Comparing Walk-In, Open Access, and Traditional Appointment Scheduling in Outpatient Health Care Clinics

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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
Objectives of Research

- **Optimize patient flow in health-care 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, OR
    - 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?
2. Appointment Scheduling Model

![Bar Chart]

- Number Waiting (k):
  - 0
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
  - 7
  - 8
  - 9
  - 10
  - 11
  - 12

- Probability:
  - 0%
  - 5%
  - 10%
  - 15%
  - 20%
Assumptions

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

- **Model flexibility**
  - Appt show rates $\sigma_j$ can vary by treatment slot $j$ (time of day)
  - Open access call-in rate $\varphi$ can vary by day.
  - Walk-in rate $\lambda_j$ can vary by treatment slot $j$
  - Number of providers $P_j$ can vary by slot $j$
  - Any arrival distribution can be accommodated

- **Patient arrivals**
  - Patients are only seen at the start of a treatment slot (early arrivals wait for next slot without cost)
  - Patients are seen in order of arrival (FCFS)
Arrival of Scheduled Appointments

- Appointment arrivals are binomially distributed:
  - $s_j$ patients scheduled for treatment slot $j$
  - Probability of a patient showing is $s$
  - $a_j \leq s_j$ actually arrive in slot $j$

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

Binomial distribution has no right tail

$s_j = 4, \; \sigma = 70\%$
Arrival of Walk-In Patients

- Walk-ins arrive at some percentage of clinic capacity
- Walk-in arrivals are Poisson distributed
  - Walk-ins arrive at rate $\lambda$ per slot
  - $w_j$ actually walk-in in slot $j$

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

Poisson distribution has a long right tail

$\lambda = 1$
Open access (OA) calls arrive at a mean rate equal to some fraction of clinic capacity (e.g., 50%).

Patients call for a same-day appointment:
- Number of OA patients calling on a particular day is Poisson distributed with mean $\phi$.
- “Turned away” if no open slots remain that day:
  - Perhaps make an appointment on another day.
  - OA patients always show for appointments.
Probability of \( k \) Clients Waiting

**Probability of new arrivals in slot \( j \)**

**Probability of \( k \) waiting at start of slot \( j \)**

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

- \( \alpha_{jk} \) = probability of \( k \) clients arriving for service at the start of appointment slot \( j \)
- \( \theta_{jk} \) = probability of \( k \) clients waiting for service at start of appointment slot \( j \)

**Binomial TS appointment arrivals**

**New WI or OA arrivals**

**Waiting plus \( k \) arrivals = \( k \)**
Relative Benefits and Penalties

- $\pi = \text{Benefit of seeing additional client}$
- $\omega = \text{Penalty for client waiting}$
- $\tau = \text{Penalty for clinic overtime}$
- Numéraire of $\pi$, $\omega$, and $\tau$ doesn’t matter
  - Ratios (relative importance) are important
- Allow linear, quadratic, and mixed (linear + quadratic) costs

Ratios (relative importance) are important
Linear & Quadratic Objectives

- **Linear Utility Function**

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

- **Quadratic Utility Function**

  - Benefit from patients served
  - Patient waiting penalties during normal clinic ops
  - Patient waiting penalties during clinic overtime
  - Clinic overtime penalties
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 \( \sigma = 70\% \)
- Number of providers \( P = \{1, 2, 4, 8\} \)
- OA call-in rate \( \lambda = \{0\%, 10\%, \ldots, 100\%\} \) capacity
  - With \( P = 4 \) and \( N = 12 \), then \( \phi = 24 \) is 50\% of capacity
- Walk-in rate \( \lambda = \{0\%, 10\%, \ldots, 100\%\} \) of capacity
  - With \( P = 4 \), then \( \lambda = 2 \) is 50\% of capacity
- Quadratic costs
  - Parameters \( \pi = 1.0, \omega = 1.0, \tau = 1.5 \)
50% Walk-Ins ($\lambda = 0.5$)

$N=12$, $P=1$, $\sigma=0.7$, $\pi=1.0$, $\omega=1.0$, $\tau=1.5$ (quadratic)
Patients Seen

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

$N=12$, $P=1$, $\sigma=0.7$, $\pi=1.0$, $\alpha=1.0$, $\omega=1.0$, $\tau=1.5$
Clinic Overtime

$N=12, \ P=1, \ \sigma = 0.7, \ \pi = 1.0, \ \alpha = 1.0, \ \omega = 1.0, \ \tau = 1.5$
Provider Utilization

$N=12, \ P=1, \ \sigma =0.7, \ \pi =1.0, \ \alpha =1.0, \ \omega =1.0, \ \tau =1.5$
Net Utility

$N=12$, $P=1$, $\sigma = 0.7$, $\pi = 1.0$, $\alpha = 1.0$, $\omega = 1.0$, $\tau = 1.5$
% of Best Utility

$N = 12, \ P = 1, \ \sigma = 0.7, \ \pi = 1.0, \ \alpha = 1.0, \ \omega = 1.0, \ \tau = 1.5$
4. Managerial Implications
Managerial Implications

- TS appointments provide better clinic 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 clinic performs worse than any clinic with some TS appointments
  - Even a relatively small percentage of scheduled appointments can significantly improve clinic utility
  - Degree of improvement depends on number of providers
- A mix of TS appointments with some OA or WI traffic does not greatly reduce clinic performance (utility)
Insights from the Model

- Loss of utility with WI traffic is due to the long right-tail of Poisson distribution
  - Excessive patient waiting & clinic overtime
- Loss of utility with OA traffic is due to uncertainty about number of OA call-ins
- TS appts reduce patient waiting and clinic overtime
  - Binomial distribution has truncated right tail
- Multiple providers improves clinic 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
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