA
Azienda Unità Sanitaria Locale di Ferrara

Local area hospital network

- 4 local area hospitals
- Different services provided with specific schedule



Objectives

- A decision support system:
  - **Automatic computation of the weekly schedules**
  - **Mid term planning horizon (weekly rolling horizon)**
- Address issues:
  - **Unequal workload**
  - **Fairness, in general**
- Introduce variability into one's mid term schedule
- Take preferences (modeled as soft constraints) into account

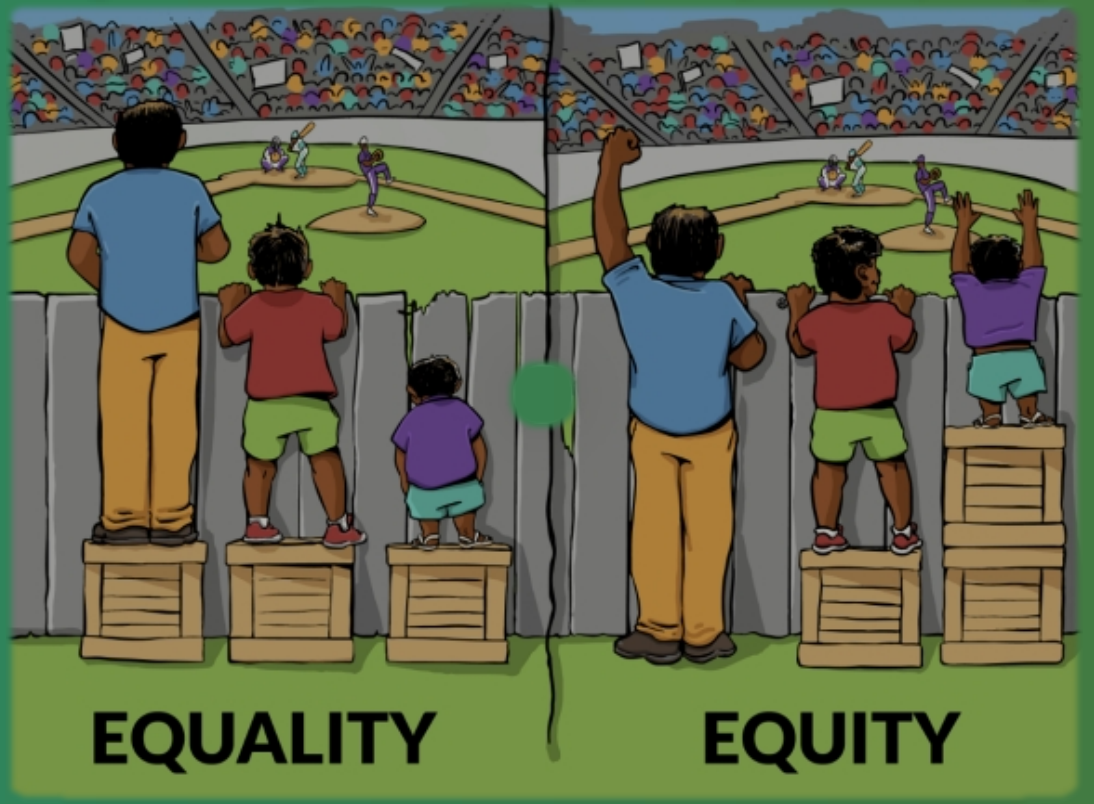
Fairness (Oxford dictionary):

treating people equally or in a way that is just or reasonable

Wolbeck 2019:

Group fairness: all individuals are treated equally

Individual fairness: subject to personal perception (subjective judgement)



S. Erdos and B. Kovari, "Examination of Fairness in Scheduling Ts with Heterogeneous Resources," 2021 8th International Conference on Soft Computing & Machine Intelligence (ISCMI), Nov. 2021.

Literature on Fairness tells us that:

- Easier to model when all employees have equal qualifications
- Easier to enforce when shifts are standard or can be divided into light and heavy (such as morning shifts vs night or holiday ones)

Literature on Fairness tells us that:

What if:

- employees have
  - different (non-disjoint) sets of skills
  - different number of skills

Task - physician Matrix

Only two rows are equal

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20	T21	T22	T23	T24	T25	T26	T27	T28	T29	T30	T31	T32	T33	T34	T35	T36	T37	T38	T39	T40	T41	T42
P1	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X			X		X	X	X	X	X			X	X	X			X		
P2	X	X				X		X																		X									X								
P3				X			X			X	X		X	X								X	X		X		X	X					X	X			X	X	X		
P4	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X			X		X	X	X	X	X			X	X	X		X		
P5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X			X		X	X	X	X	X				X					
P6				X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X			X		X	X	X	X	X			X	X	X		X		X
P7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X				X		X	X	X	X	X	X		X		X		X		
P8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X		X		X	X	X	X	X	X		X		X	X	X		
P9	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X		X	X				X		X	X	X	X	X			X		X		X		
P10				X			X	X		X	X		X	X								X	X				X	X					X			X		X		X		
P11	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X			X		X	X	X	X	X			X	X	X		X		
P12	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X		X		X	X	X	X	X	X		X		X	X	X		
P13	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X				X		X	X	X	X	X			X		X		X		
P14	X	X					X		X	X	X	X	X	X		X	X	X	X		X					X			X	X						X					X	

Literature on Fairness tells us that:

What if:

- employees have
  - different (non-disjoint) sets of skills
  - different number of skills

You must build shifts tailored to the individual employee

Input

- **Set of physicians** (surgeons) with different status (senior, expert, resident) and working agreements
- **List of Tasks** (ward management, on-site guard, on call guard, surgery, clinics), some sought after, others considered as heavy ones
- **Compatibility matrix physician/Task**: each physician is qualified to perform some tasks
- **Tasks occurrences** in time and space, on a weekly base, yielding a set of duties
- **System + individual preferences**

Hard Constraints

- skill-task matching
- working hours and rest constraints
- care continuity
  - The same physician stays in charge of the ward for at least 5 days a week (from Monday to Saturday)
- ...

Soft Constraints

- Each week, each physician should work at least a number of hours equal to (6.3 * working days) hours
- Keep the maximum overtime* among physicians at the lowest possible level
- Same physician in charge of the ward from Monday to Saturday (6 days)
- No morning shift after a night on call
- Geographically driven rules (no day surgery clinic at Delta 8-13 and on site guard 14-17 at Argenta on the same shift)
- No overlapping duties in a shift at the main hospital, potential overlapping at the others
- Individual preferences or suitability

Our proposal

- **Logical model** of the problem (Answer Set Programming)
  → A framework able to formalize and efficiently manage soft constraints
- Weekly rolling horizon
- Encourage **rotation** among physicians in task assignment
  → dynamic mechanism exploiting soft constraints

Enforcing fairness
A memory based mechanism

Tasks are partitioned into categories:

Major categories (*tasks that are preferred the most ↑ or the least ↓*)

- Surgery room ↑
- on call guards (at night) ↓
- Night shifts ↓

Minor categories,

- Clinics
- Ward
- On site morning and afternoon
- holidays

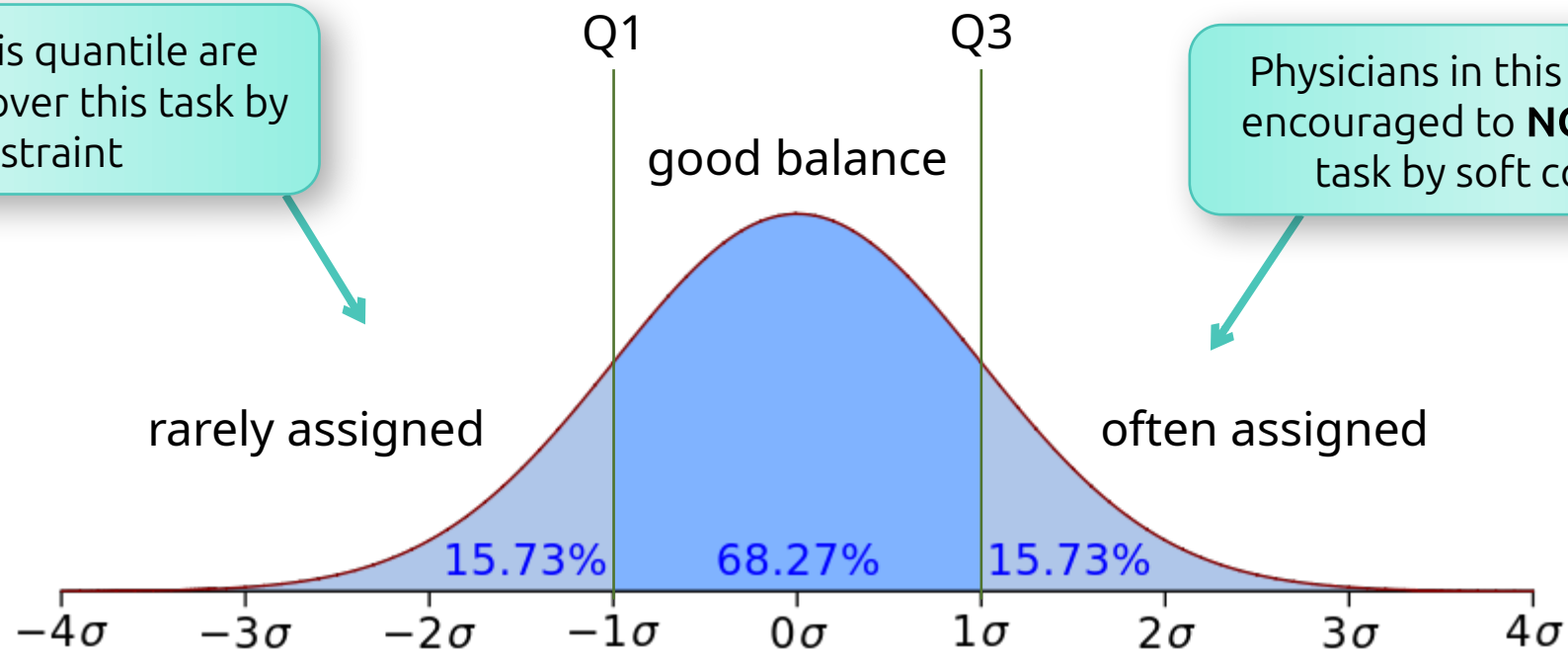
Each assignment task-physician has a weight that is a function of the assignments collected in the past weeks, for all tasks in the same category.

Enforcing fairness
A memory based mechanism

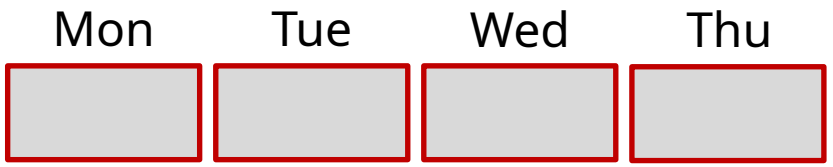
At the end of each week, quartiles are computed for the weights in the same category

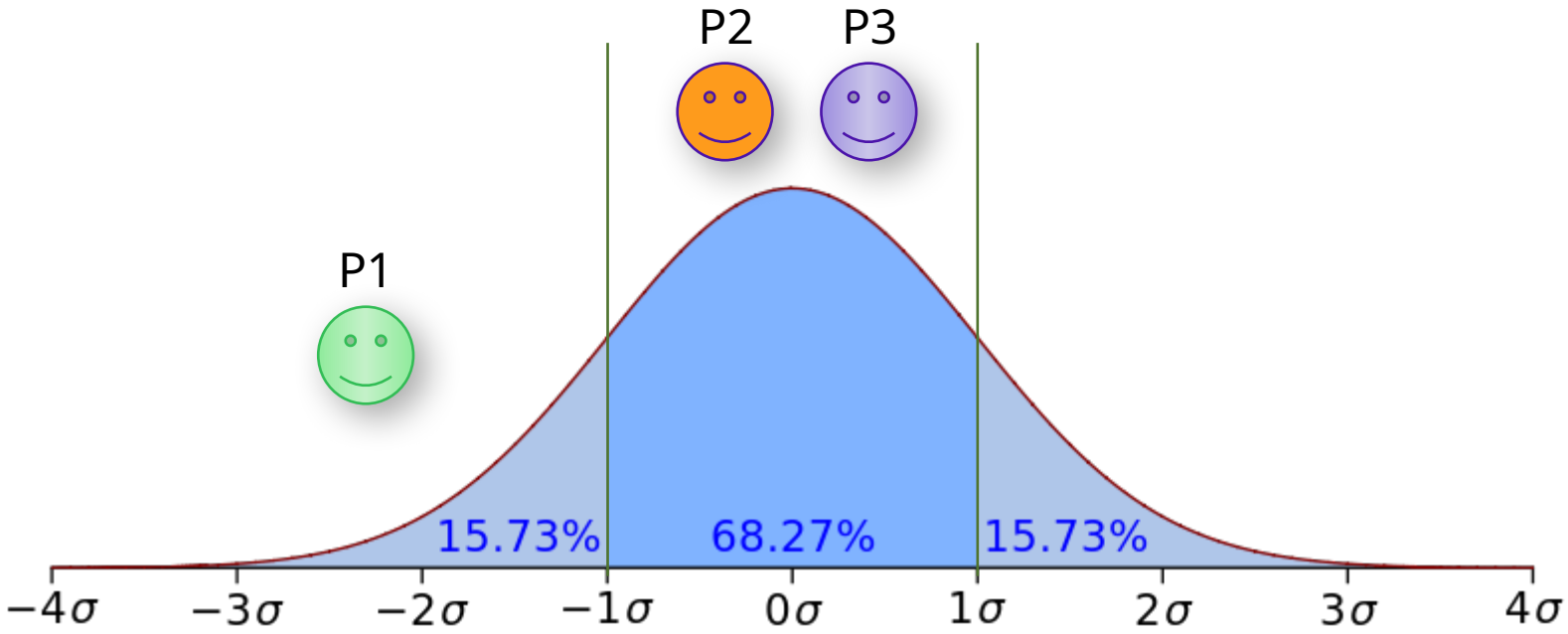
Physicians in this quantile are encouraged to cover this task by soft constraint

Physicians in this quantile are encouraged to **NOT** cover this task by soft constraint



Enforcing fairness
Undesired side effect





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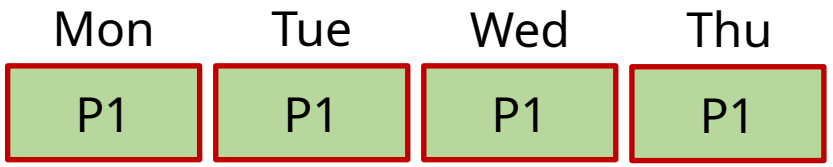
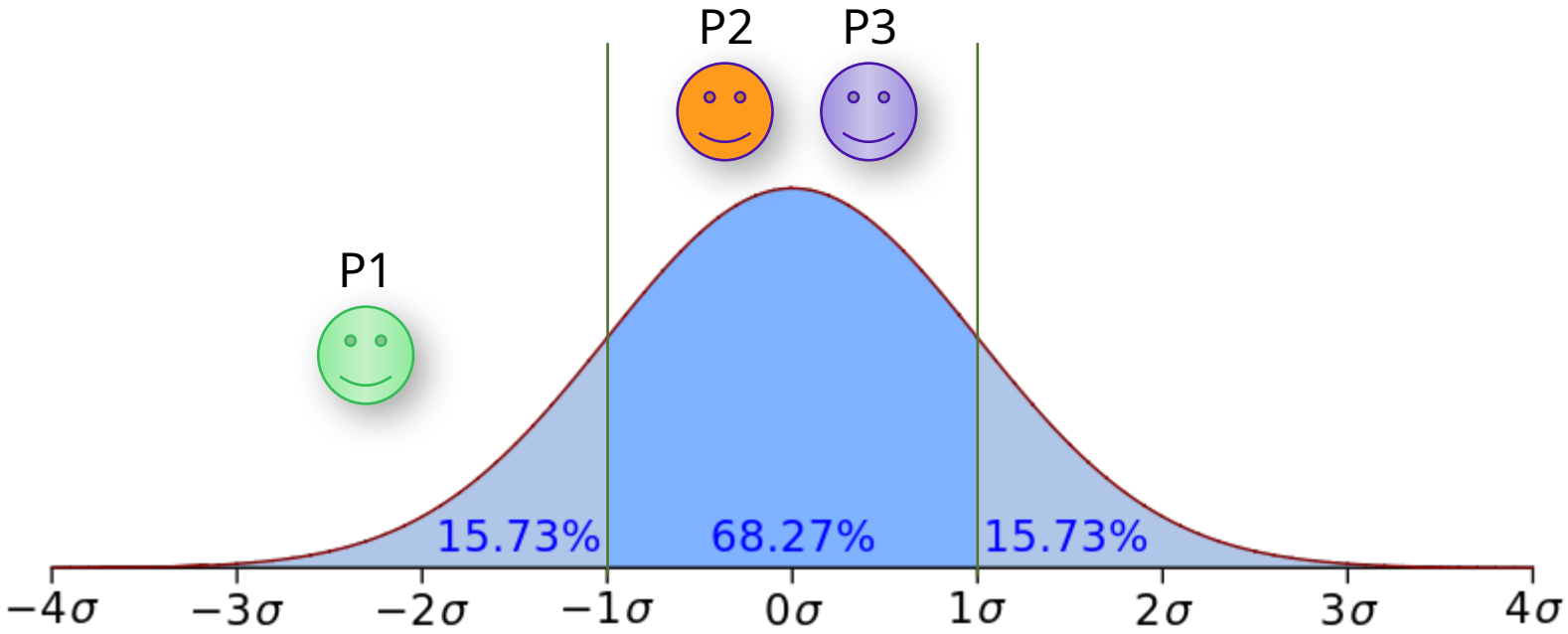




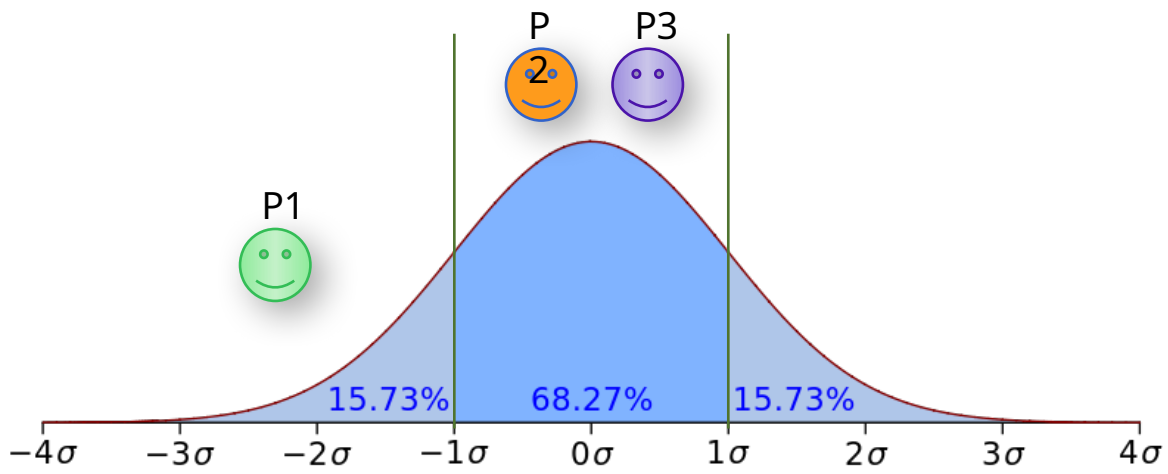
Enforcing fairness
J-Constraint

Without J-Constraint

Mon	Tue	Wed	Thu
P1	P1	P1	P1

With J-Constraint

Mon	Tue	Wed	Thu
P1	P2	P1	P3

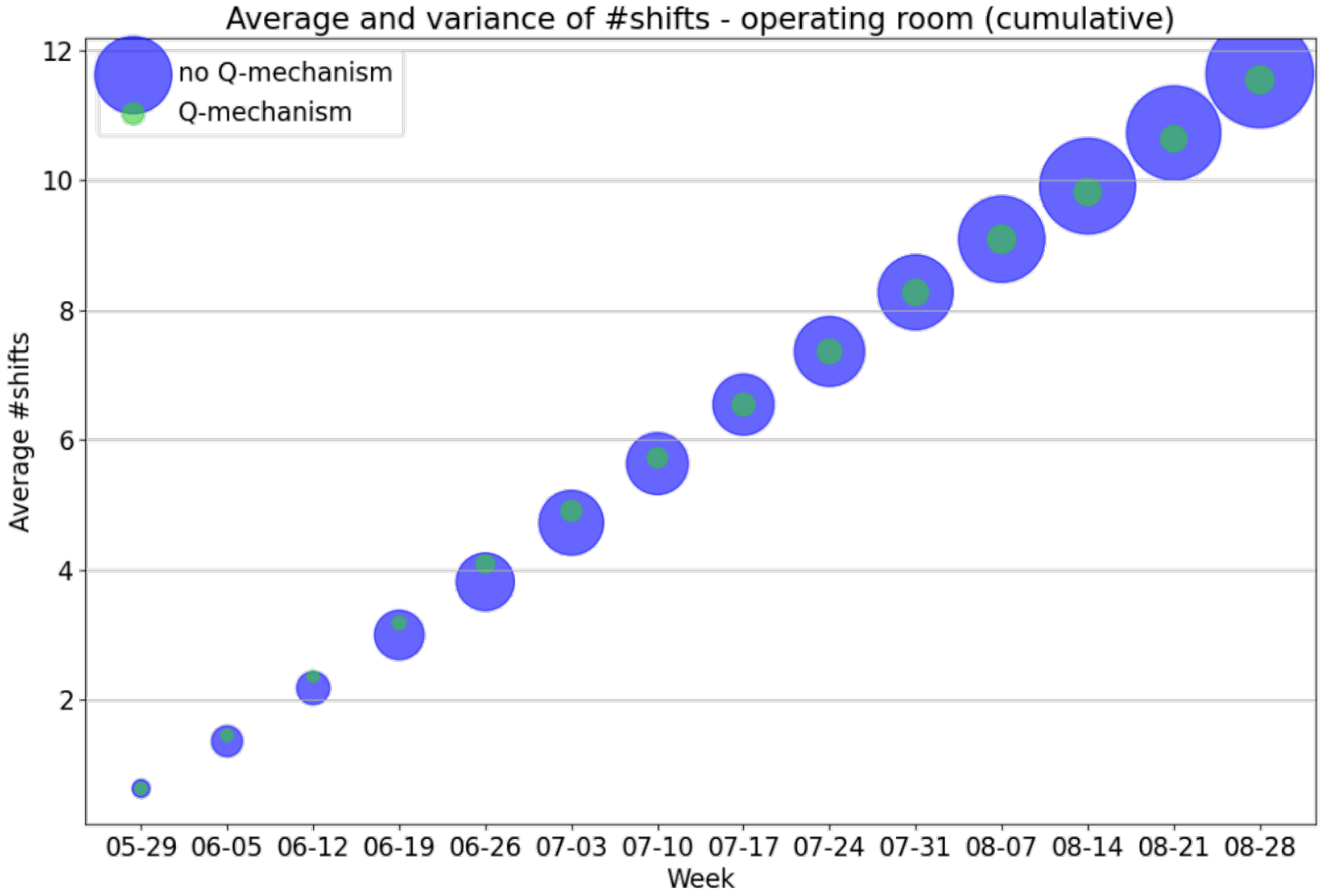


Features

- **Q-based mechanism**
  - mid-term effect
  - reduction of the **variance** of the number of shifts accumulated in the past by the different physicians for a task
- **J-Constraint**
  - short-term effect (week)
  - reduction of the **variance** of the number of shifts assigned to the physicians during the week for a task
- Abide by the minimum working time for each physician at the end of the month (weak)
- Try to keep low and evenly distributed the overtime accumulated by the physicians

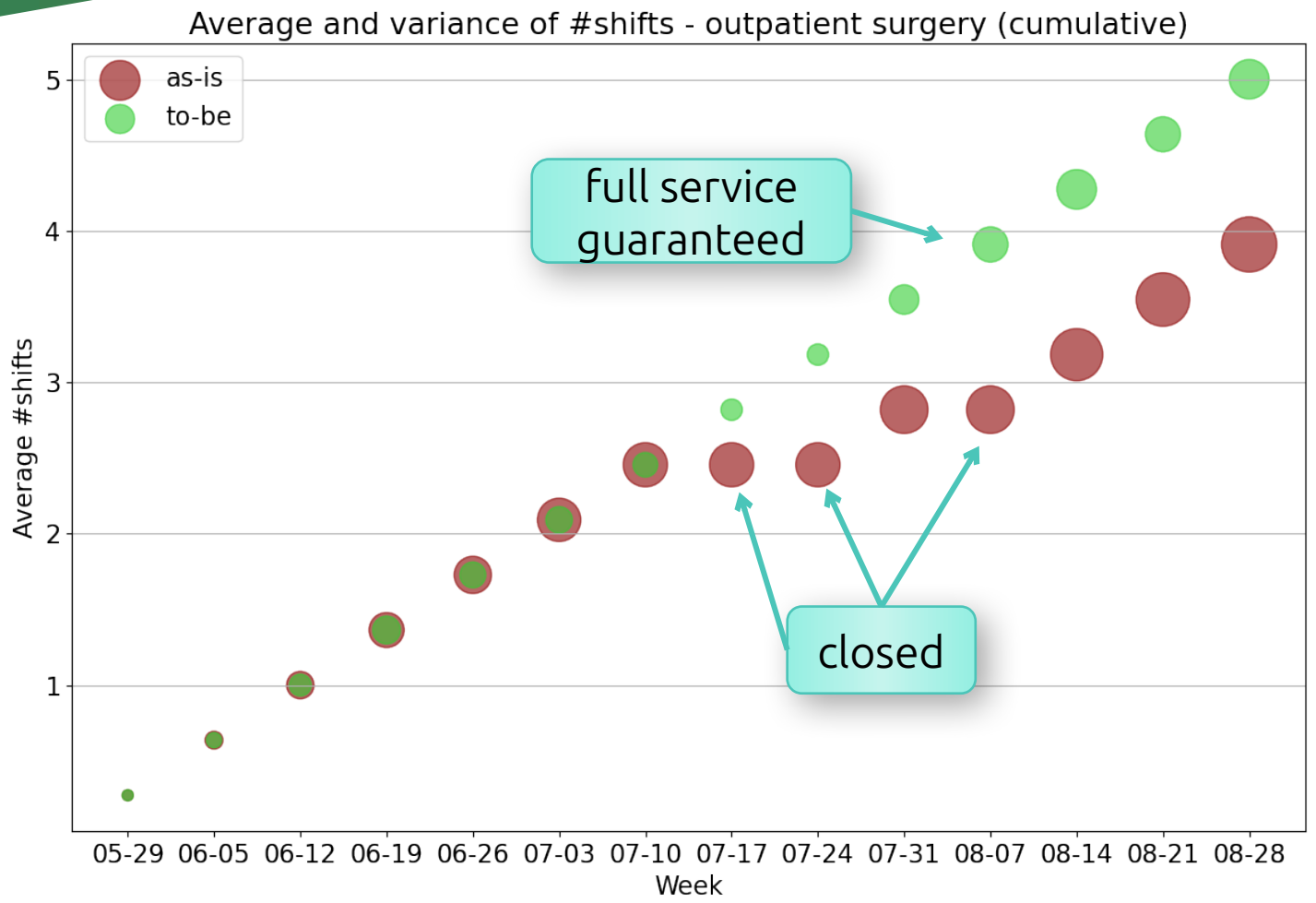
The Quartile based mechanism
Operating Room

- Mean and variance (dimension) of the number of past shifts for operating room for the skilled physicians
- The Q-based mechanism reduces the variance among the physicians

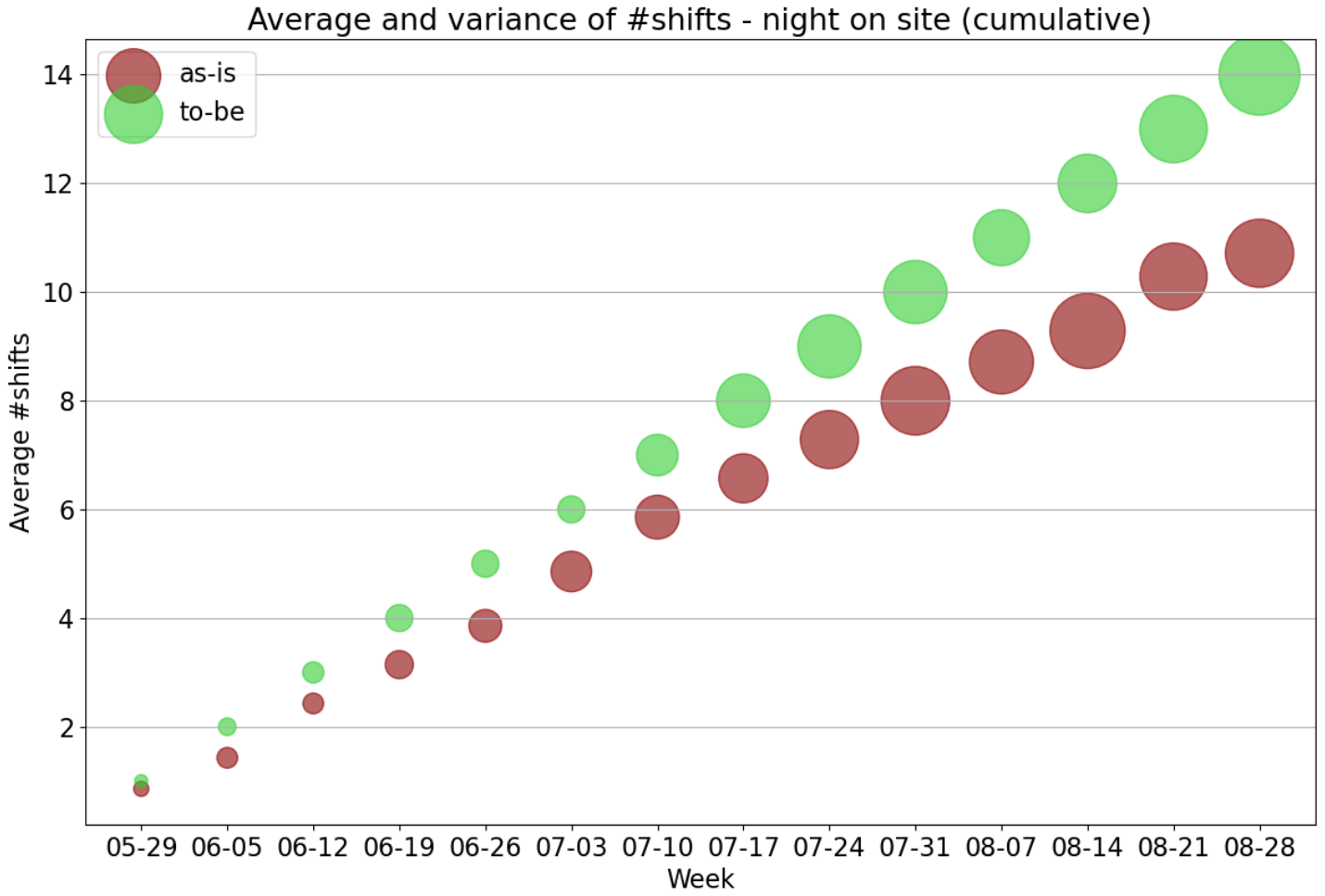


As-is VS to-be comparison
Outpatient surgery

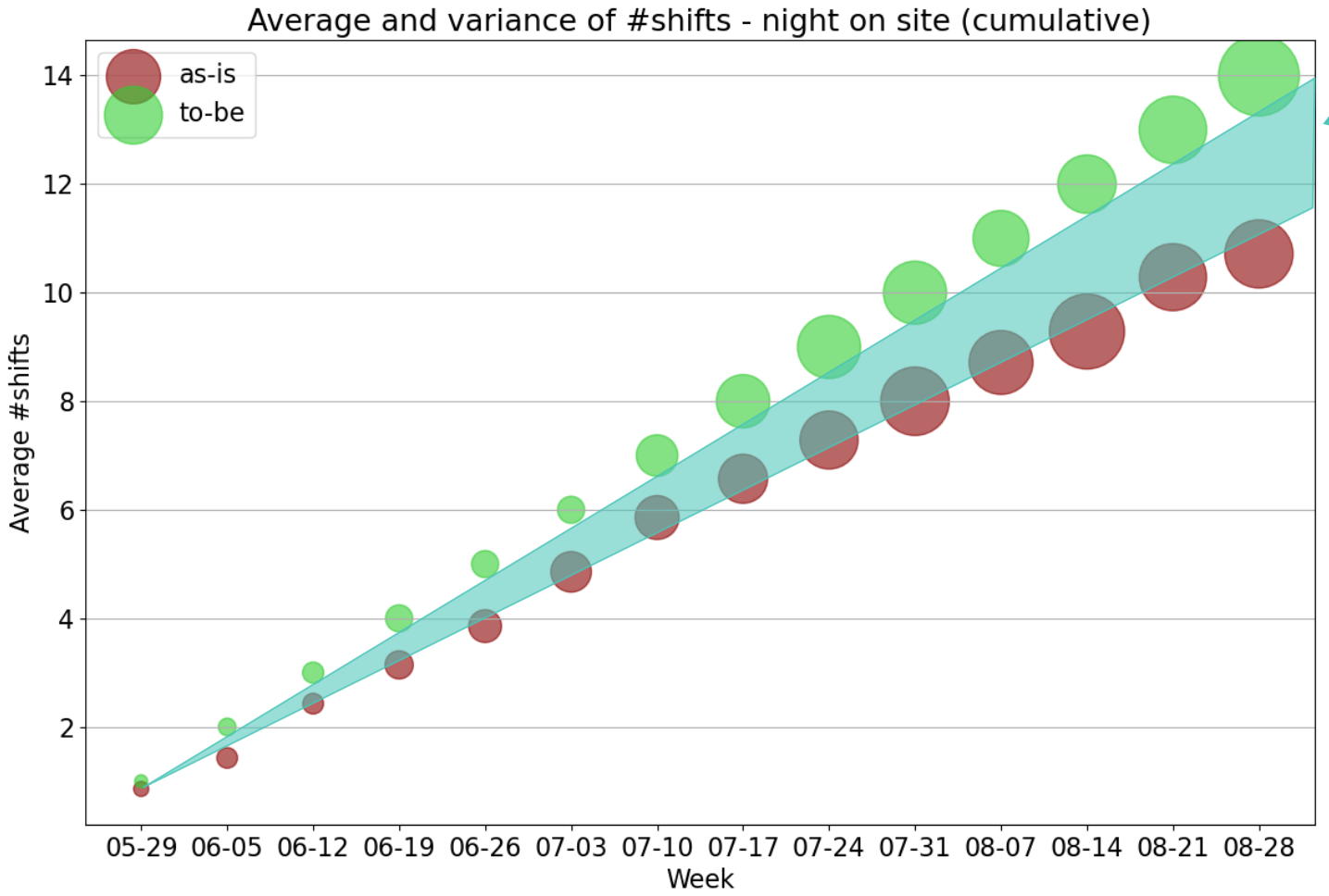
- The summer period registers a high request for **days off**
- The lack of staff leads to the reduction of the service



As-is VS to-be comparison
Night on site guard

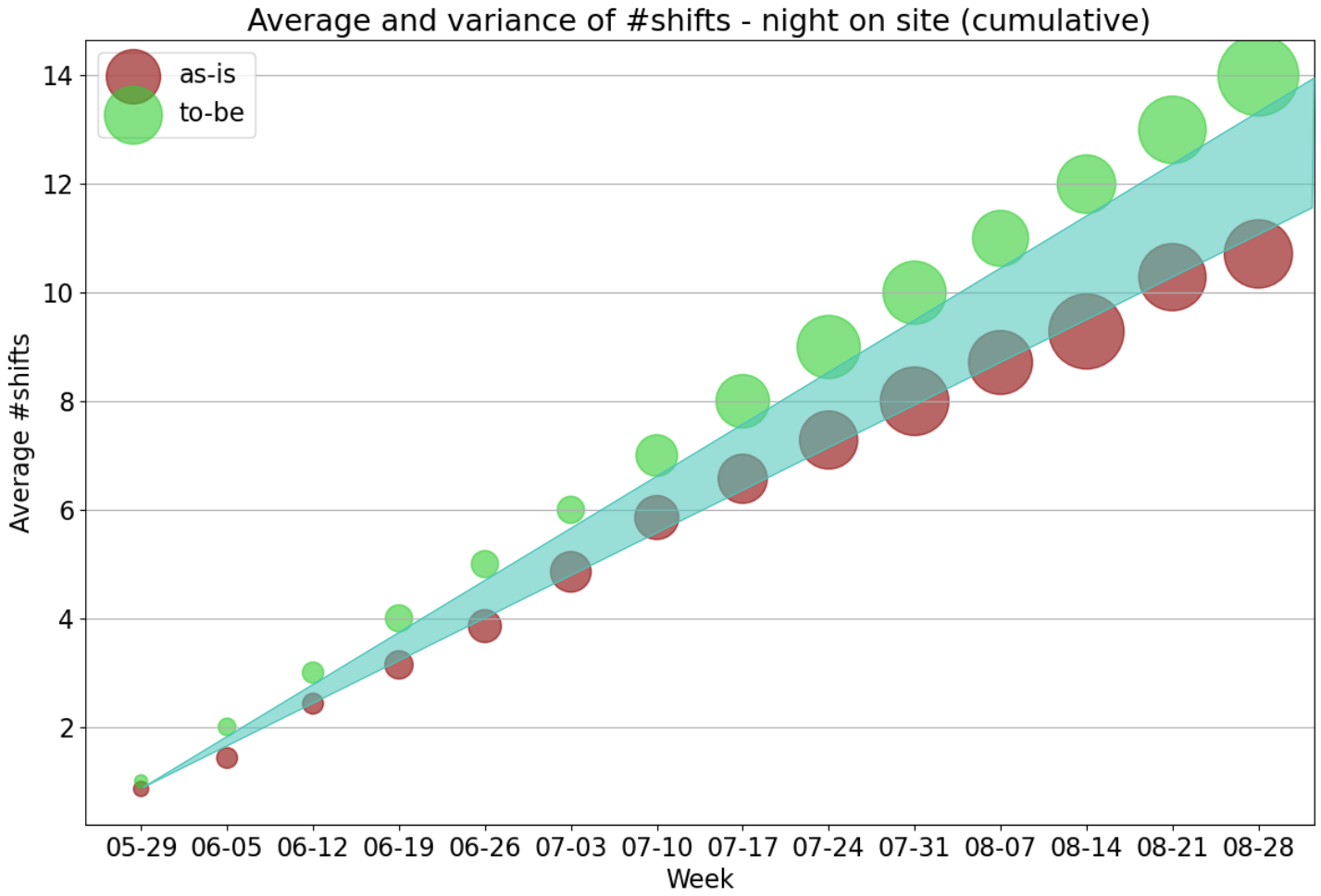


As-is VS to-be comparison
Night on site guard



gap?

As-is VS to-be comparison
Night on site guard

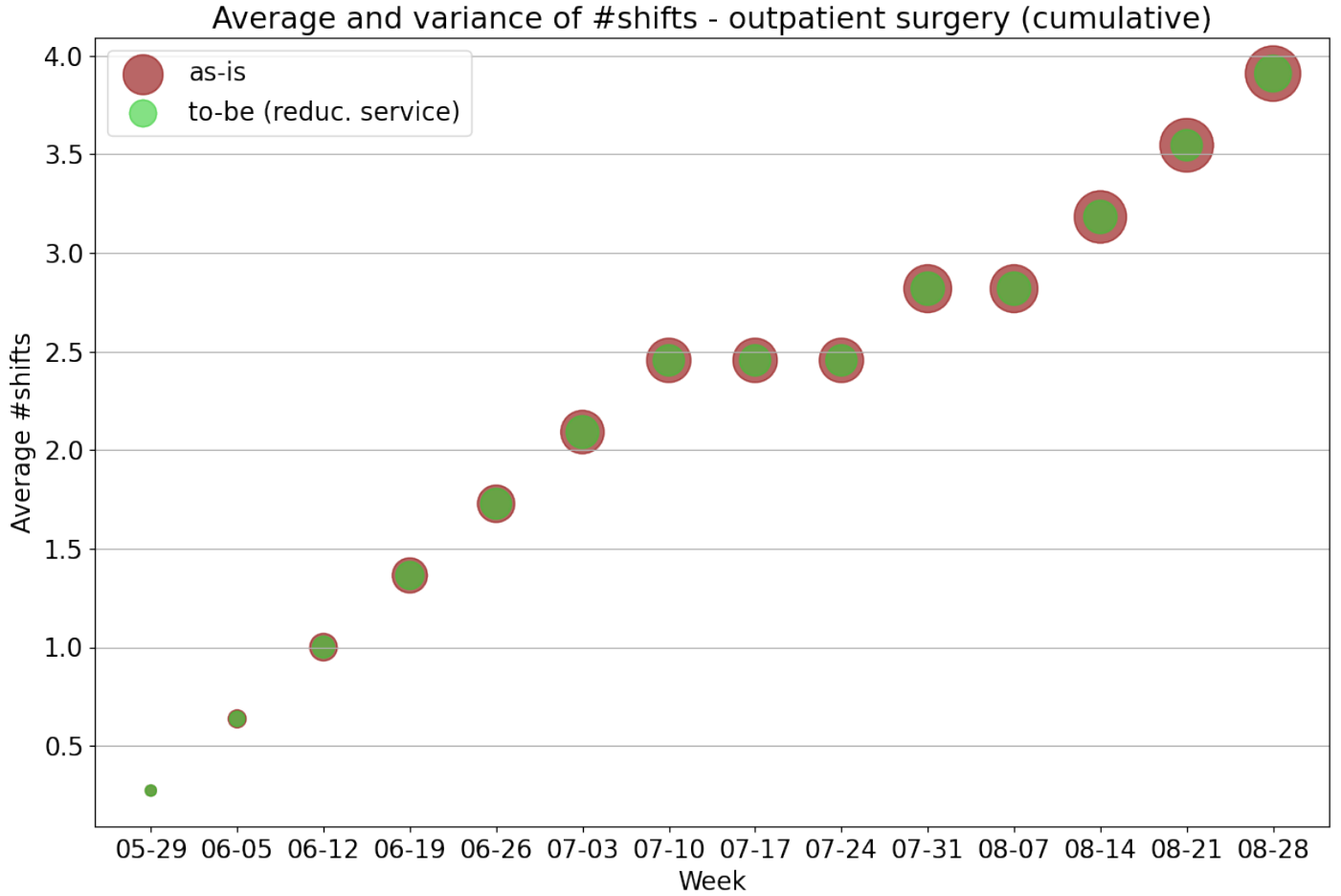


To fill the gaps left by absent doctors, other doctors who normally don't work night shifts take their place. We have been asked to **prevent this from happening**

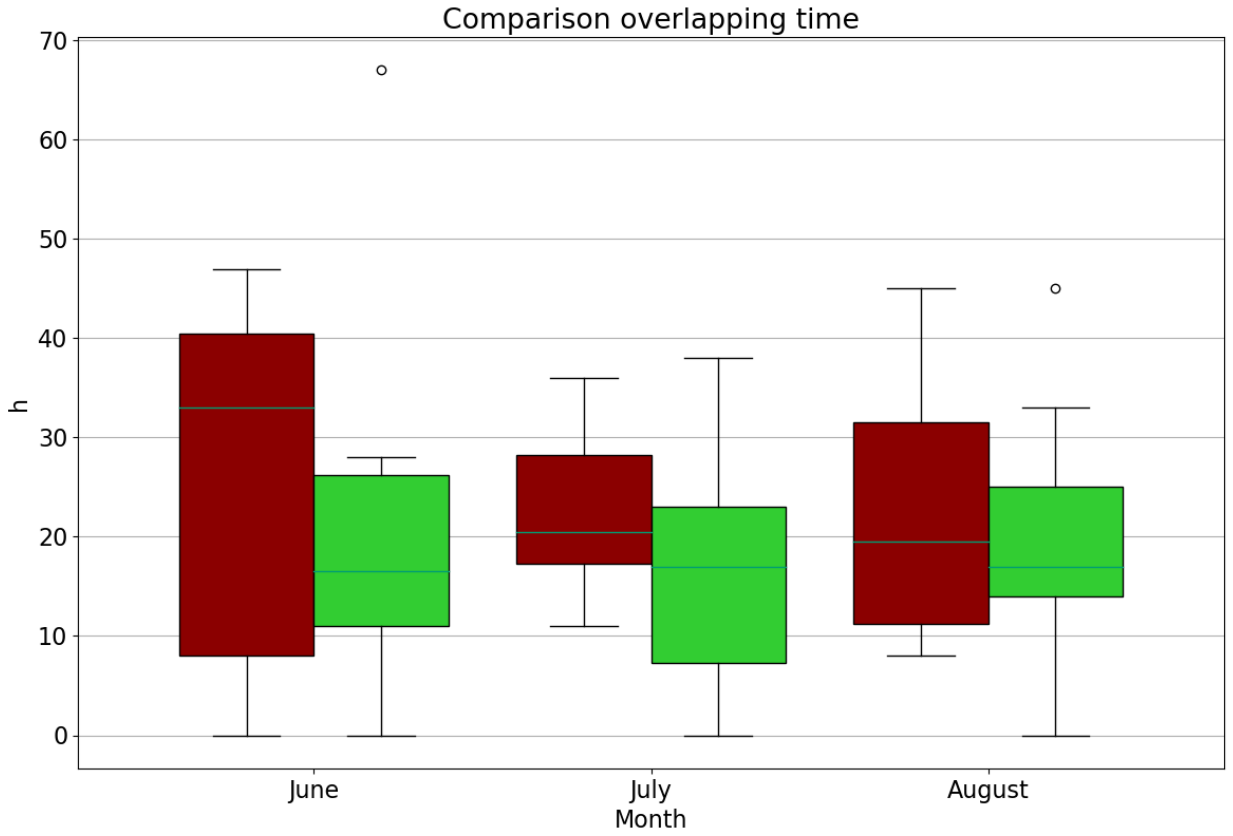
	Phys-Task Matrix violations (night on site)
2023-05-29	1
2023-06-05	3
2023-06-12	0
2023-06-19	2
2023-06-26	2
2023-07-03	0
2023-07-10	0
2023-07-17	2
2023-07-24	2
2023-07-31	2
2023-08-07	2
2023-08-14	3
2023-08-21	0
2023-08-28	4

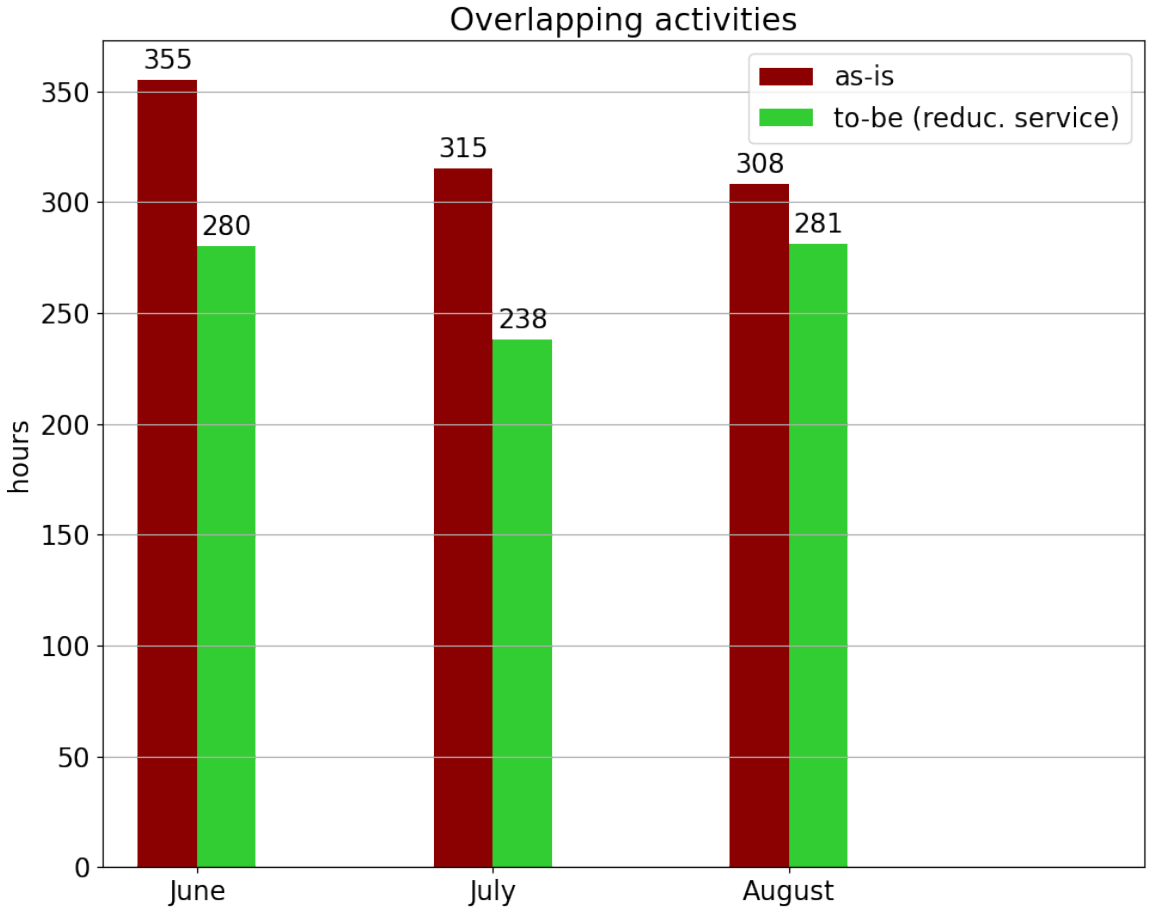
Same service setting
Outpatient surgery

Using the same setting, introducing the service reduction we observe a variance shrinkage



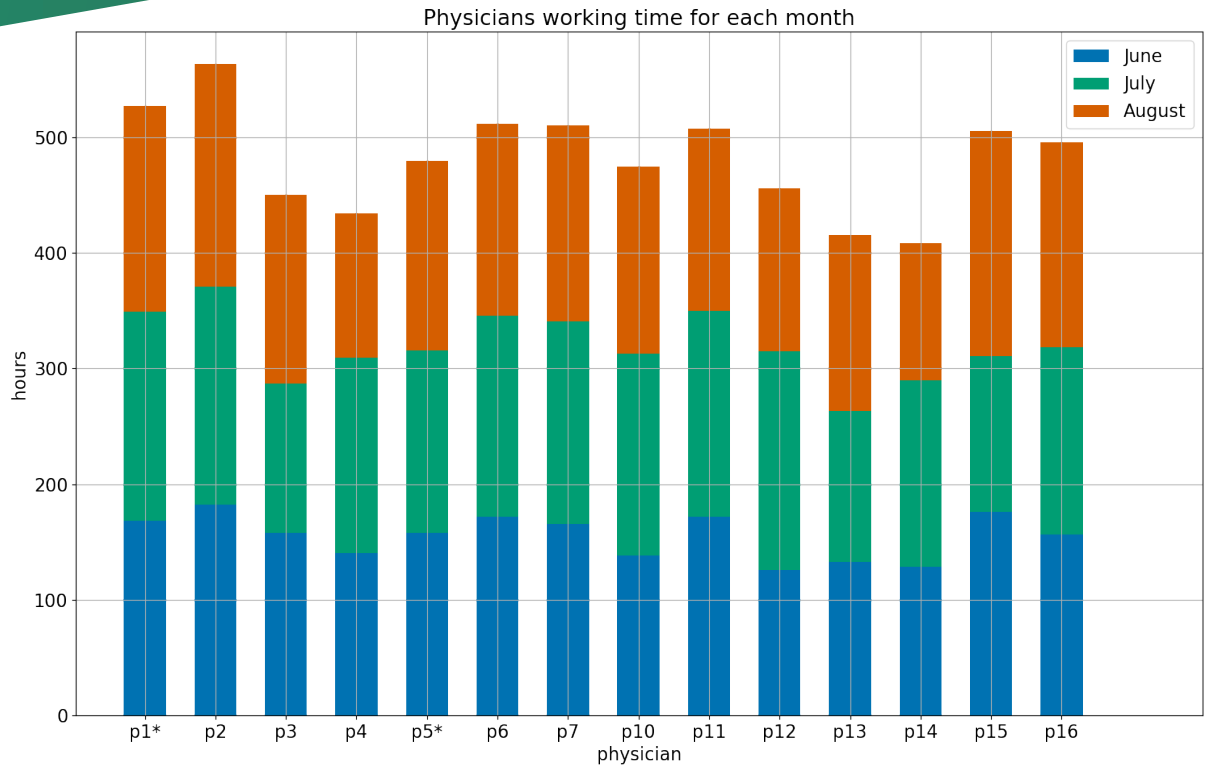
Same service setting
Overlapping time



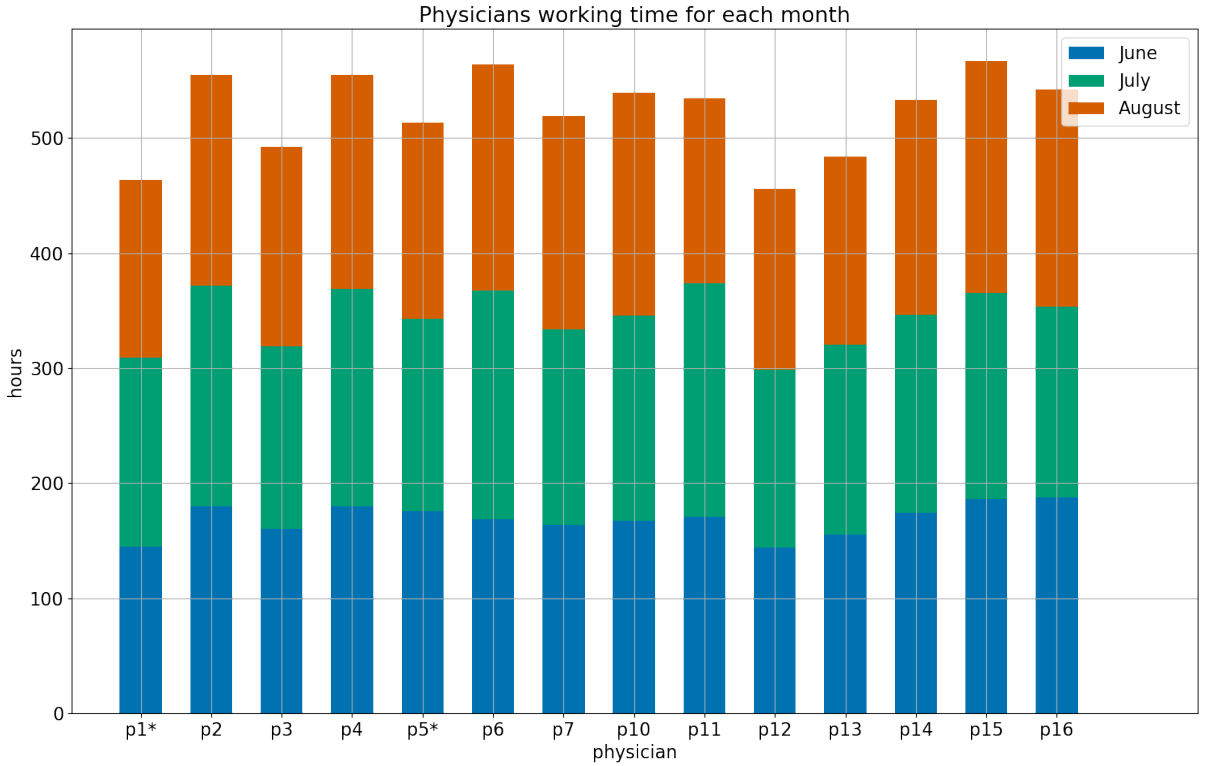


Same service setting
Working time balance

as-is

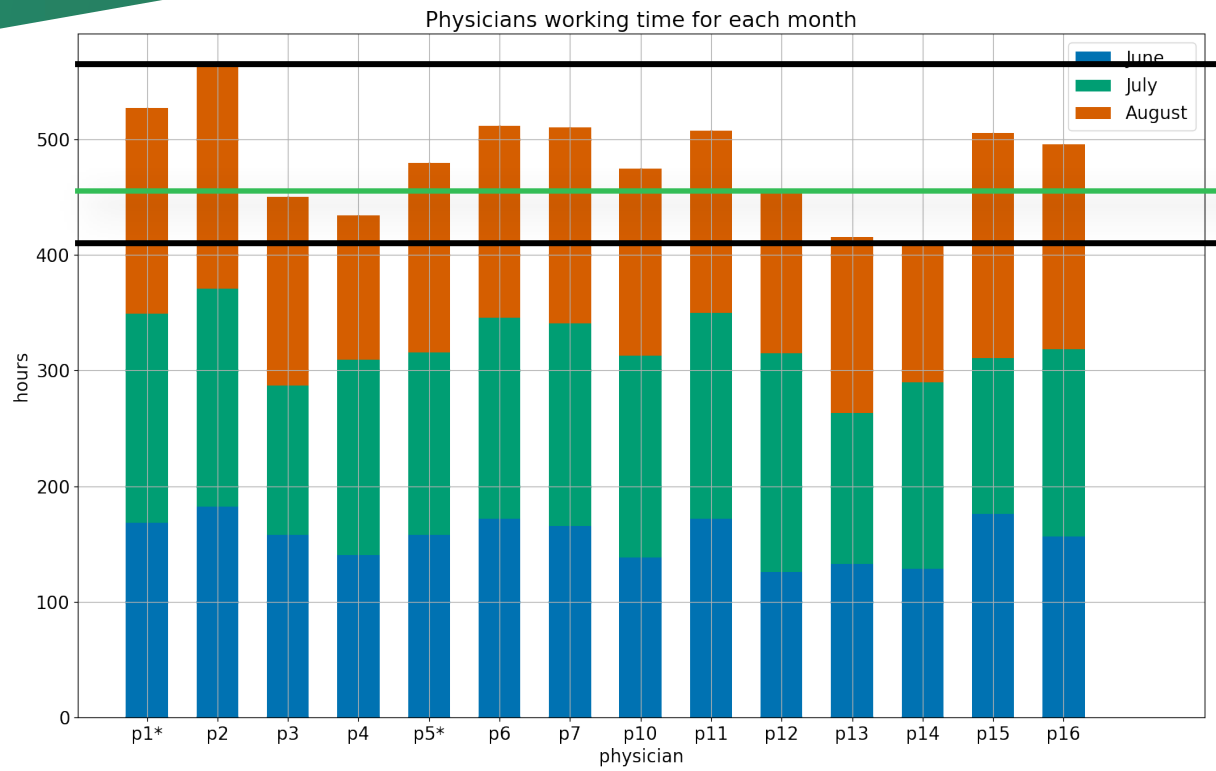


to-be



Same service setting
Working time balance

as-is



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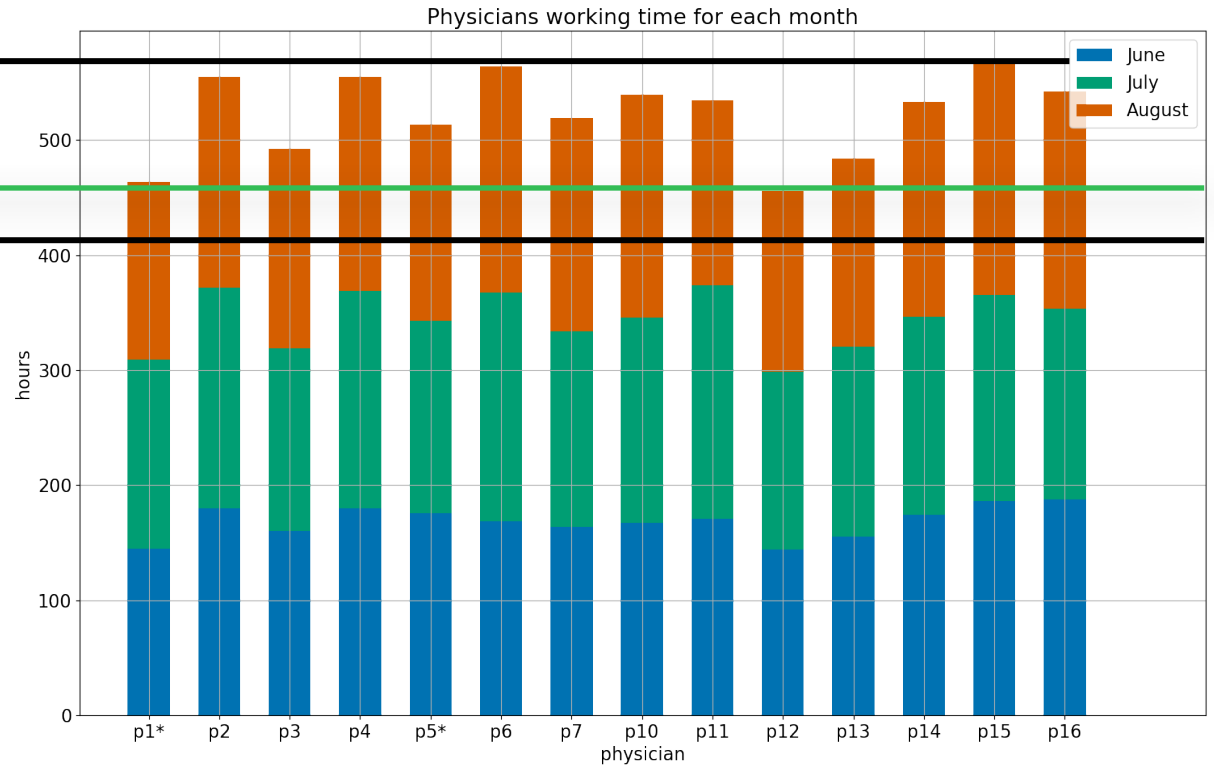
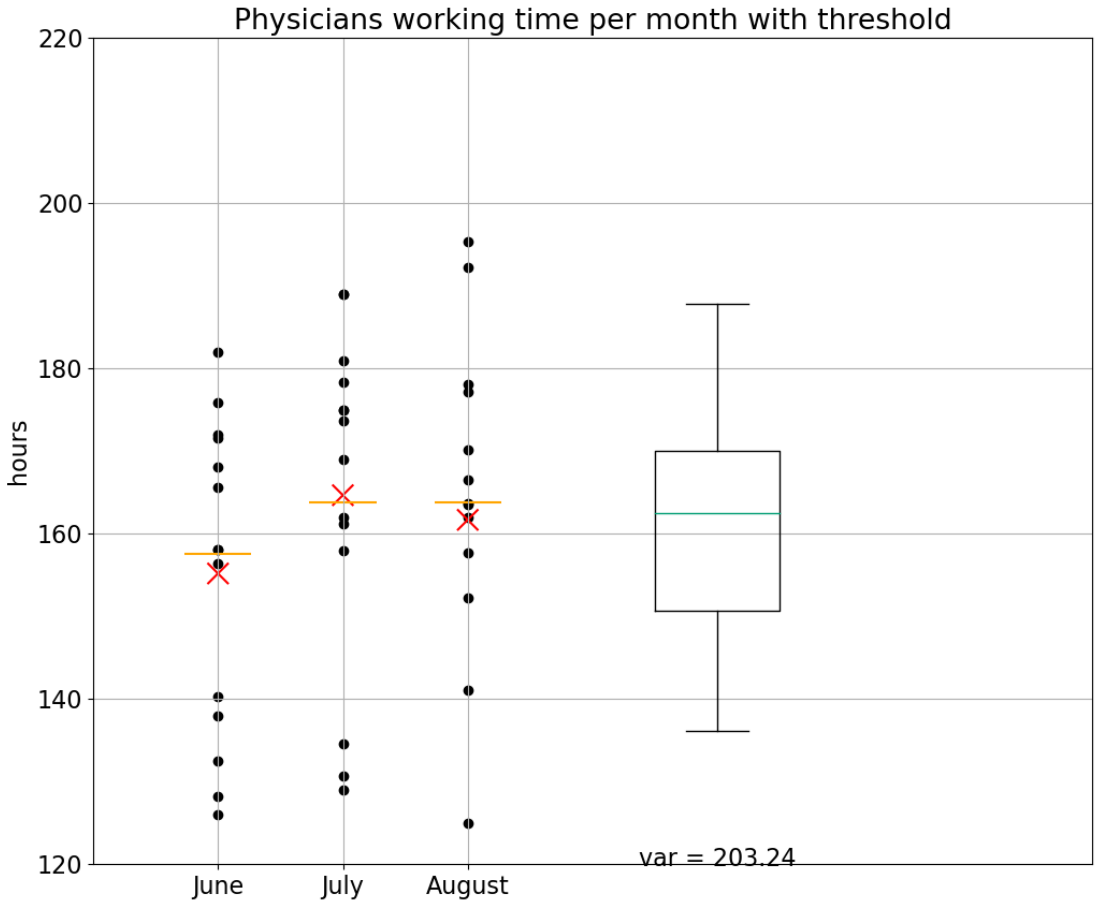


Same service setting
Working time threshold

as-is



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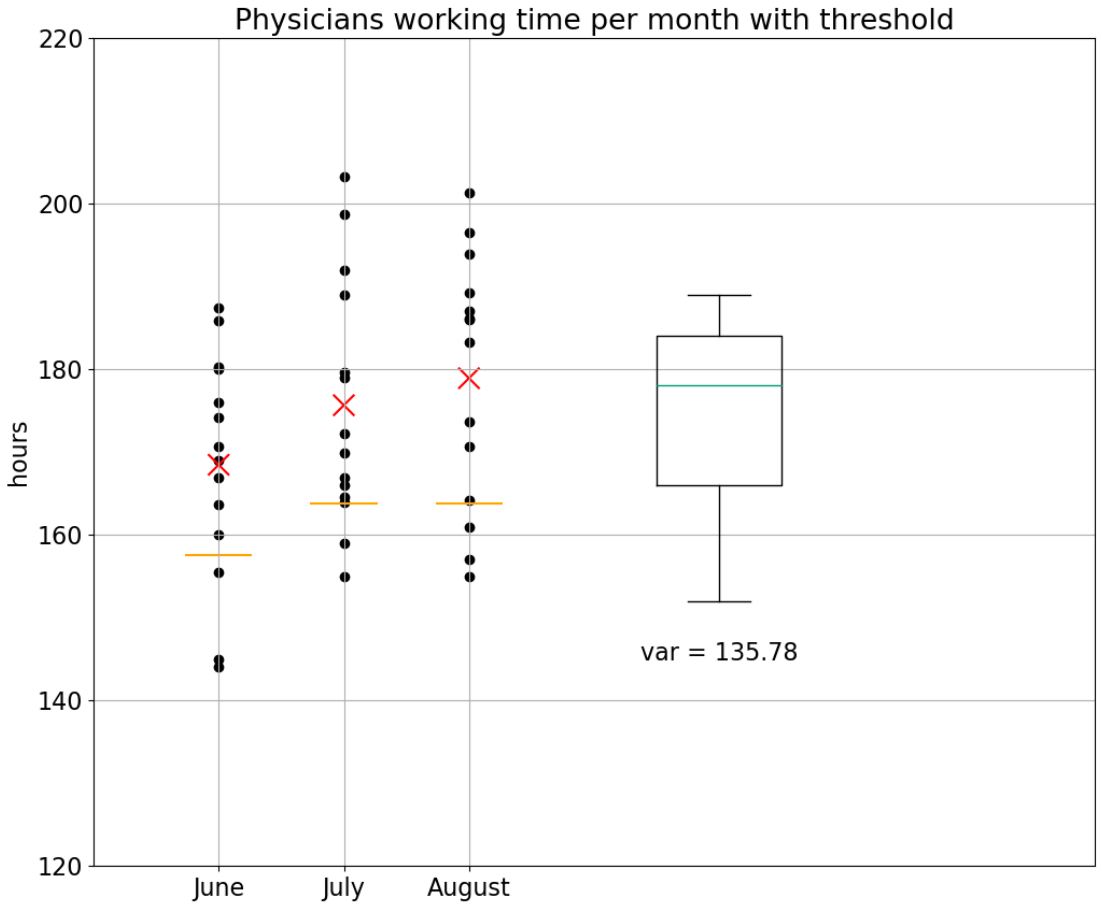

Same service setting
Working time threshold

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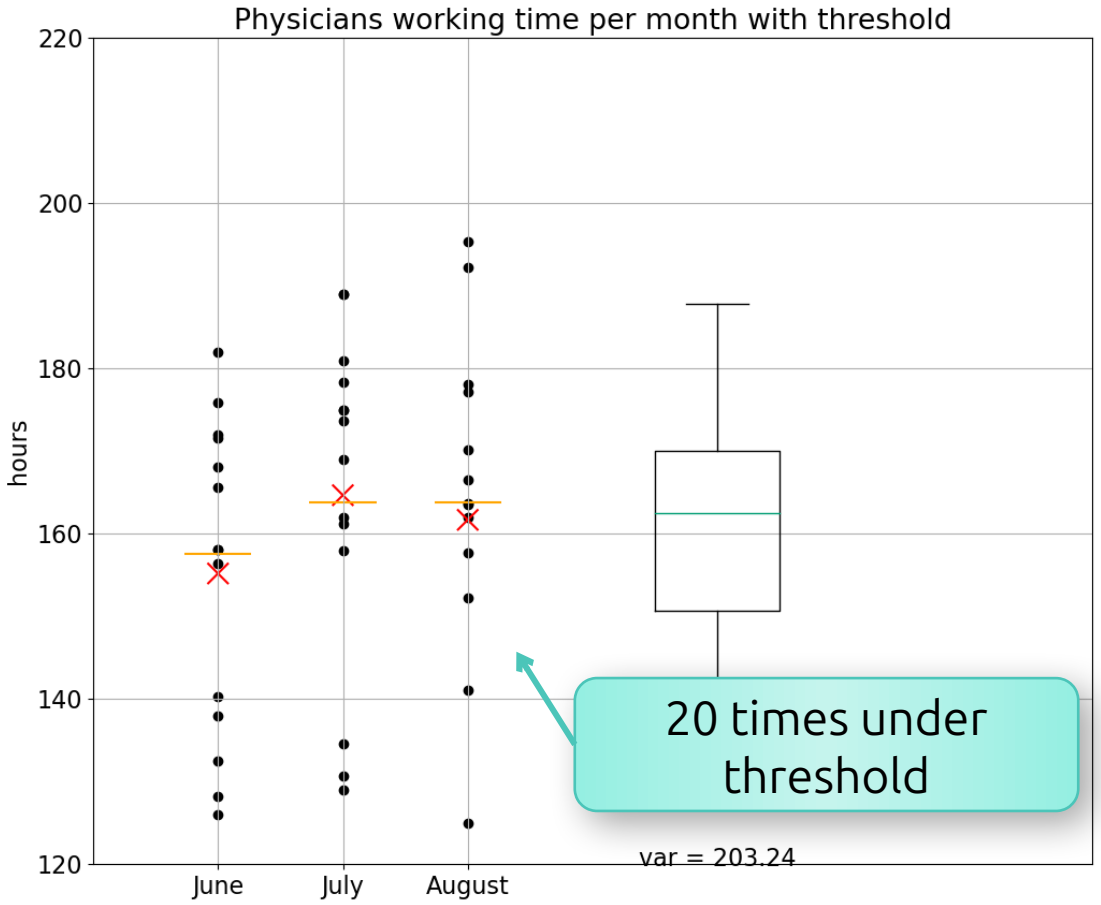

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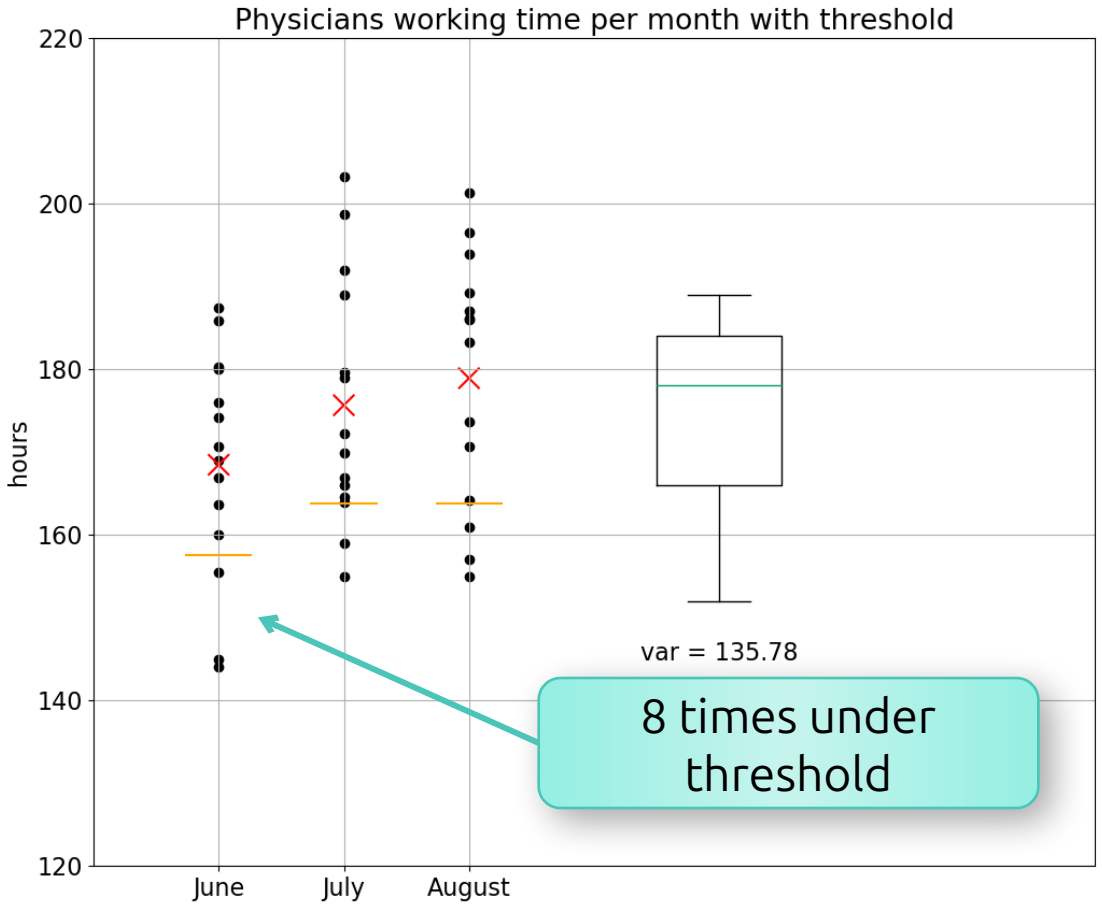

Conclusions

- **Real life scheduling problem** involving surgeons at a network of local hospitals
- Many soft and hard constraints suggest a **logical model**
- Challenge: how to achieve **fairness** in case of unequal skill distribution and large task variety
- A **memory-based mechanism** to implement a rotation in the mid term
- A comparison with hand-made solutions: full service guaranteed and more equal distribution of workload among physicians when the system is stressed
- Future works:
  - Involve stakeholders (management and surgeons) in solution ranking to induce a preference structure and capture individual preferences
  - Benders Decomposition to certify optimality and allow backtracking

Thank you for your attention!

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