Service Appointment Scheduling with Walk-In, Short-term, and Traditional Scheduling

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Agenda

1. Problem Setting
2. Open Access and Walk-in Models
3. Computational Results
4. Managerial Implications
5. Future Research and Conclusions

1. Problem Setting

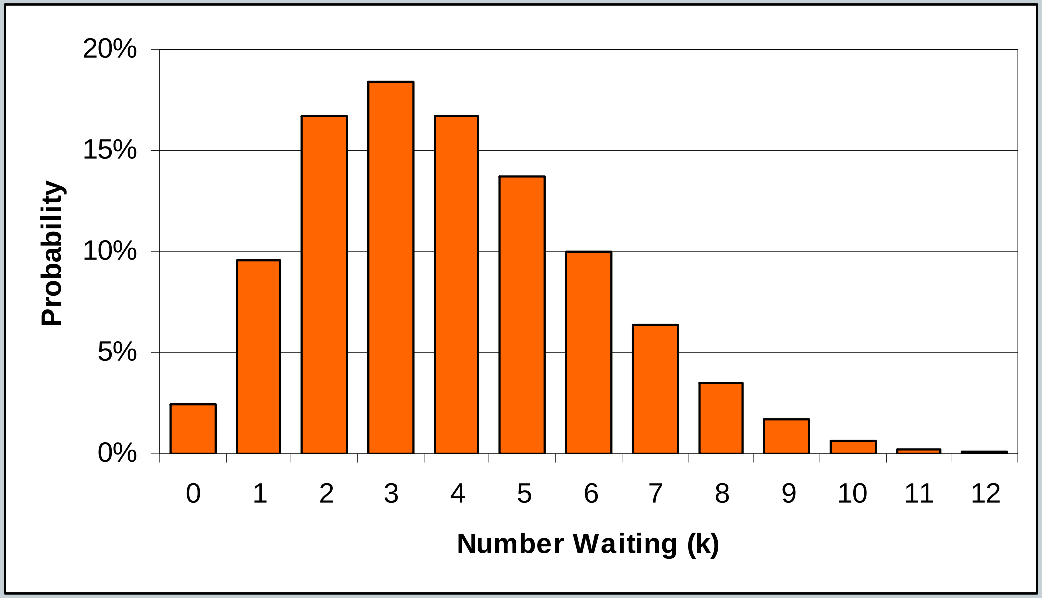
Objectives of Research

- Using what we've learned in healthcare clinics
  - Traditionally scheduled (TS) clinic
    - Some patients do not "show" for scheduled appointments
  - TS clinic wishes to increase scheduling flexibility
    - Some capacity allocated to "open access" (OA) appointments, <u>OR</u>
    - Some capacity allocated to "walk-in" traffic
  - Balance needs of clinic, providers, and patients
- Study impact of open access and walk-in traffic
  - When is open access or walk-in traffic beneficial?
  - What mix of TS, OA, and WI traffic is best?
  - What are trade-offs of TS, OA, and WI on clinic performance?

Optimize customer flow in service operations

- Restaurants
- Haircuts
- Automobile repair, maintenance, inspection
- Tax preparation
- Legal consultation
- Counseling
- Any real-time service provided directly to the customer or performed on their property, usually at the provider's location

2. Appointment Scheduling Model



Assumptions

- A service operation has N service slots
  - Each slot is d time units long (deterministic)
  - A service session then is $D=Nd$ time units in duration
- One or multiple undifferentiated providers P
  - Clients serviced by any available provider
- Customers can arrive in one of three ways
  - Binomial traditional appointments “show” with probability σ
  - Poisson open access call-ins with mean φ (per day)
  - Poisson walk-ins with mean λ (per appointment slot)
  - Arrivals have equal service priority (undifferentiated)

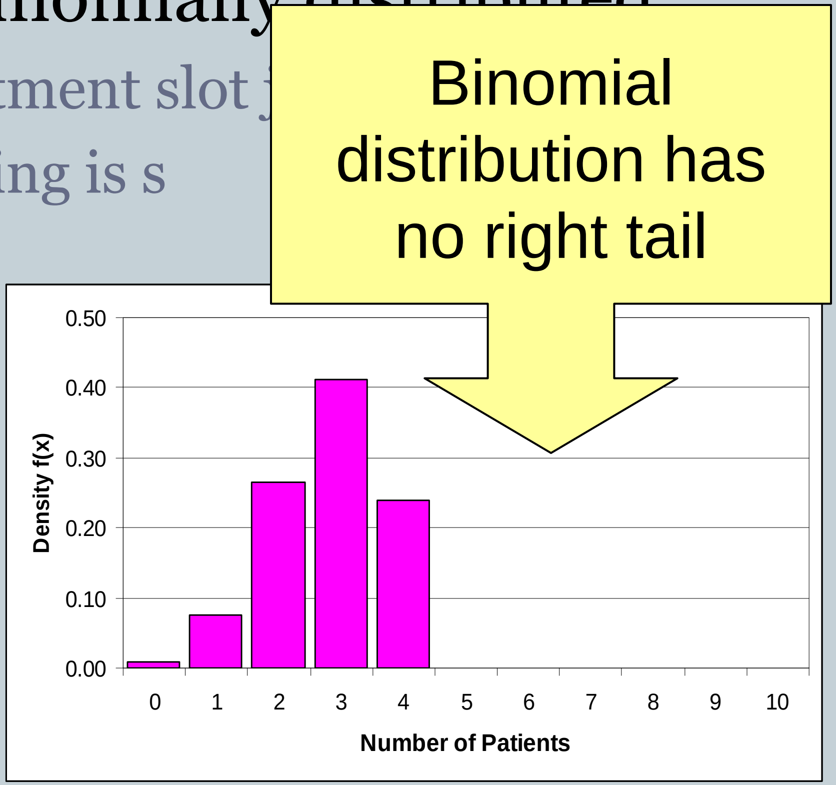
Characteristics of Model

- Model flexibility
  - Appt show rates σ_j can vary by service slot j (time of day)
  - Open access call-in rate φ can vary by day.
  - Walk-in rate λ_j can vary by treatment slot j
  - Number of providers P_j can vary by slot j
  - Any arrival distribution can be accommodated
- Customer arrivals
  - Customers are only seen at the start of a service slot (early arrivals wait for next slot without cost)
  - Customers are seen in order of arrival (FCFS)

Arrival of Scheduled Appointments

- Appointment arrivals are binomially distributed
  - s_j customers scheduled for treatment slot j
  - Probability of a customer showing is s
  - $a_j \le s_j$ actually arrive in slot j

$$b\left(a_j; s_j, \sigma\right) = \binom{s_j}{a_j} \sigma^k \left(1-\sigma\right)^{s_j - a_j}$$

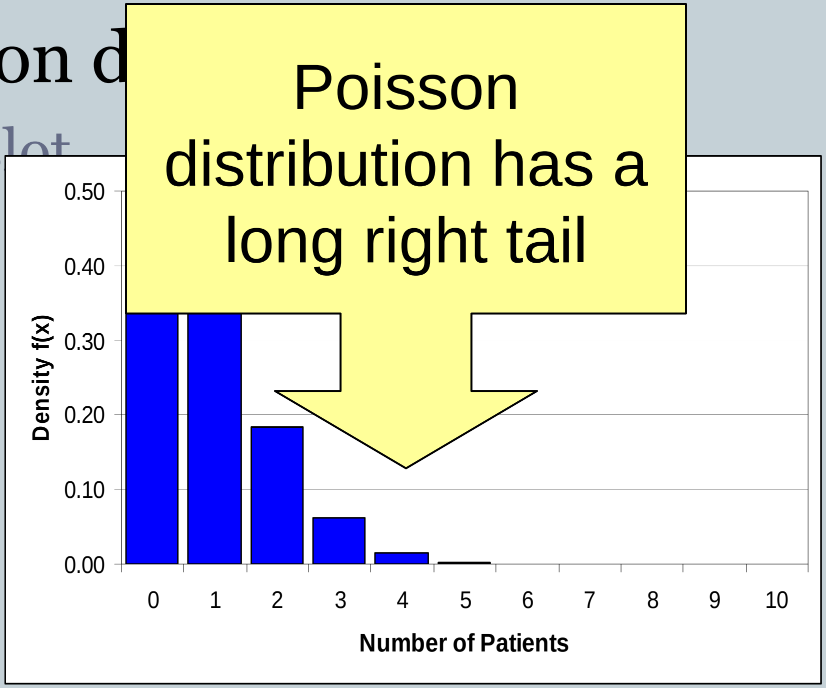


$s_j = 4, \ \sigma = 70\%$

Arrival of Walk-In Customers

- Walk-ins arrive at some percentage of service capacity
- Walk-in arrivals are Poisson d
  - Walk-ins arrive at rate λ per slot
  - w_j actually walk-in in slot j

$$p\left(w_j;\lambda\right)=\frac{\lambda^k e^{-\lambda}}{w_j!}$$



$\lambda = 1$

Arrival of Open Access Customers

- Open access (OA) calls arrive at a mean rate equal to some fraction of service capacity (e.g., 50%)
- Customers call for a same-day appointment
  - Number of OA customers calling on a particular day is Poisson distributed with mean φ
  - "Turned away" if no open slots remain that day
    - Perhaps make an appointment on another day
    - OA customers always show for appointments

Probability of *k* Clients Waiting

Probability of
new arrivals
slot *j*

Binomia
appointm
arriva

New
WI or OA
arrivals

Probability of *k*
waiting at start of
slot *j*

he waiting
s *k* arrivals

Waiting plus
arrivals = *k*

$$\theta_{j+1,k} = \theta_{j,0}\alpha_{j+1,k} + \sum_{i=0}^{k} \theta_{j,i+1}\alpha_{j+1,k-i}$$

- α_{jk} = probability of *k* clients arriving for service at the start of appointment slot *j*
- θ_{jk} = probability of *k* clients waiting for service at start of appointment slot *j*

Relative Benefits and Penalties

- π = Benefit of seeing additional customer
- ω = Penalty for customer waiting
- τ = Penalty for service operation overtime
- Numéraire of π, ω, and τ doesn't matter
  - Ratios (relative importance) are important
- Allow linear, quadratic, and mixed (linear + quadratic) costs

Linear & Quadratic Objectives

- Linear Utility Function

Benefit from clients serve

Client waiting penalties during normal service ops

Client waiti penalties du clinic overti

Service op overtime penalties

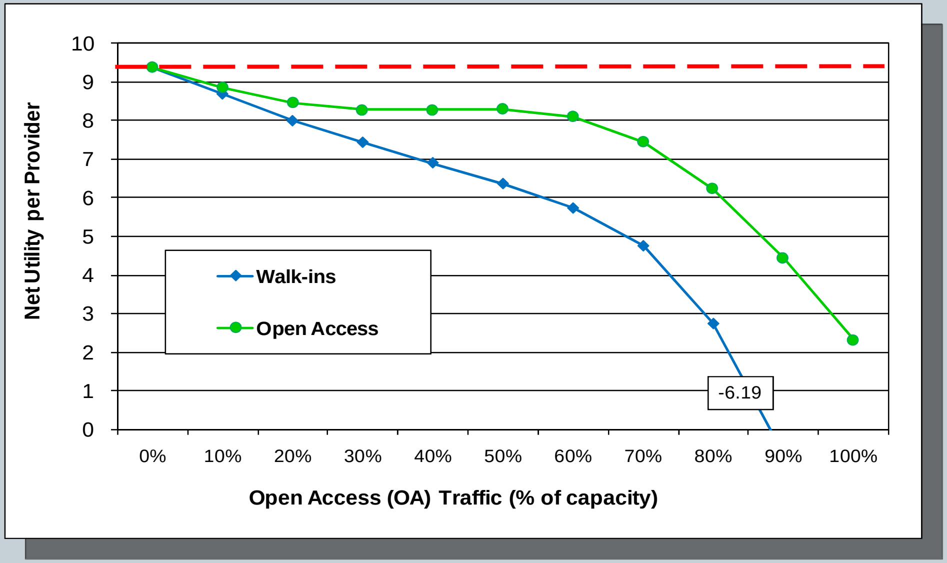
- Qu tic Utility nction

$$\hat{U}(\mathbf{S}) = \pi\hat{A} - \frac{\omega}{\hat{A}}\left(\sum_{j=1}^{N}\sum_{k}(2k-1)\theta_{jk} + \sum_{k}\sum_{i=1}^{k}(i-1)^2\theta_{N+1,k}\right) - \tau\sum_{k}k^2\theta_{N+1,k}$$

Heuristic Solution Methodology

1. Gradient search
   - Increment/decrement appts scheduled in each slot
   - Choose the single change with greatest utility
   - Iterate until no further improvement found
2. Pairwise interchange
   - Exchange appts scheduled in all slot pairs
   - Choose the single swap with greatest utility
   - Iterate until no further improvement found
3. Iterate (1) and (2) while utility improves
4. Prior research: Optimality not guaranteed, but almost always obtained

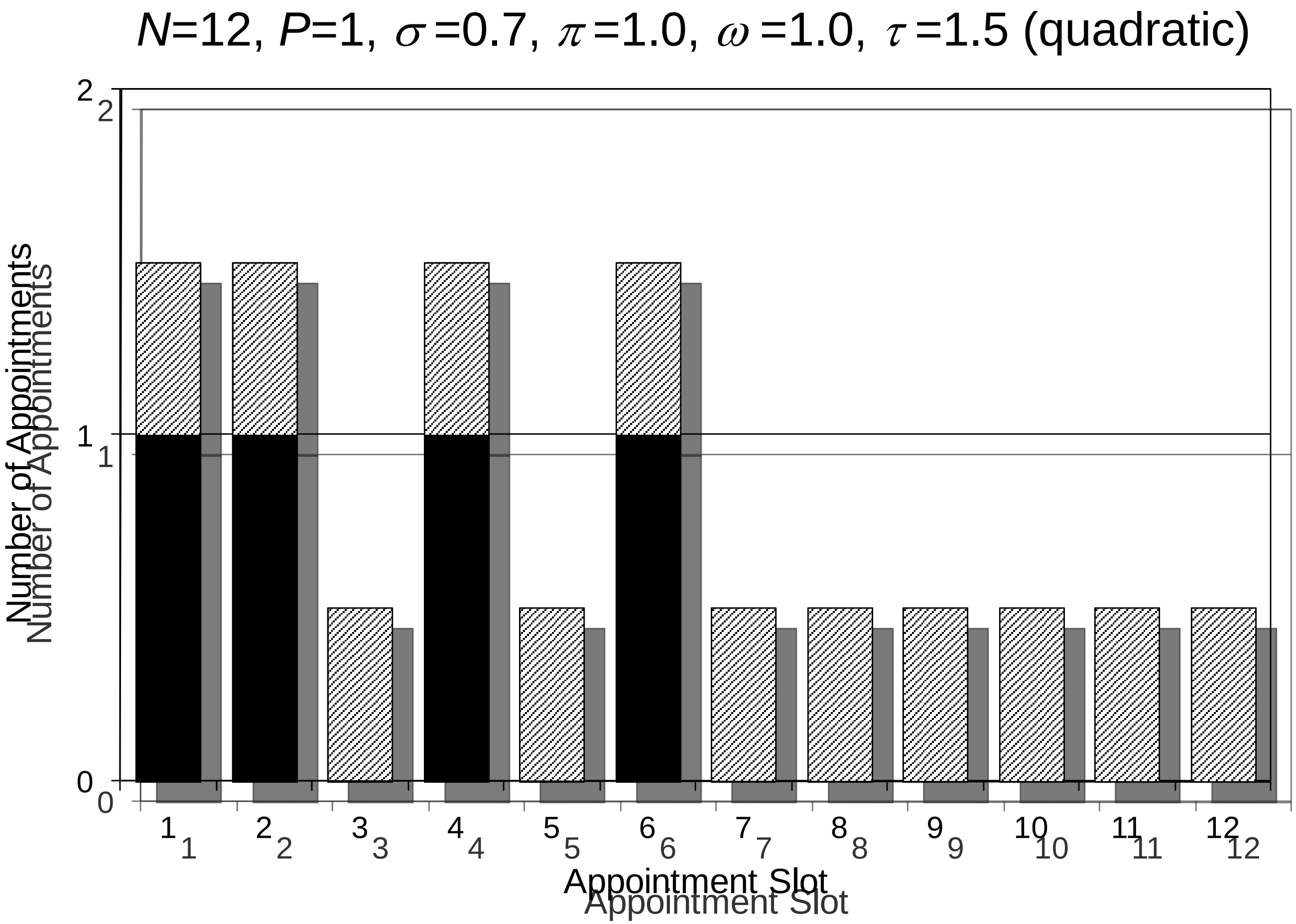
3. Computational Results



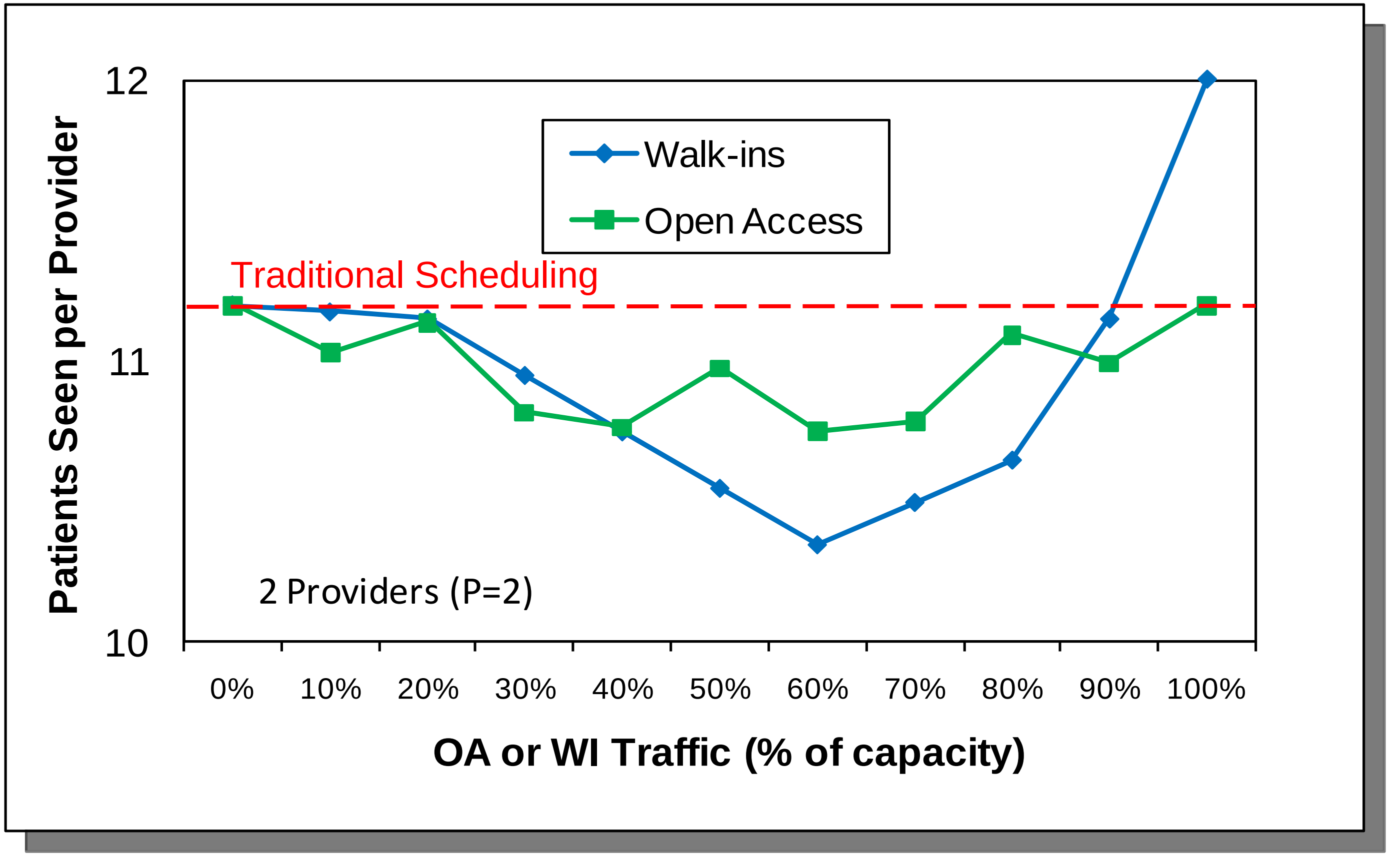
Computational Trials

- 44 sample problems solved
- Session size N = 12
- Appointment show rate σ = 70%
- Number of providers P = {1, 2, 4, 8}
- OA call-in rate λ = {0%, 10%, …100%} capacity
  - With P = 4 and N = 12, then φ = 24 is 50% of capacity
- Walk-in rate λ = {0%, 10%, …100%} of capacity
  - With P = 4, then λ = 2 is 50% of capacity
- Quadratic costs
  - Parameters π =1.0, ω =1.0, τ =1.5

50% Walk-Ins ($\lambda = 0.5$)

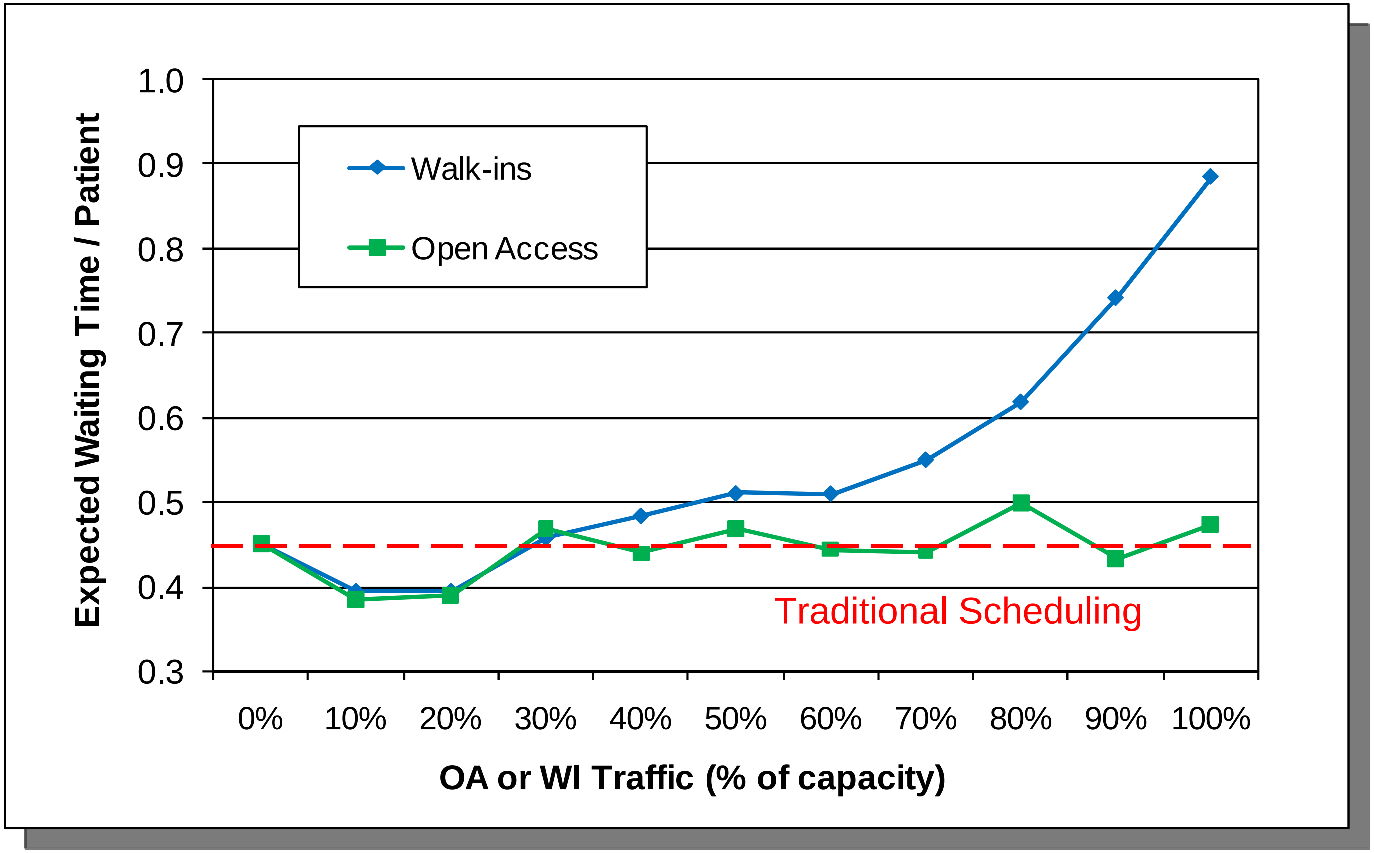


Customers Serviced



N=12, P=1, σ =0.7, π =1.0, α =1.0, ω =1.0, τ =1.5

Customer Waiting Time



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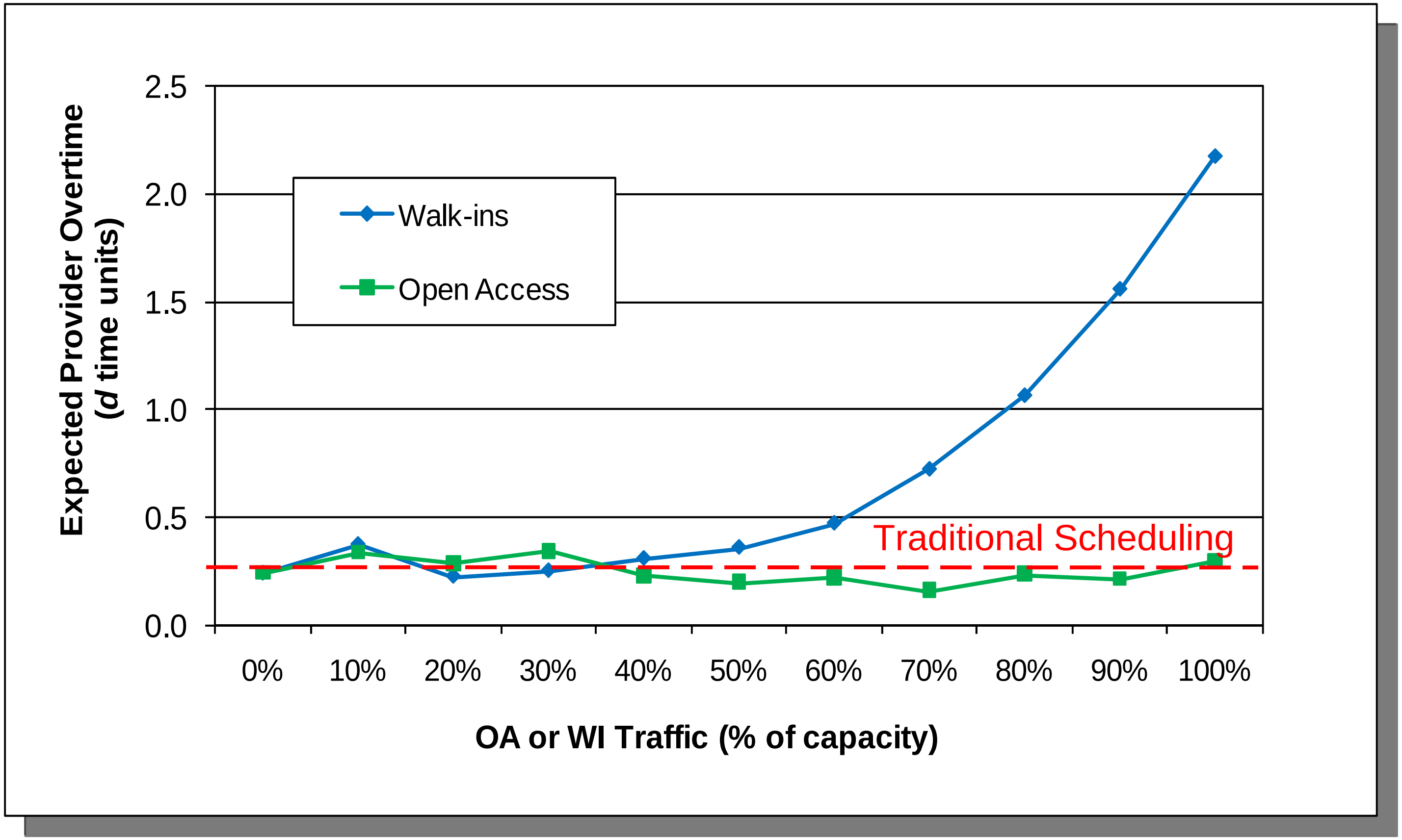
Service Operation Overtime



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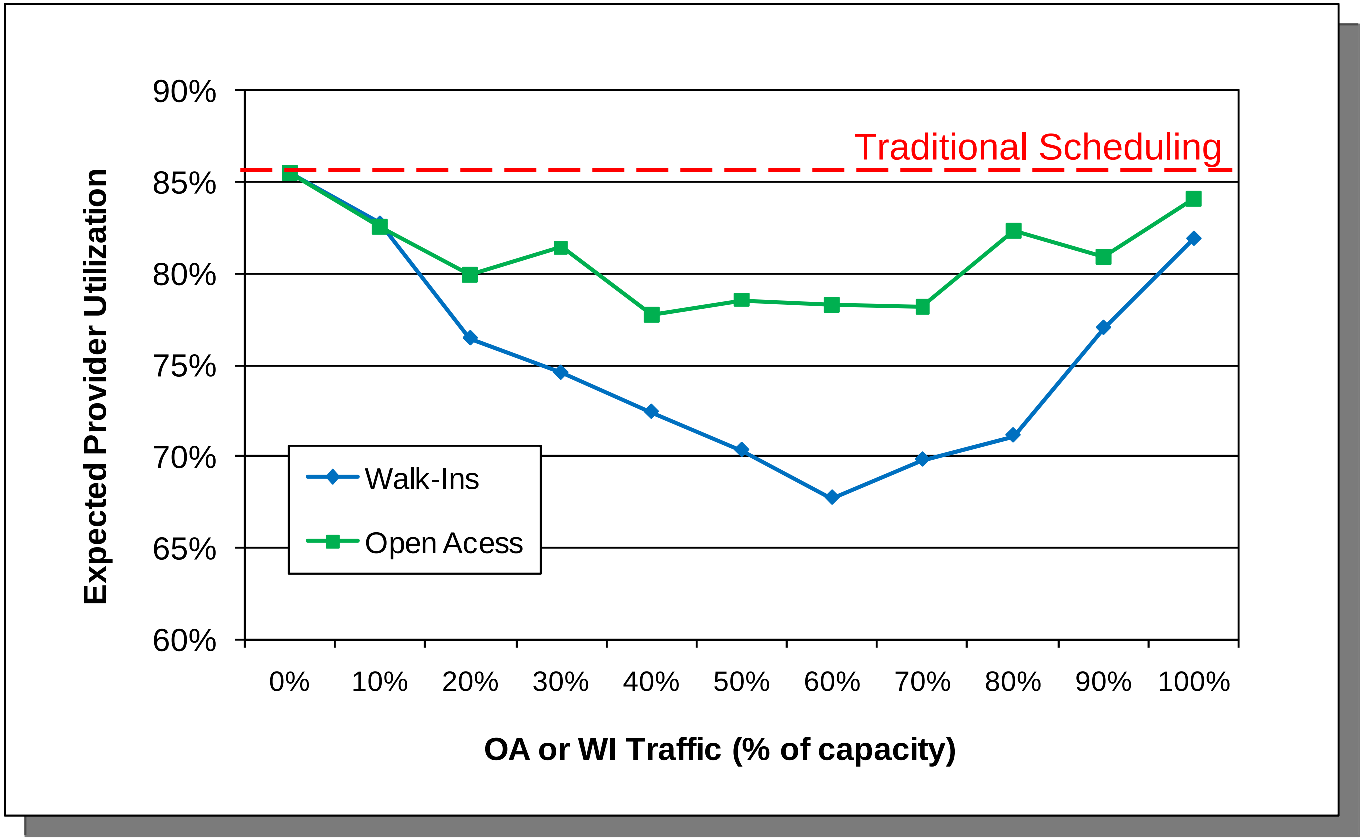
Provider Utilization



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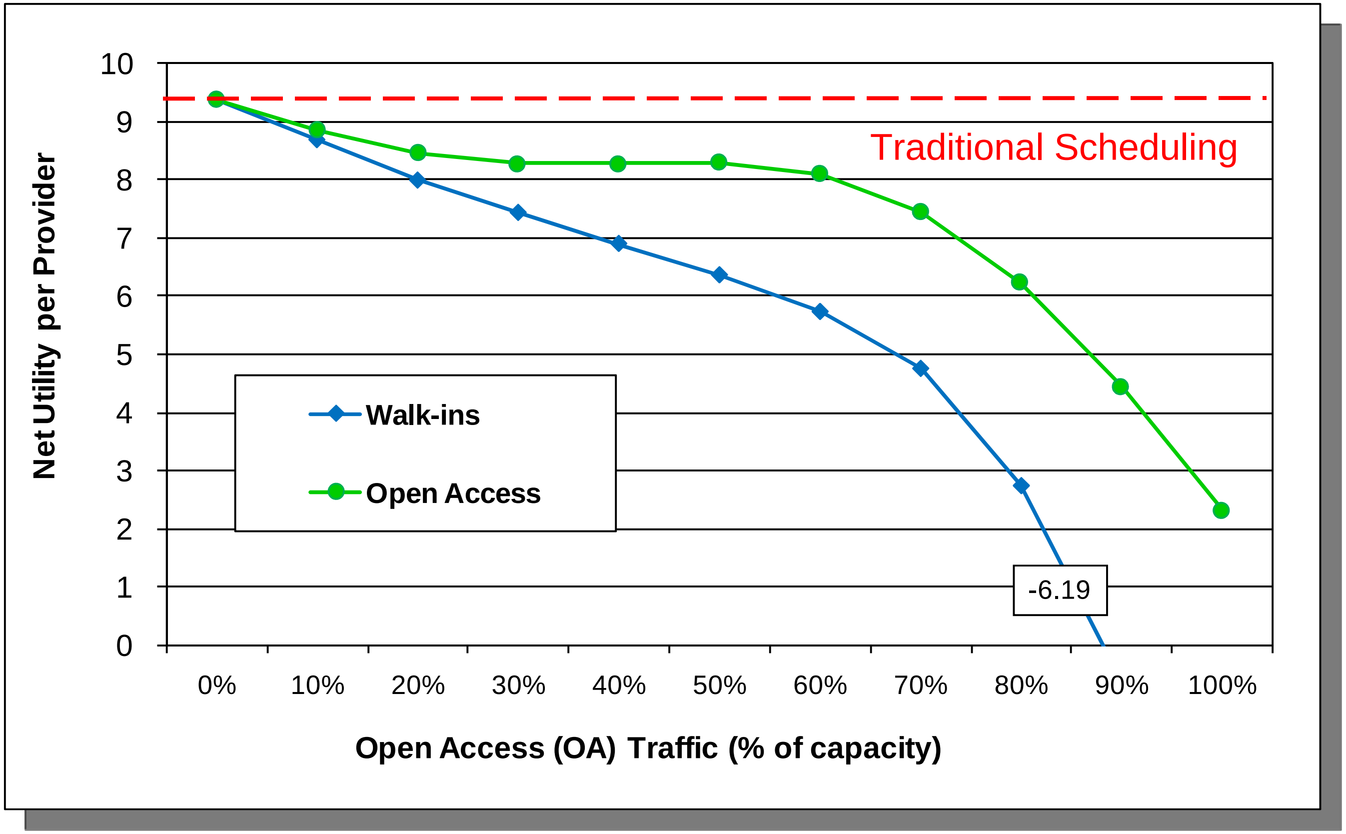
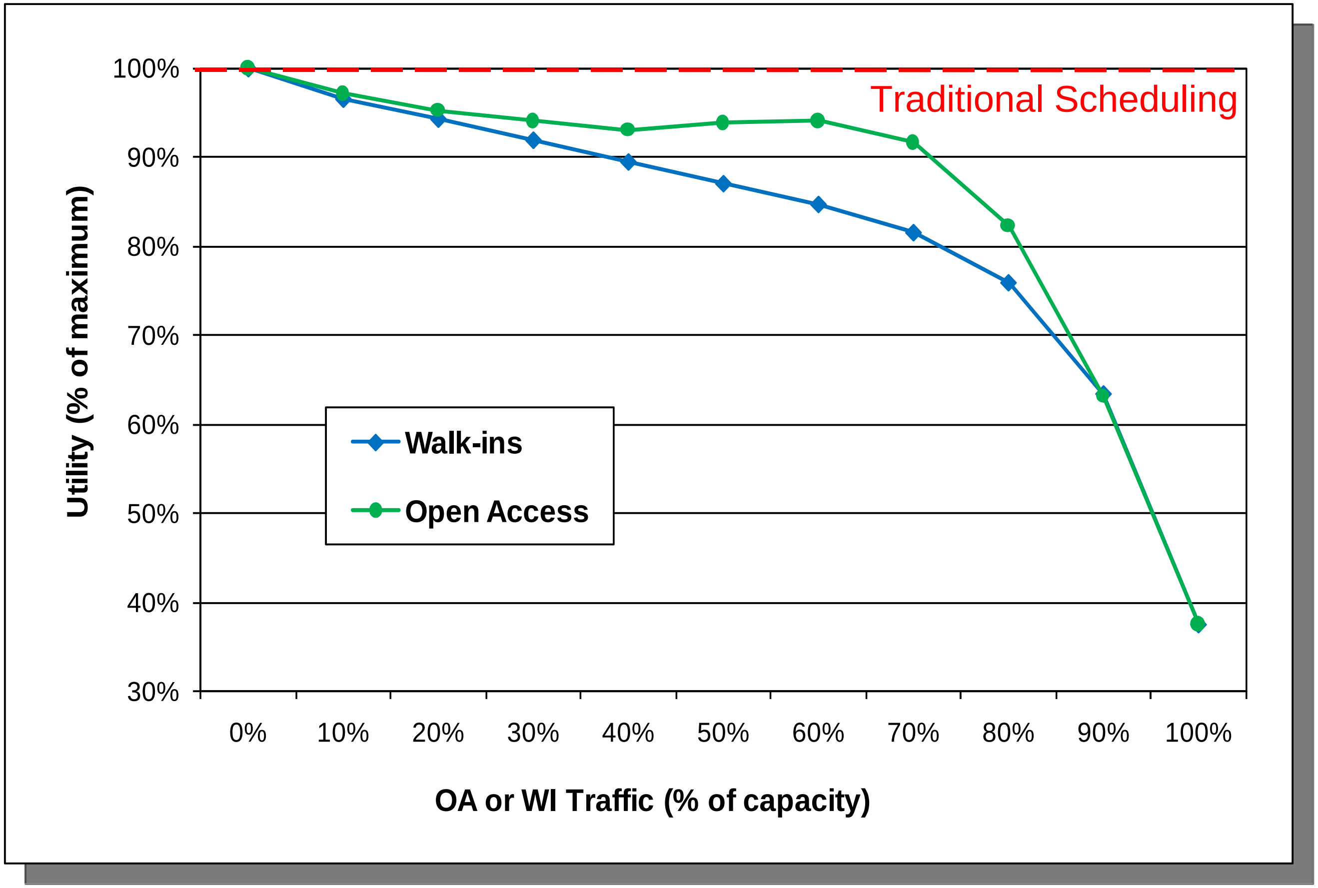
Net Utility



N=12, P=1, σ =0.7, π =1.0, α =1.0, ω =1.0, τ =1.5

% of Best Utility



N=12, P=1, σ =0.7, π =1.0, α =1.0, ω =1.0, τ =1.5

4. Managerial Implications

Managerial Implications

- TS appointments provide better service utility than does WI traffic or OA call-ins
  - Any WI or OA traffic causes some decline in utility
- An all-WI or all-OA service operation performs worse than any service operation with some TS appointments
  - Even a relatively small percentage of scheduled appointments can significantly improve service operation utility
  - Degree of improvement depends on number of providers
- A mix of TS appointments with some OA or WI traffic does not greatly reduce service operation performance (utility)

Insights from the Model

- Loss of utility with WI traffic is due to the long right-tail of Poisson distribution
  - Excessive customer waiting & service operation overtime
- Loss of utility with OA traffic is due to uncertainty about number of OA call-ins
- TS appts reduce customer waiting and service operation overtime
  - Binomial distribution has truncated right tail
- Multiple providers improves service operation utility
  - Portfolio effect – variance reduction

Managerial Caveats

- Results (to date) are for "reasonable" utility parameters
  - Sensitivity analysis currently under way
- Attractiveness of WI and OA traffic may improve if they have a higher utility benefit than do scheduled appointments ($\pi_{WI} > \pi_{TS}$; $\pi_{OA} > \pi_{TS}$)
  - Currently under investigation

5. Contributions & Future Research

Contributions of Research

- Analytic yield management model for health care clinics with OA traffic
  - First to examine analytically examine combinations of TS and OA
- Fast and effective near-optimal solutions
- Demonstrate the trade-offs of OA traffic
  - Scheduled appointments provide higher utility
  - Even some appointments improve utility of an all OA clinic

Future Work

- Determine sensitivity of results
  - Utility parameters, number of slots, show rates, linear costs
  - Show rates, walk-in rates, and providers vary by time of day
- Extend model
  - Different utility parameters for appointments and walk-ins
  - Walk-ins seen before appointments and vice versa
  - Stochastic service times

Service Policies and Alternate Configurations

- Use of Flexible Capacity
- Service downgrade or alternatives
  - Shorter service
  - Restaurant: Seating at the bar
- Compensation or discounts for excessive customer waiting
- Waitlists and Flexible Customer Pool

Questions? Comments?

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