IF CAPACITY INCREASES, WHY DO MRI QUEUES PERSIST?

MRI PLANNING WITH FLUID MODELS AND REINFORCEMENT LEARNING

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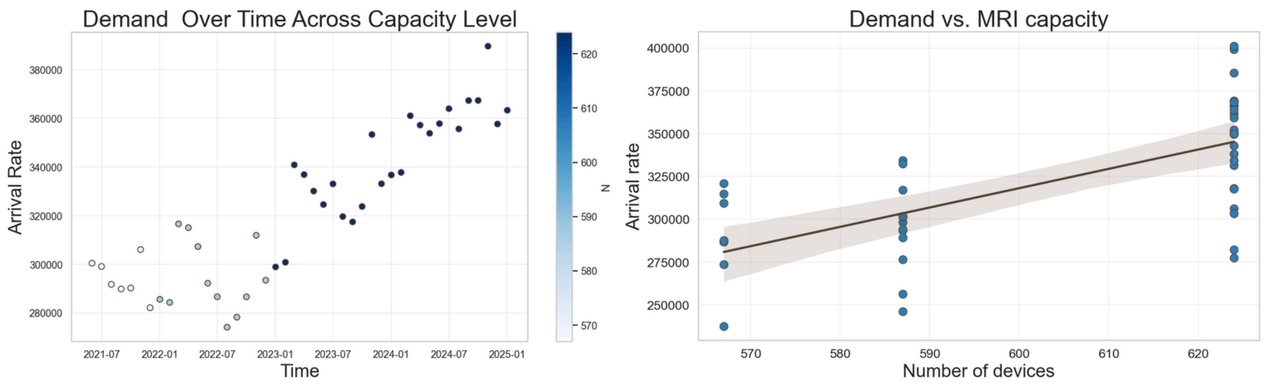
Health Economics

"Thousands of shekels for a test": The shortage of MRI machines is worsening, and some are making money from it

The shortage of MRI machines and radiologists in Israel means that people have to wait months for an examination — and for its interpretation. ■ Those who ask to advance their appointment will discover a fertile market of scammers. ■ Ministry of Health: "This is cynical and unacceptable exploitation. Appointments can be scheduled free of charge through the hospital's appointment scheduling centers."

THE MRI PARADOX

MRI capacity has grown rapidly (e.g., +50% in Israel), yet waiting times remain high. This MRI Paradox arises because added capacity may induce additional demand: lower referral thresholds reveal unmet need, leading to a new highly utilized equilibrium with persistent congestion. Using four years (2021-2025) of NHS MRI data, we estimate demand and model congestion as functions of time and installed capacity. A fluid approximation then captures system dynamics and defines a simulation environment. Since capacity decisions affect demand, congestion, and future system states, the optimal acquisition policy is analytically intractable; we therefore use reinforcement learning to learn adaptive planning policies.



Estimated demand increases over time and is positively associated with installed MRI capacity.

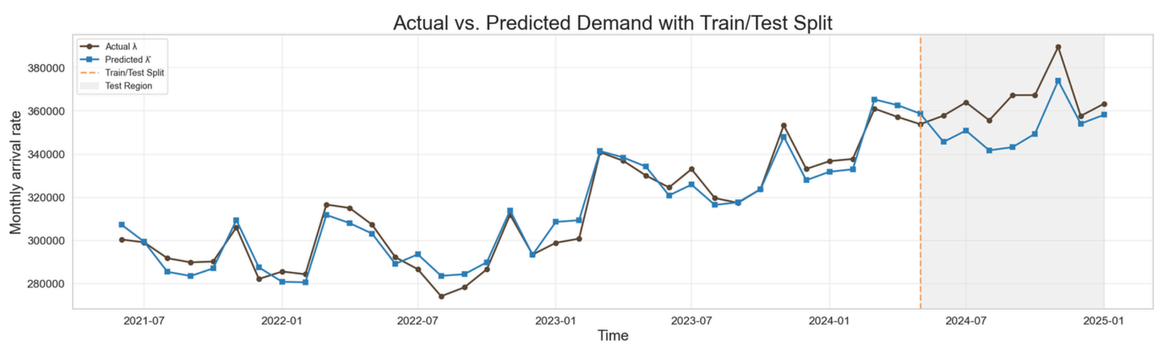
STATISTICAL DEMAND ESTIMATION

$$\lambda_t = \beta_0 + \beta_1 N_t + \beta_2 \sqrt{N_t} + \beta_3 t + \beta_4 \sqrt{t} + \gamma_m + \varepsilon_t$$

N_t : installed MRI capacity t : time trend

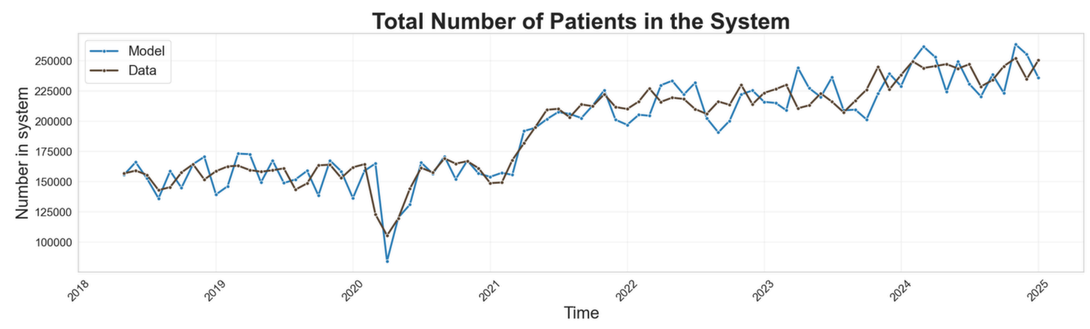
γ_m : month effect ε_t : unexplained variation

The estimated relationship between capacity and demand motivates the endogenous-demand formulation.



STATISTICAL DEMAND ESTIMATION

The fluid model captures how MRI capacity decisions affect monthly system dynamics: patient accumulation, service, and queue evolution. It provides the simulation environment used to evaluate acquisition policies.

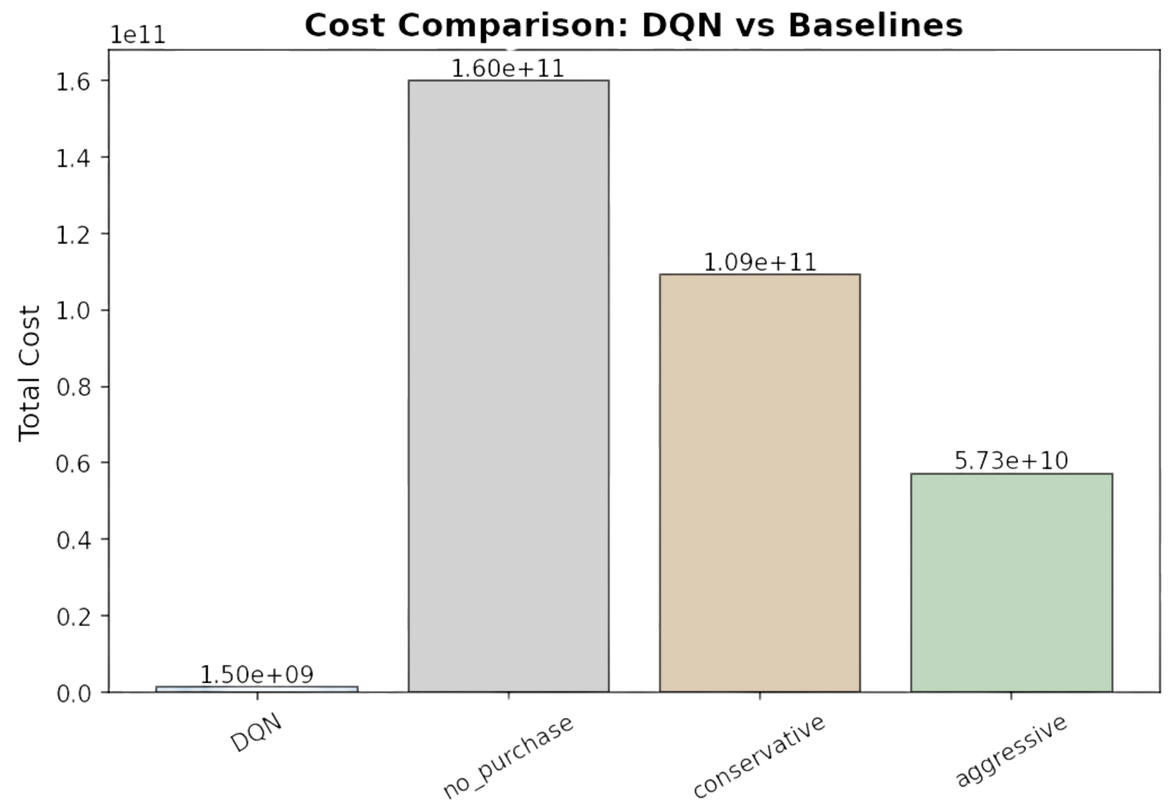


DQN ACQUISITION POLICY

A Deep Q-Network learns a capacity acquisition policy by interacting with the fluid simulation.

- State: time, capacity, demand, queue
- Action: purchase additional MRI machines
- Reward: total system cost, combining purchase costs, maintenance costs, and waiting costs, offset by service rewards

The learned policy adapts purchase timing to the evolving demand-congestion feedback.



FROM PARADOX TO POLICY

Increasing MRI capacity alone does not resolve congestion due to endogenous demand.
By combining fluid modeling with reinforcement learning, the DQN learns adaptive policies that account for demand response and optimize not only how much to invest, but when, achieving lower total cost than fixed baseline policies.