WORK DESIGN AND SCHEDULING FOR DIALYSIS CLINICS

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Overview

"[This is] an ICU-type procedure, that would ideally be conducted in an inpatient sterile setting, being done outpatient with providers who often have much less training and expertise."

Parker et al (2024) in *American Journal of Kidney Disease*

1. Characterizing dialysis clinic challenges

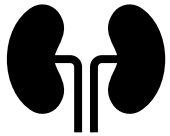
- Scheduling challenges
- Economic/societal importance
- Connections to other operations

2. Work design and scheduling analysis

- "Push" vs "Interlaced" vs "Tandem"
- Optimality structure and time trade-offs
- Strategic decisions for clinic operations

Dialysis as an Operations

Put-on	Treatment	Take-Off
25 min *(15 min 1st shift)*	*Duration prescribed by doctor, usually 3-4 hours (MWF or TTS)* *Negligible labor requirement*	*20 min*


Labor Considerations

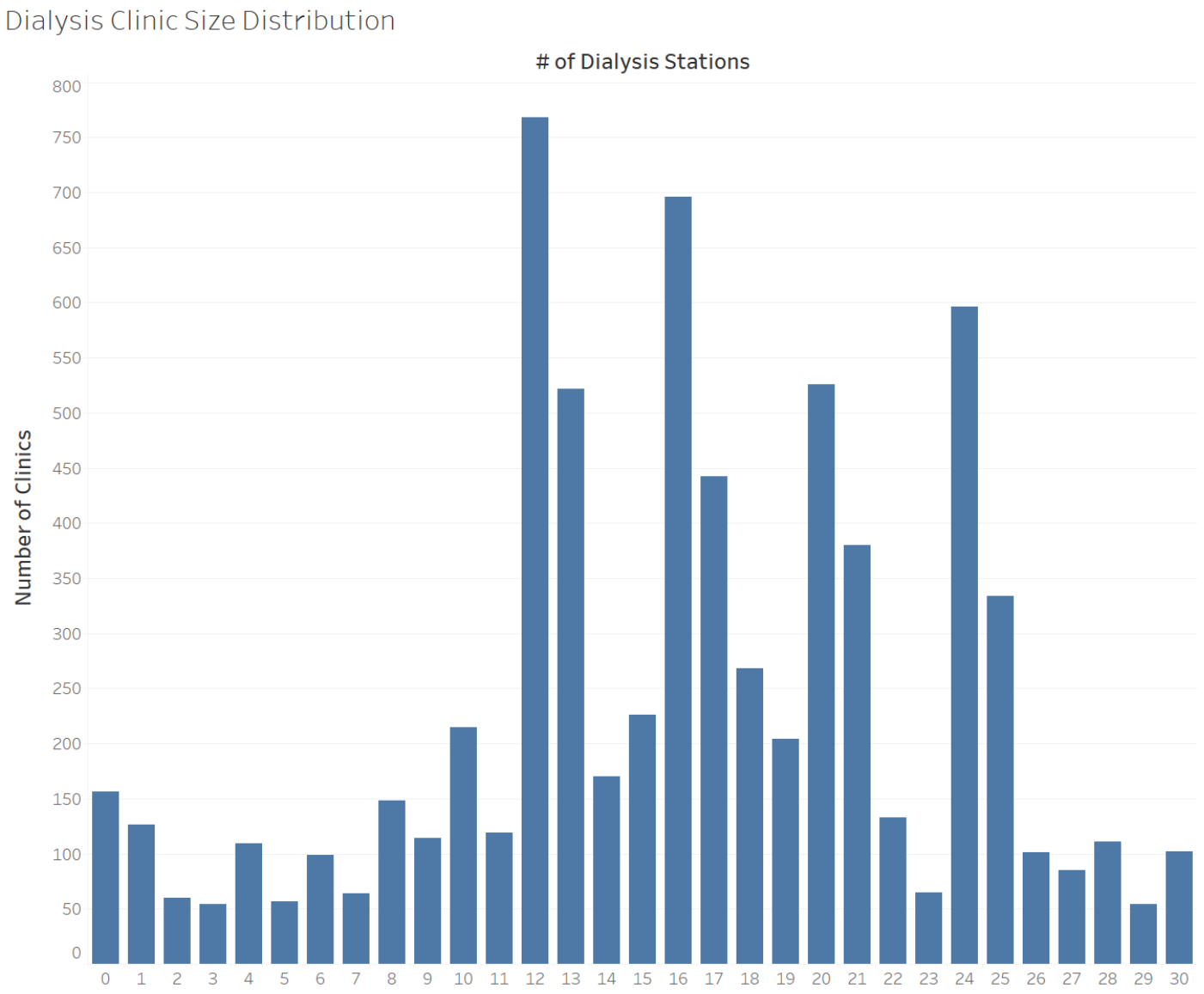
- ***Personal care technicians (PCTs)*** care for up to 4 patients simultaneously
- A typical shift is 4 AM – 7 PM, 3 times per week
- Frustrations from “conflicts” in schedules leads to stress and turnover
- ***Registered nurses (RNs)*** support up to 12 stations at once

Facility Considerations

- Usually have 12/16/20/24 stations, grouped into “pods” of 4 stations
- Each day has three “shifts” of patients
- Patients belong to MWF group or TTS cohorts
- Early morning treatment times are prized
- Waiting is very costly

A Dialysis Clinic: Pods of 4 stations

Clinics usually have 12, 16, 20, or 24 chairs



CMS reports that there are 7,581 dialysis facilities comprising 133,195 stations

Clinics sometimes have an extra chair with additional infection control protocols

Kidney Dialysis: 6% of Medicare Spending

DaVita

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News & Events

NEWS RELEASES EVENTS 2021 CAPI

Volume: Total U.S. dialysis treatments for the second quarter of 2023 were 7,231,242, or an average of 92,708 treatments per d
compared to the first quarter of 2023. Normalized non-acquired treatment growth in the second quarter of 2023 compared to t

	Three months ended			Six months ended		
	June 30, 2023	March 31, 2023	Quarter change	June 30, 2023	June 30, 2022	Year to date change
	(dollars in millions, except per treatment data)					
Revenue per treatment	$ 376.73	$ 366.14	$ 10.59	$ 371.48	$ 363.47	$ 8.01
Patient care costs per treatment	$ 252.57	$ 257.34	$ (4.77)	$ 254.94	$ 249.85	$ 5.09
General and administrative	$ 279	$ 259	$ 20	$ 538	$ 458	$ 80

Related Literature

- **Mathematical Programming Approaches to Dialysis Clinic Scheduling**
  - Farhadi et al (2023)
  - Reihaneh et al (2023)
  - Nwaneri et al (2021)
  - Fleming et al (2020)

- **Other Research on Dialysis Clinics**
  - Webb and Wish (2024) on care technician staffing ratios
  - Bozkir et al (2023) on patient cohorting during the pandemic

- **Related Topics**
  - Li and Slaugh (2024) on resource turnaround operations, such as hotel housekeeping
  - Allahverdi et al (2008), a survey of scheduling problems with setup times

What are our goals?

Minimizing Labor Costs

Various ways to define…

Day Length

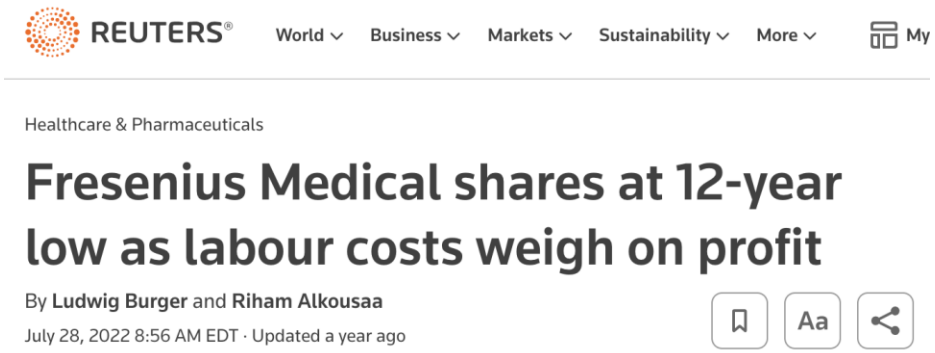
- Reducing the facility end time

Labor Efficiency: Direct Patient Care (DPC) Hours Ratio

- Reducing total labor hours, including PCTs and RNs

Skills-Mix Weighted Costs

- Weighting labor costs by hourly wage differences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Healthcare & Pharmaceuticals

Fresenius Medical shares at 12-year low as labour costs weigh on profit

By **Ludwig Burger** and **Riham Alkousaa**

July 28, 2022 8:56 AM EDT · Updated a year ago

Aa

Work Design

Without increasing DPC, improve the job by…

Reducing Stress

- Facility administrators manually build infeasible schedules(!) with conflicts for put-ons and take-offs
- Allow sufficient time: 25/20 minutes for put-ons and take-offs vs. only 15 minutes

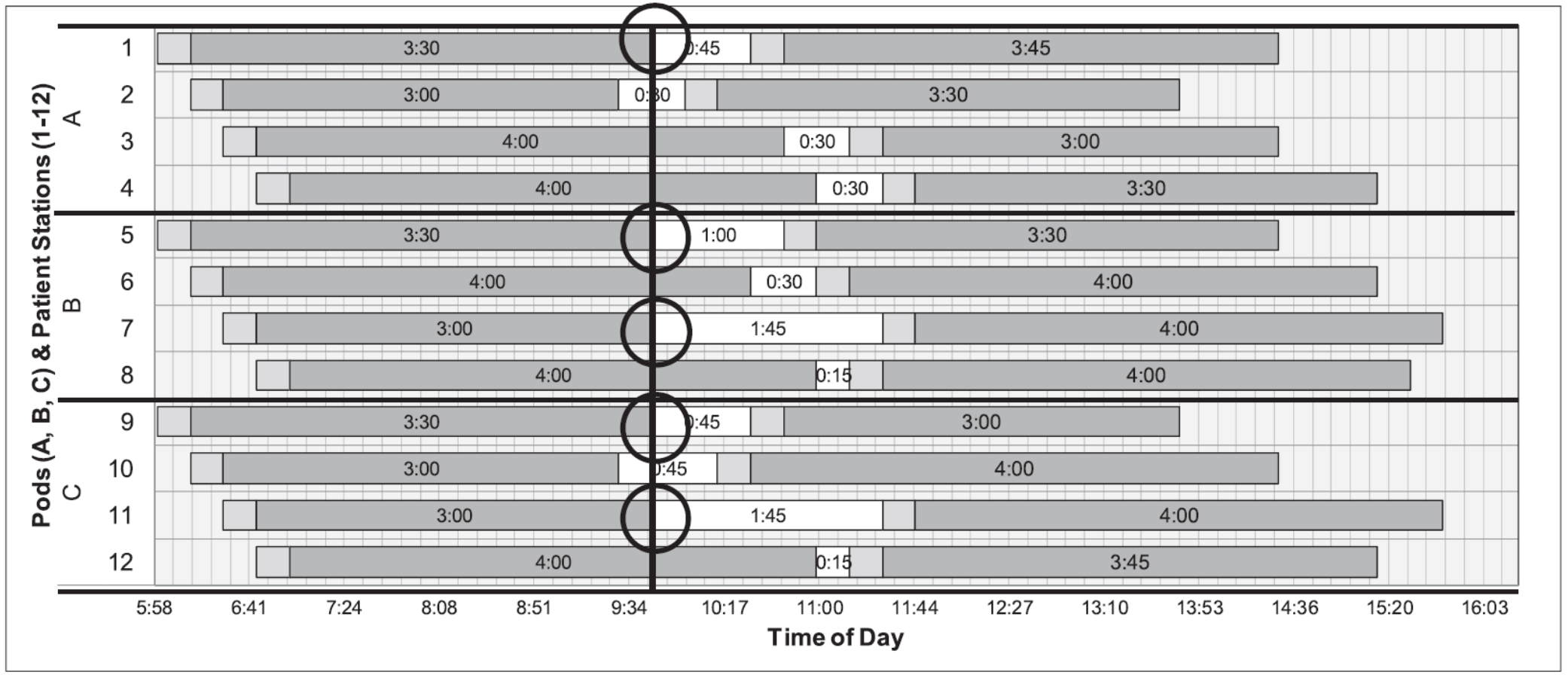
Reducing Switchovers

- Work in tandem to specialize in put-ons or take-offs to avoid switching between complex tasks

Facilitating High-Value Care

- Schedule stability allows caregivers to invest in secondary care tasks

Clinic Operations: The Current Challenge



from Parker et al (2024) in *American Journal of Kidney Disease*

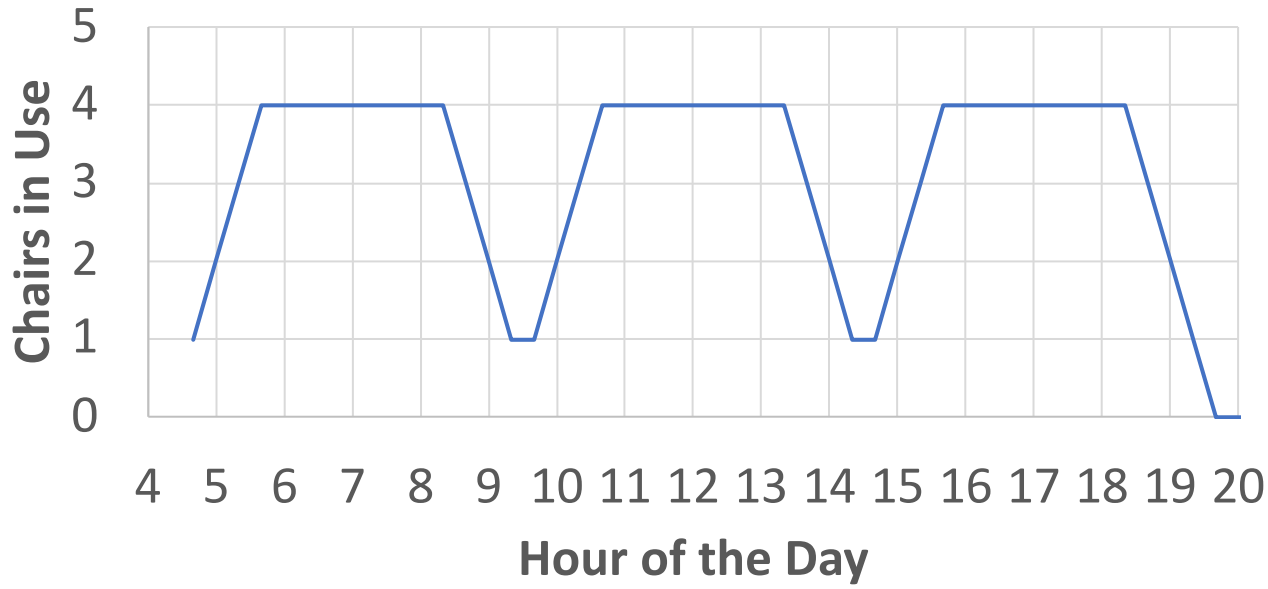
The PUSH system

***PUSH (aka "stacked")*: Schedule patients to begin put-ons as early as possible**

- Patients tend to prefer earlier treatment times
- Nice and tidy: no overlap between 1st, 2nd, and 3rd shifts of patients
- Investigated dozens of facilities' schedules, and all had the hallmark "peaks-and-valleys" graph for the number of patients in treatment over time → this strategy is standard

Simplified push model with 20-minute put-on, 20-minute take-off, and 3:20 treatment duration

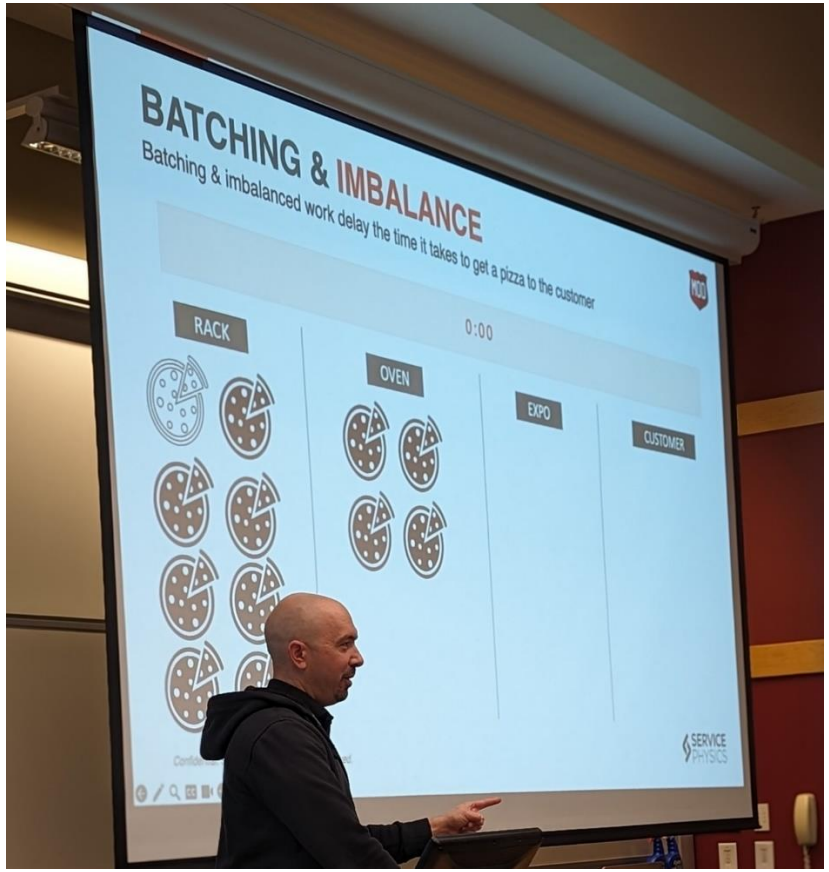
This *should be* optimal, right??



Last take-off ends at 7:40 PM

No!

- Intuition: *The MOD Pizza's Oven Bottleneck Problem*

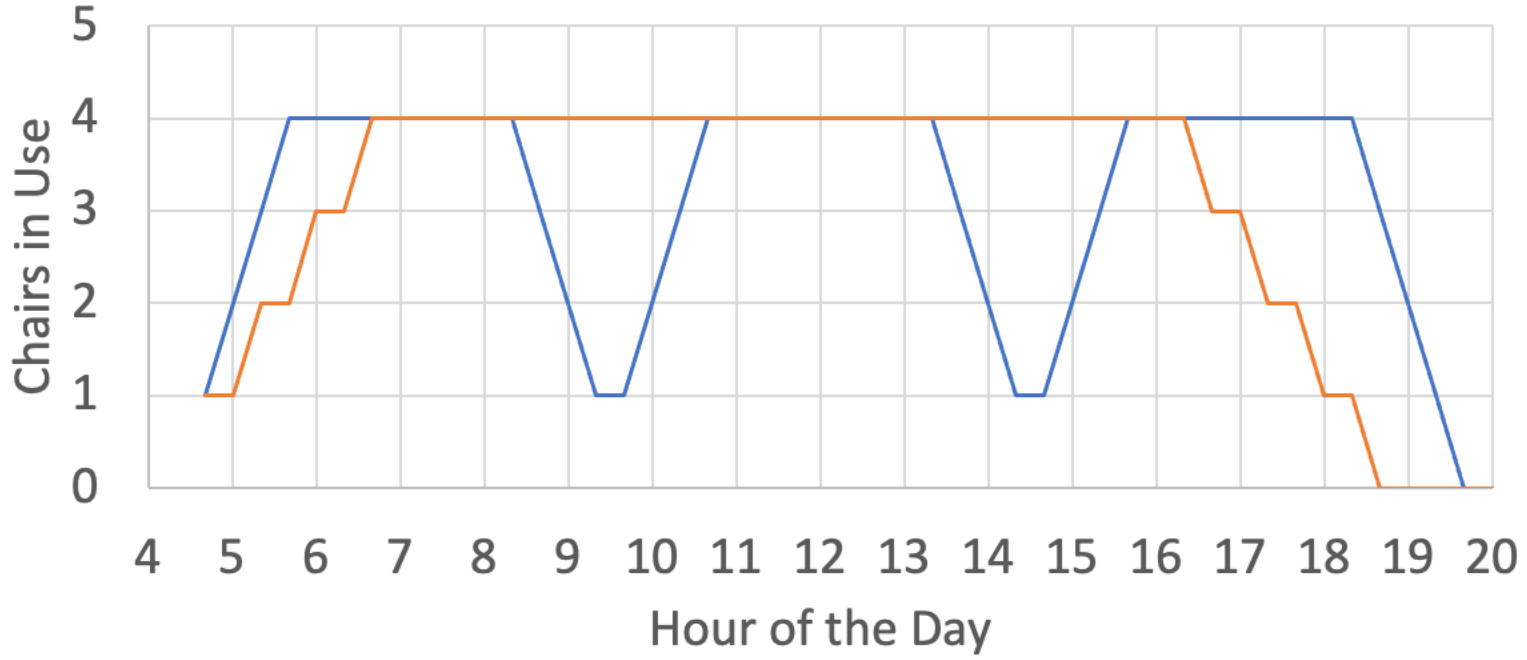


No!

- Intuition: *The MOD Pizza's Oven Bottleneck Problem*

What is the optimal strategy?

- The **Interlaced** strategy: leave gaps between patient put-ons



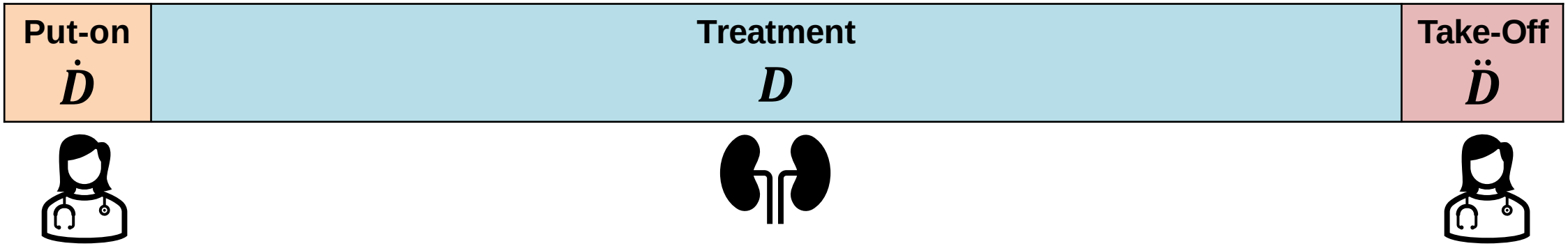
Last take-off ends at 6:40 PM

1 hour savings!!!

*This is an **interlaced** strategy because we are interlacing patients from 1st shift with 2nd shift and 2nd shift with 3rd shift*

Benefit of Rotary Systems

General Structure



PROPOSITION 1. *Consider a pod with C chairs and one technician, and suppose that $D > (C-1)\cdot\dot{D}$. The completion time of the n-th patient in the push system is*

$$Z^P(n) := n\cdot\dot{D} + \left(\left\lfloor\frac{n-1}{C}\right\rfloor + 1\right)\cdot(D+\ddot{D}). \qquad (7)$$

Key insight: grows linearly with the number of patients *n* and put-on times

Characterizing the INTERLACED system

- What happens to the **interlaced system**?

PROPOSITION 2. *Consider a pod with C chairs and one technician, and suppose that $D > (C-1)\cdot\dot{D}$. The completion time of the n-th patient in the interlaced system is*

$$Z^I(n) := \left(\left\lfloor \frac{n-1}{C} \right\rfloor + 1\right)(\dot{D} + D + \ddot{D}) + ((n-1) \mod C)(\dot{D} + \ddot{D}). \qquad (11)$$

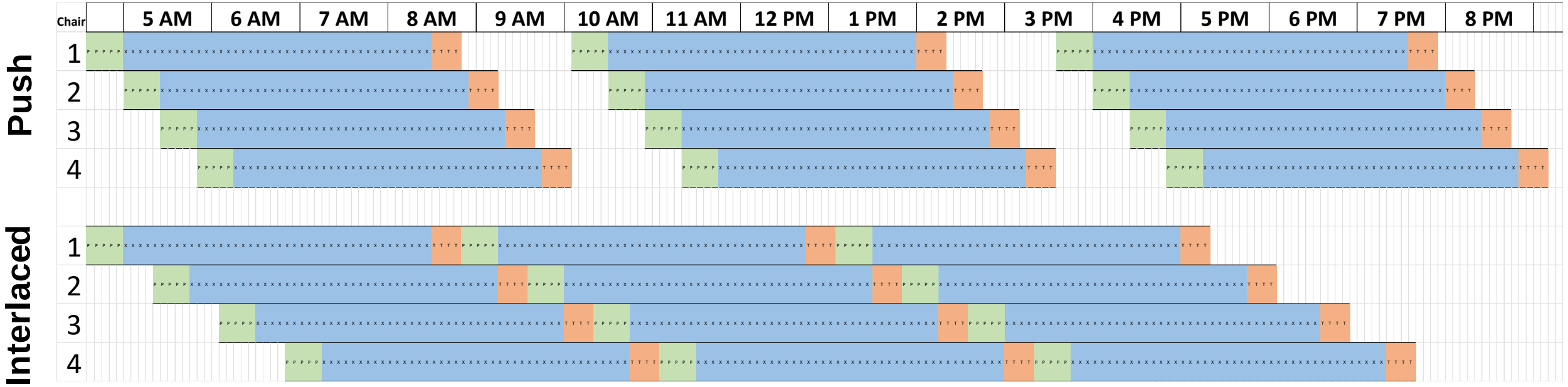
Key insight: removes that linear term as patients do not need to wait until a chair is available

PROPOSITION 3. *The makespan of an interlaced system is shorter than the makespan of a push system by*

$$\left((C-1)\left\lfloor \frac{n-1}{C} \right\rfloor\right)\cdot\dot{D} - ((n-1) \mod C)\cdot\ddot{D}.$$

Interlacing is optimal for solo PCT pods

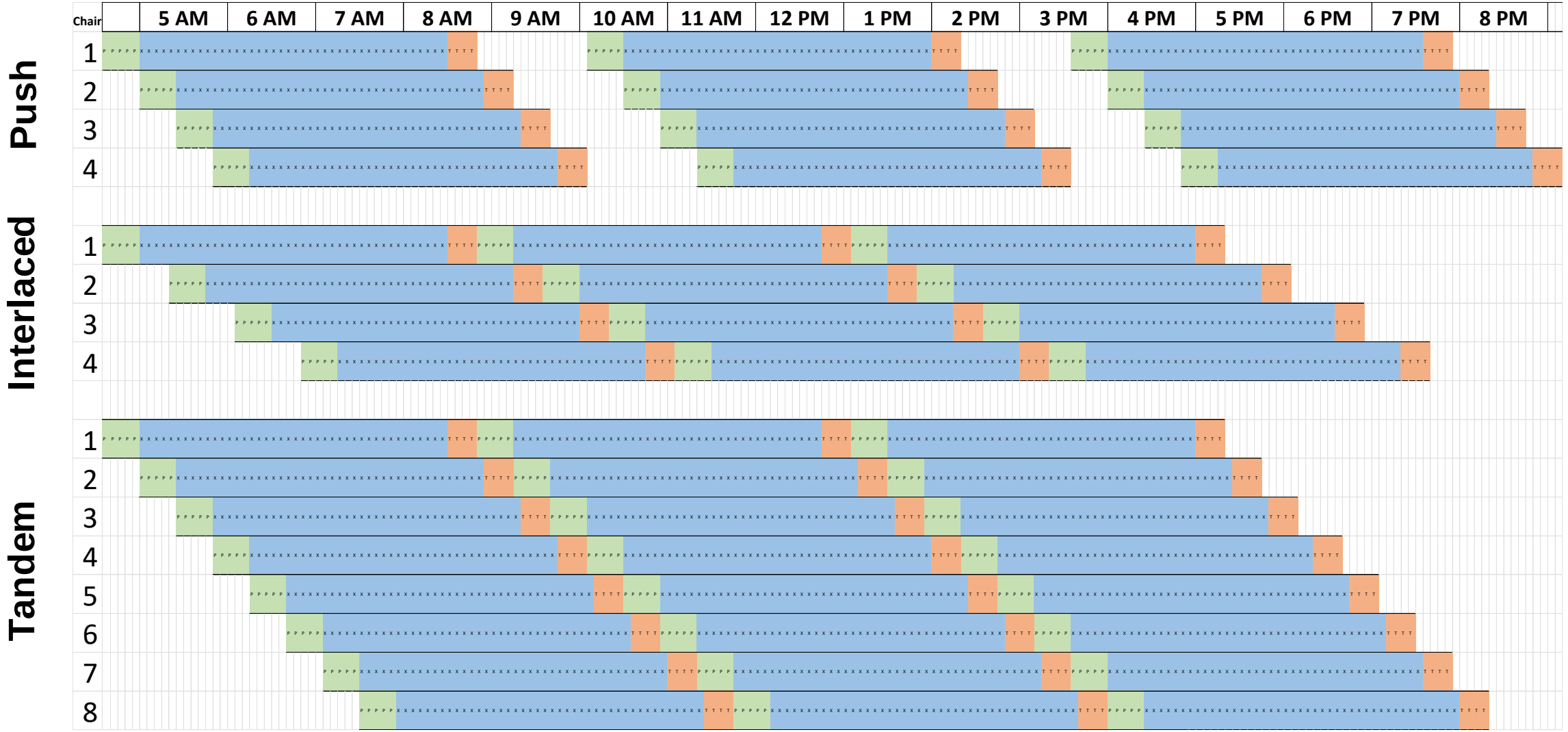
PROPOSITION 4. *The interlaced system minimizes the makespan for* $n \geq C+1$.



With 25-min put-ons, 20-min take-offs, and 3.5-hour treatments for 12 patients, the interlaced strategy ends the PCT shift 1.5 hours earlier!

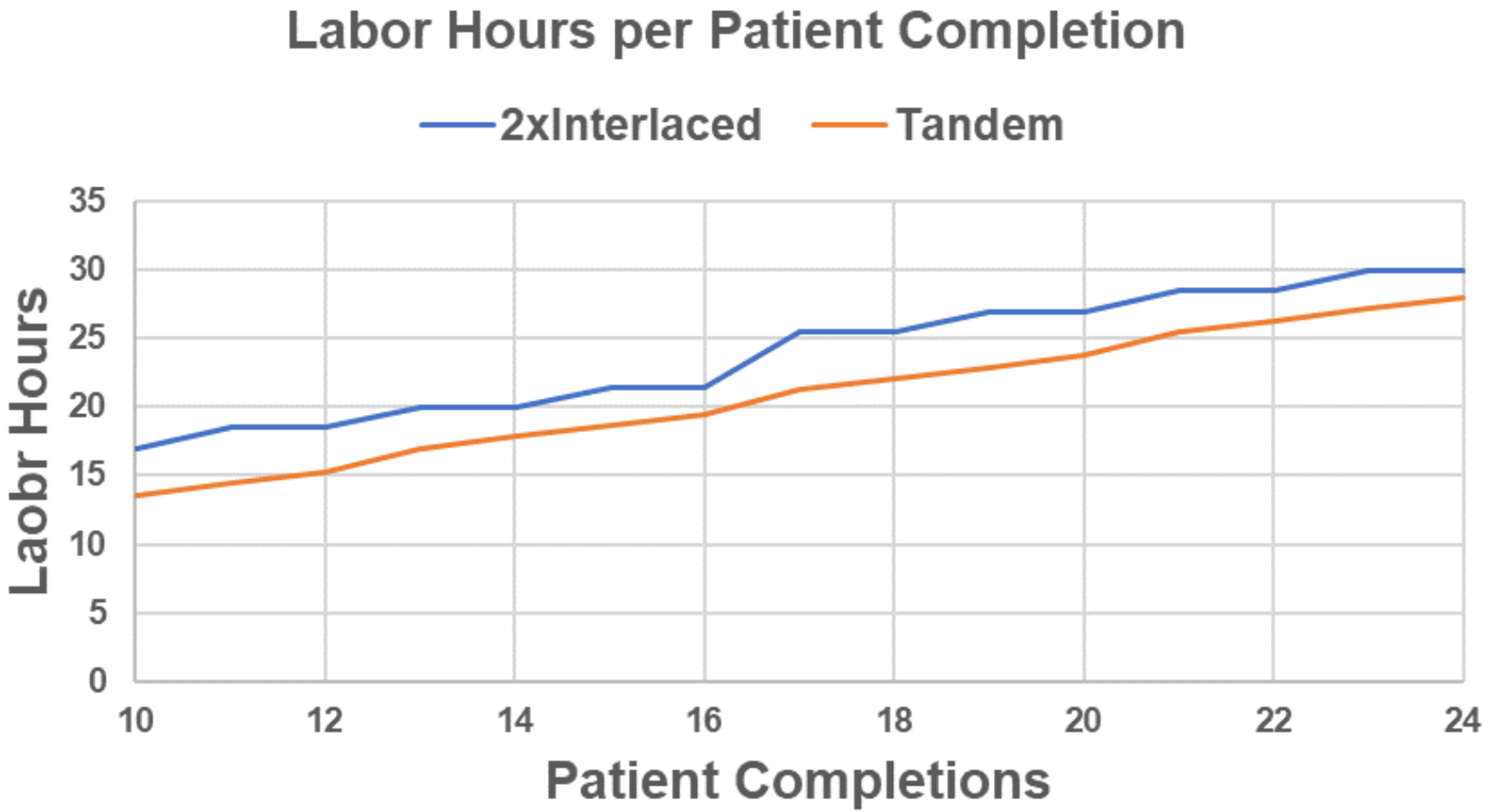
TANDEM System: What if 2 PCTS work together?

Combine 2 pods so that 2 PCTs serve 8 stations. What could be the benefit?



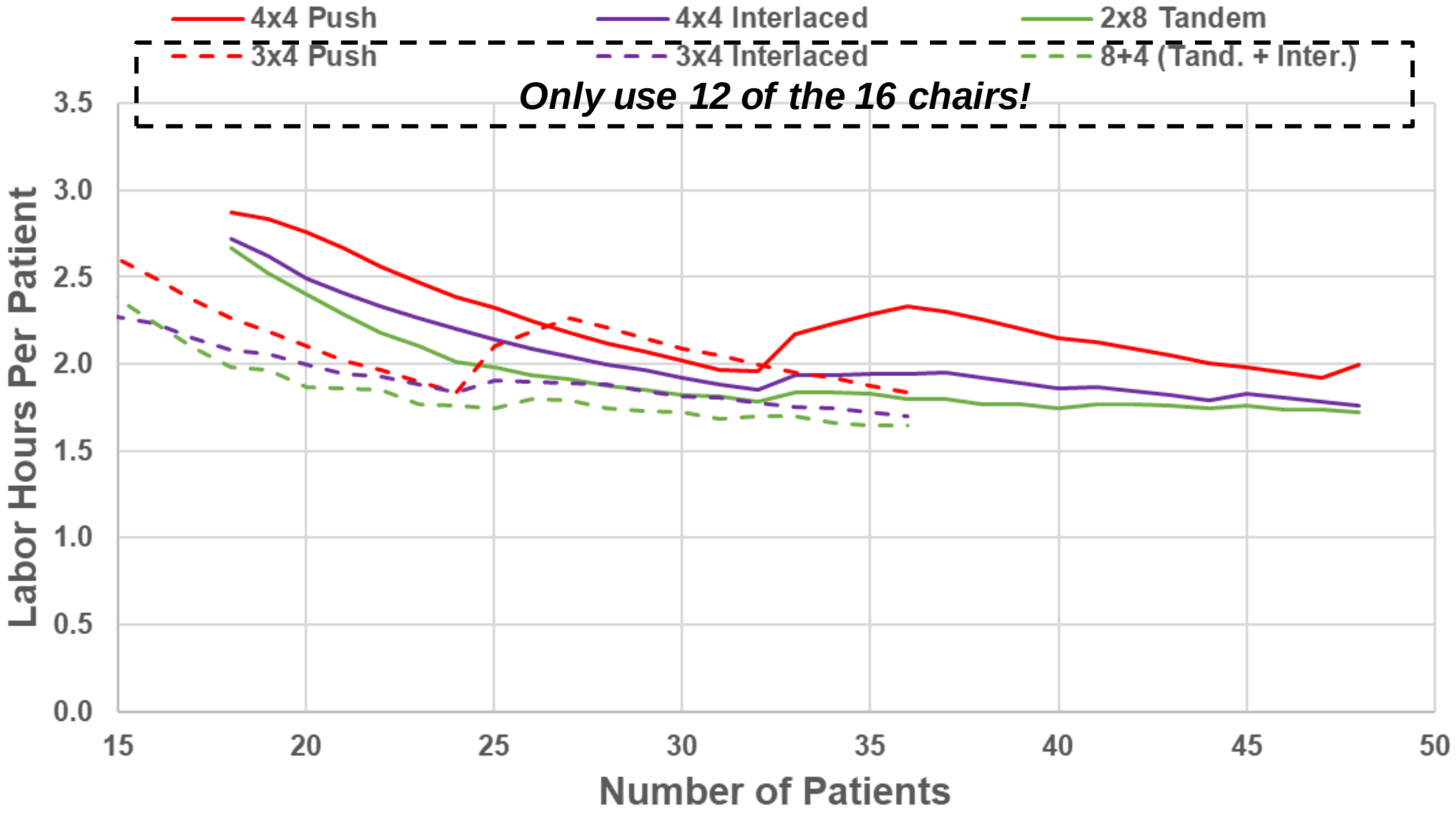
The Tandem system improves labor efficiency

With specialized roles, the take-off specialist PCT can come in later, and the put-on specialist PCT can leave earlier.



A strategic view of operating a 16-chair clinic

When there are fewer than 36 patients, operate one tandem and one interlaced pod



Lessons Learned

1. Process modeling for optimization can **uncover** firefighting and workarounds.
2. Human utilization **differs** from machine utilization, and sometimes the optimal policy can be counter-intuitive when humans and machines interact.
3. It **pays off** to think carefully about work design and consider new models for how work can be performed.

Thank you!

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