UW BUSINESS SCHOOL

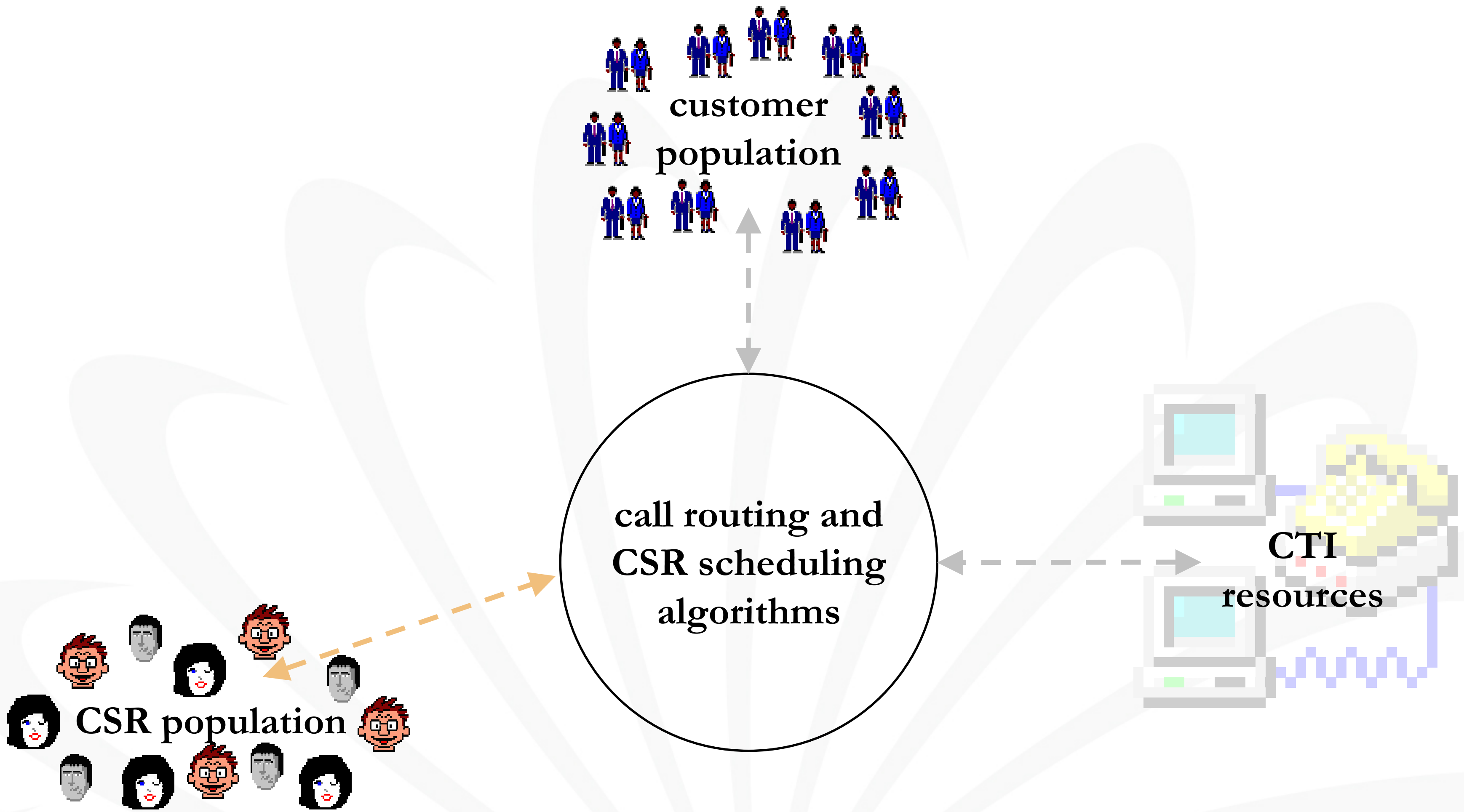
Managing Learning and Turnover in Employee Staffing*

Yong-Pin Zhou
University of Washington Business School

Coauthor:
Noah Gans, Wharton School, UPenn

* Supported by Wharton Financial Institutions Center and the Sloan Foundation

Call Center Operations



CSR Plans Are Made at 3 Levels

- Moment-by-moment
  - on-the-fly adjustments of call routing, overtime, lunch, breaks
- Week-by-week
  - assignment of CSRs to schedules
- Monthly, quarterly
  - target staffing levels set and hiring plans made

Our Hierarchical Approach

- Focus on high level staffing problem
  - formulate as discrete-time dynamic program
- Embed lower level scheduling and call routing problems
  - scheduling software

Related Literature

- Aggregate Planning
  - HMMS Model (1960)
  - Orrbeck, Schuette, and Thompson (1968)
  - Grinold and Stanford (1974)
  - Ebert (1976)
  - Khoshnevis and Wolfe (1986)
  - Gerchak, Parlar, and Sengupta (1990)
- Human Resources
  - Bartholomew, Forbes, and McClean (1991)

Related Literature

- Inventory Theory
  - Arrow, Karlin and Scarf (1958)
  - Veinott (1965)
  - Iglehart and Jacquett (1969)
  - Karlin (1960) and Zipkin (1989)
  - Gerchak and Wang (1994)
- Call Center

  ……

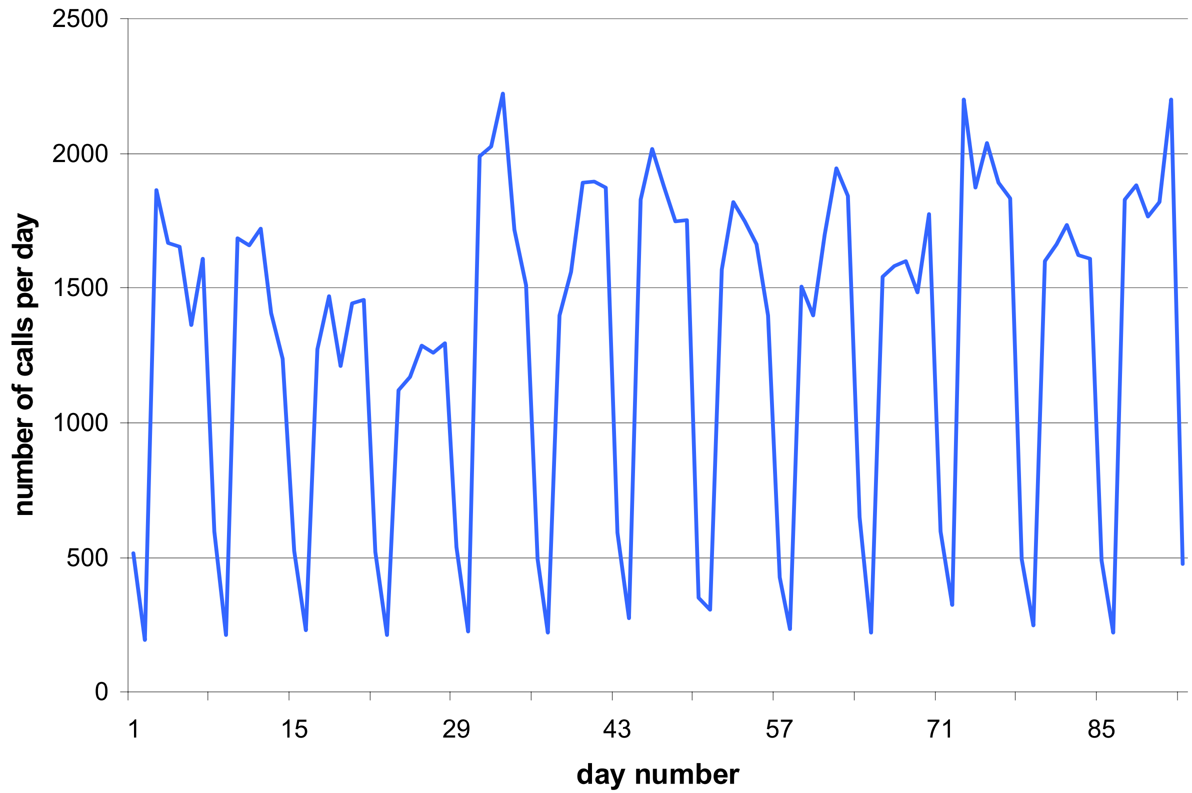
Staffing Problem Description

- Stochastic non-stationary service requirement
- Uncertain service capacity: people's service capacities change
  - Random learning
  - Random turnover
- Long hiring/training leadtime

Service Requirement …

… Varies by

- Time of day
- Day of week / month
- Month of year
- Promotion
- Special events



UW Business School

Learning

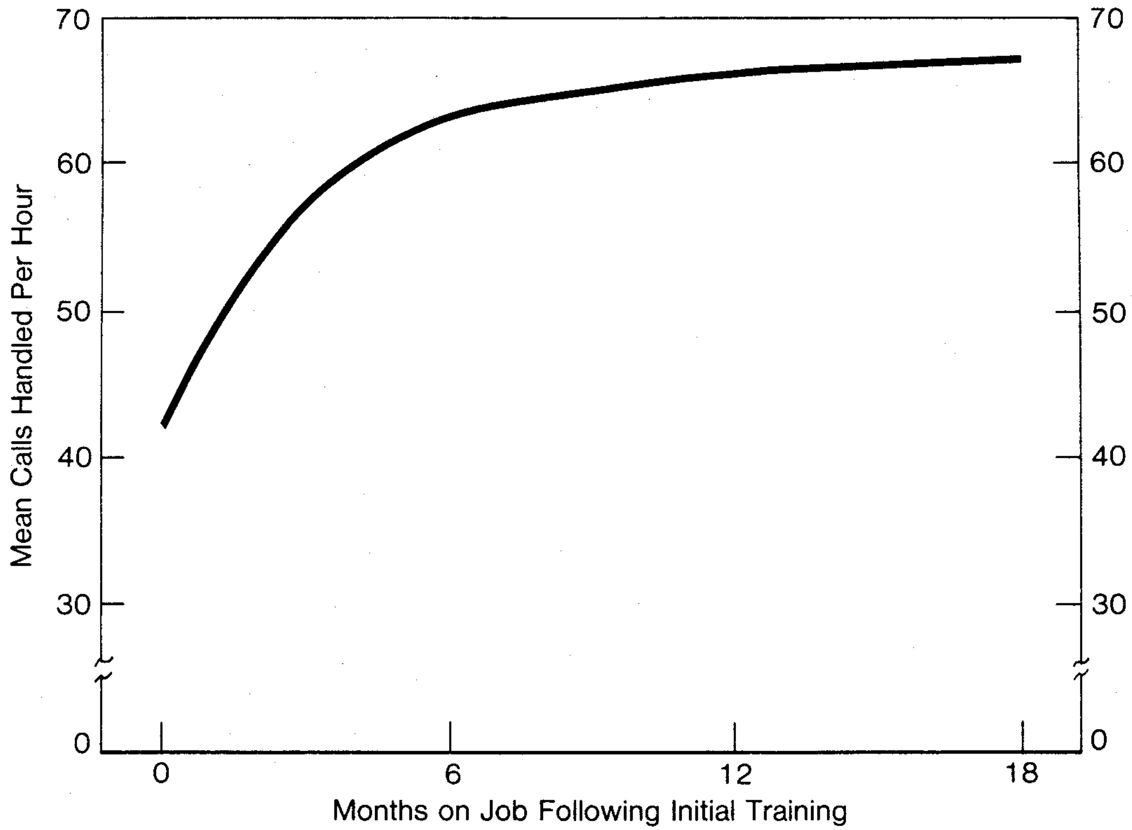


Fig. 3. *Proficiency acquisition curves for Directory Assistance Operators*

Source: Gustafson, 1982

Turnover

- Call centers have high turnover rates
- Turnover decreases with job tenure
  - Empirical evidence
    - National Longitudinal surveys (Light and Ureda 1990)
    - AT&T service representatives (Gustafson 1982)
  - Theoretical explanations
    - longer tenure implies better ``fit" (Jovanovic 1979)
    - repeated searches for a better job (Parsons 1973)

Outline

- Model
- Structural Properties of The Optimal Policy
- Model Details
- Numerical Analysis

Model: Dynamics

- Indices
  - $i = 1, 2, \ldots, m$: employee type
  - $t = 0, 1, \ldots, T$: discrete time periods
- State variables
  - $n_{i,t}$: type i employee, time period t
    (before hiring)
  - x_t : type 1 employee hired, time period t
    (decision variable)
  - y_t : type1 employee, time period t
    (after hiring)

$$y_t = n_{1,t} + x_t$$

Model: Dynamics (contd)

- Transition variables
  - $\tilde{q}_{i,t}(n_{i,t})$: type-*i* employees who turn over, out of $n_{i,t}$ **random variable**

$$\tilde{q}_{i,t}(n_{i,t}) = n_{i,t} \cdot \tilde{q}_{i,t}$$

  - $\tilde{l}_{i,t}(n_{i,t})$: type-*i* employees who learn, out of $n_{i,t}$ **random variable**

$$\tilde{l}_{i,t}(n_{i,t}) = n_{i,t} \cdot (1 - \tilde{q}_{i,t}) \cdot \tilde{l}_{i,t}$$

Model: Costs

- α : discount factor
- h : unit hiring cost
- W_i : per stage wage cost, type *i* employee
- $O_t(y_t, n_{2,t}, \ldots, n_{m,t}; D_t)$: operating cost including overtime and outsourcing costs
  - jointly convex in $(y_t, n_{2,t}, \ldots, n_{m,t})$

Dynamic Programming Model

$$V_t(n_{1,t},\ldots,n_{m,t})$$

$$= \min_{x_t \geq 0} \left\{ \begin{array}{l} hx_t + W_1(n_{1,t} + x_t) + \sum_{i=2}^{m} W_i n_{i,t} \\ + O_t(n_{1,t} + x_t, n_{2,t},\ldots,n_{m,t}) \\ + \alpha E_{\{\tilde{q}_{1,t},\ldots,\tilde{q}_{m,t},\tilde{l}_{1,t},\ldots,\tilde{l}_{m-1,t}\}} \left\{ V_{t+1}(n_{1,t+1},\ldots,n_{m,t+1}) \right\} \end{array} \right\}$$

Constraints

- Subject to the system dynamics:

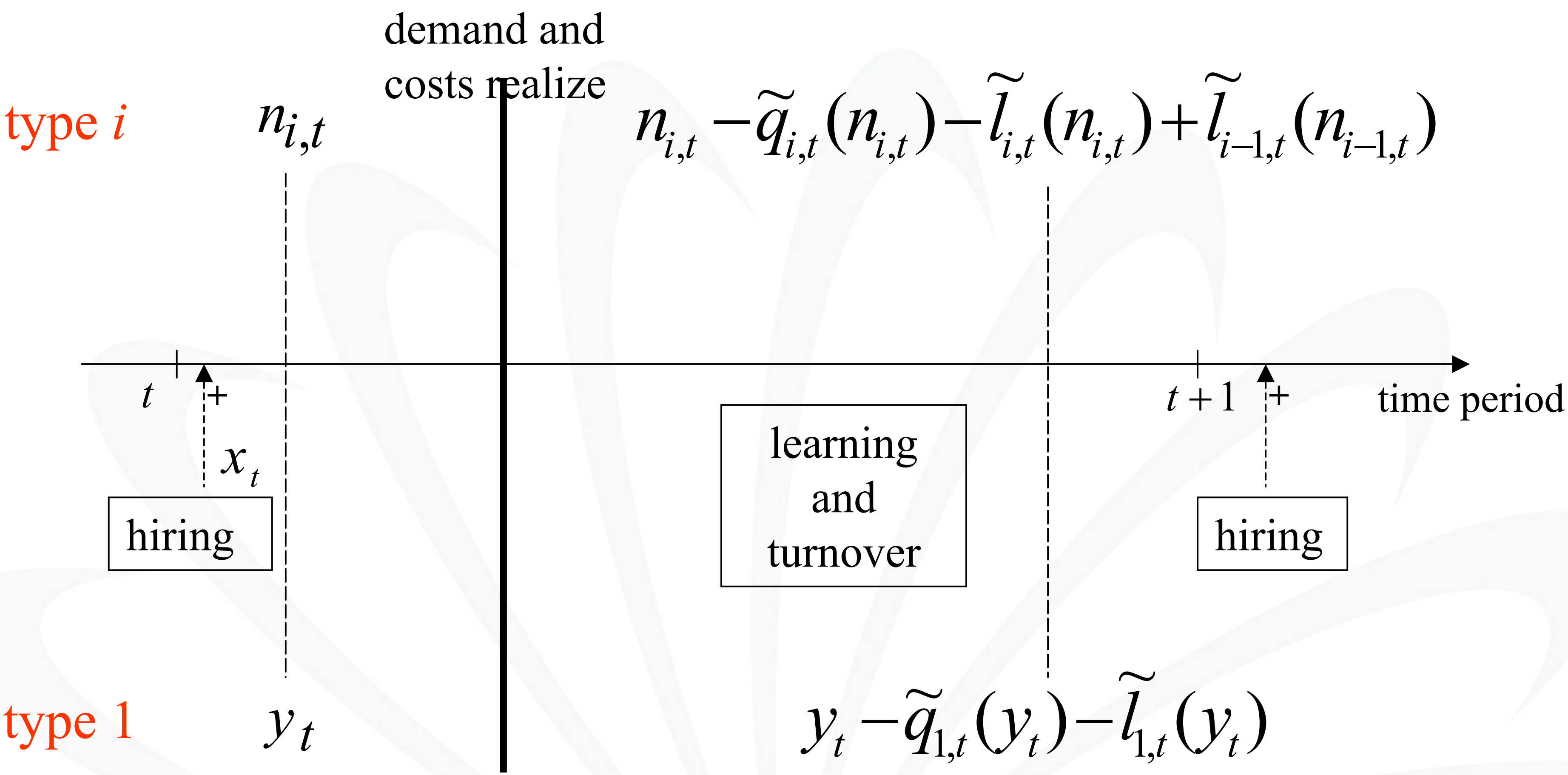
$$y_t = n_{1,t} + x_t$$

$$n_{1,t+1} = y_t - \tilde{q}_{1,t}(y_t) - \tilde{l}_{1,t}(y_t)$$

$$n_{i,t+1} = n_{i,t} - \tilde{q}_{i,t}(n_{i,t}) - \tilde{l}_{i,t}(n_{i,t}) + \tilde{l}_{i-1,t}(n_{i-1,t})$$

$$\forall 1 < i \leq m.$$

System Dynamics Illustrated



Optimality of "Base-Level" Policy

- Base-Level Policy: there exist state-dependent base-levels $y_t^*(n_{2,t},\ldots,n_{m,t})$ such that the optimal number to hire is

$$x_t^* = \begin{cases} y_t^*(n_{2,t},\ldots,n_{m,t}) - n_{1,t} & \text{if } n_{1,t} < y_t^*(n_{2,t},\ldots,n_{m,t}) \\ 0 & \text{otherwise} \end{cases}$$

Proof Idea

Convexity of one-period cost function propagates

$$V_t(n_{1,t},\ldots,n_{m,t})$$

$$= \min_{y_t \geq n_{1,t}} \left\{ \begin{array}{l} (h+W_1)y_t + O_t(y_t,\ldots,n_{m,t}) \\ +\alpha E\left\{ V_{t+1}(n_{1,t+1},\ldots,n_{m,t+1}) \right\} \end{array} \right\} - h\, n_{1,t} + \sum_{i=2}^{m} W_i n_{i,t}$$

where

$$n_{1,t+1} = (1-\tilde{q}_{1,t})(1-\tilde{l}_{1,t})y_t$$

$$\ldots$$

$$n_{i,t+1} = (1-\tilde{q}_{i,t})(1-\tilde{l}_{i,t})n_{i,t} + \tilde{l}_{i-1,t}n_{i-1,t}$$

$$\ldots$$

$$n_{m,t+1} = (1-\tilde{q}_{m,t})n_{m,t} + \tilde{l}_{m-1,t}n_{m-1,t}$$

Proof Idea

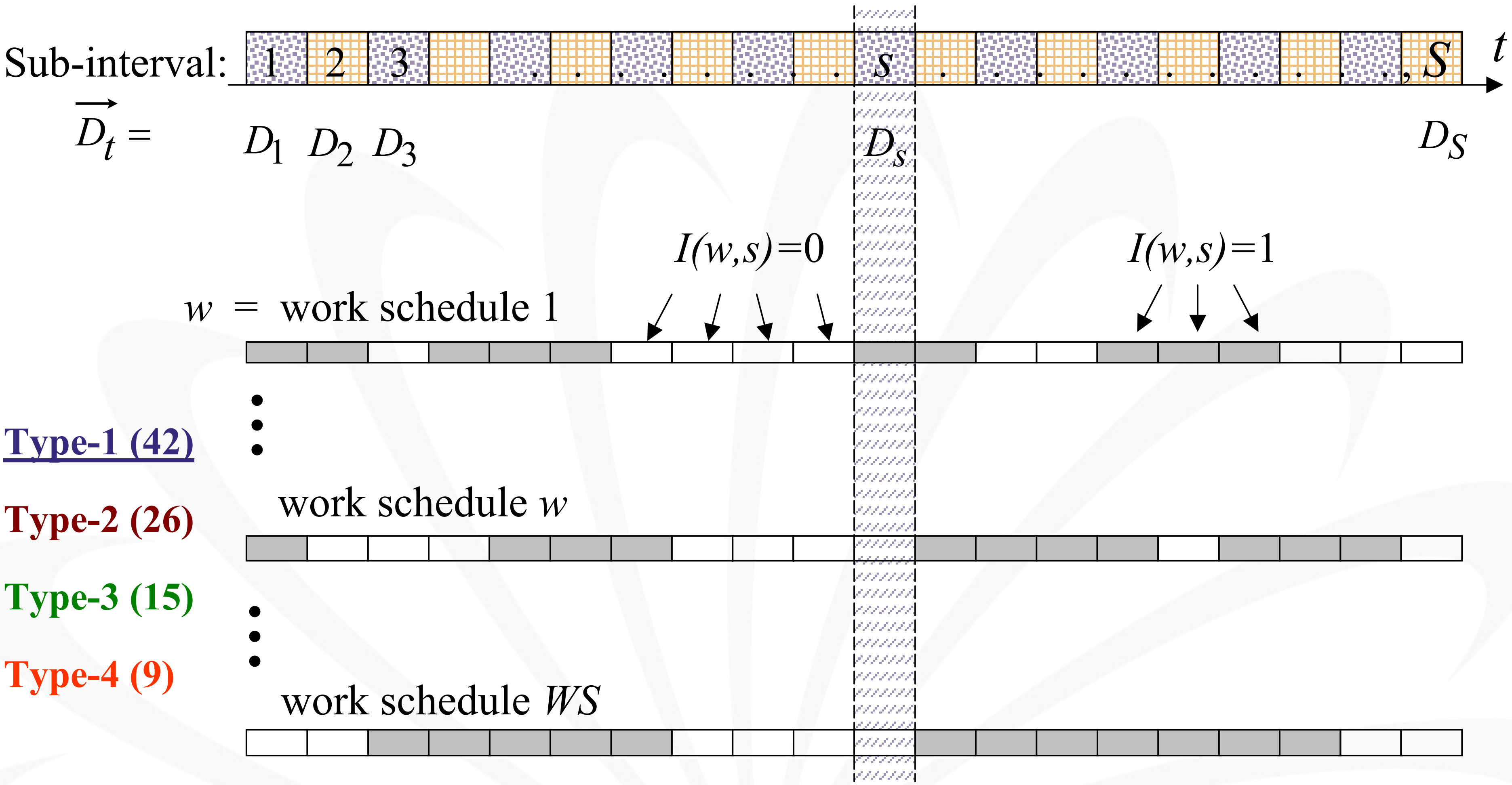
Lemma 1

If $V_{t+1}(n_{1,t+1},\ldots,n_{m,t+1})$ *is jointly convex in* $(n_{1,t+1},\ldots,n_{m,t+1})$ *and* $n_{i,t+1}(i=1,\ldots,m)$ *are linear functions of* $(y_t,\ldots,n_{m,t})$, *then* $V_{t+1}(n_{1,t+1},\ldots,n_{m,t+1})$ *is jointly convex in* $(y_t,\ldots,n_{m,t})$.

Lemma 2

Let $f(n_1,n_2,\ldots,n_m) = \inf_{y\geq n_1}\{h(y,n_2,\ldots,n_m)\}$. *If* $h(y,n_2,\ldots,n_m)$ *is jointly convex in* $(y,n_2,\ldots,n_m)$, *then* $f(n_1,n_2,\ldots,n_m)$ *is jointly convex in* $(n_1,n_2,\ldots,n_m)$.

Model Details (I): Operating Cost Function $O_t(y_t \ldots n_{m,t}; D_t)$



Type-1 (42)

Type-2 (26)

Type-3 (15)

Type-4 (9)

Operating Cost Function *O(t)*

- $s = 1, \ldots, S$: sub-intervals in any hiring period t
- $w = 1, \ldots, WS$: work schedules ($I(w,s) = 1$ if w requires working in sub-interval s, 0 otherwise).
- $x_{i,w}$ = the number of type-i employees assigned to work schedule w
- z_s : the amount of work to be outsourced in sub-interval s

Operating Cost Function *O(t)*

$$
\begin{aligned}
O_t(y_t, n_{2,t}, \ldots, n_{m,t}; \overrightarrow{D_t}) \;=\; \min_{x_{iw}, z_s} \quad & \sum_{i=1}^{m} \sum_{w=1}^{WS} C_{iw} x_{iw} + \sum_{s=1}^{S} OS_s z_s \\
\text{s.t.} \quad \sum_{i=1}^{m} \sum_{w:I(w,s)=1} \mu_i x_{iw} + z_s & \geq D_s \quad \forall s \qquad (1) \\
\sum_{w=1}^{WS} x_{1w} & \leq y_t \\
\sum_{w=1}^{WS} x_{iw} & \leq n_{i,t} \quad \forall 1 < i \leq m \\
x_{iw}, \; z_s & \geq 0 \quad \forall i, w, s
\end{aligned}
$$

- c.f. Berman, Larson, Pinker (1997)

More General *O(t)*

$$O_t(y_t, n_{2,t}, \ldots, n_{m,t}; \overrightarrow{D_t}) = \min_{x_{iw}, z_{sj}} \sum_{i=1}^{m} \sum_{w=1}^{WS} C_{iw}(x_{iw}) + \sum_{s=1}^{S} \sum_{j=1}^{J} OS_{sj}(z_{sj})$$

$$\begin{aligned} \text{s.t.} \quad f(x_{11}, \ldots, x_{mWS}, z_{11}, \ldots, z_{SJ}; \overrightarrow{D_t}) &\geq 0 && (2) \\ \sum_{w=1}^{WS} x_{1w} &\leq y_t \\ \sum_{w=1}^{WS} x_{iw} &\leq n_{i,t} && \forall 1 < i \leq m \\ x_{iw}, \ z_{sj} &\geq 0 && \forall i, w, s, j \end{aligned}$$

Example of (2): P{waiting in queue $\geq U$} $\leq a\%$.

Model Details (II): Hiring/Training Lead Time

- Hiring/training lead time $\lambda > 0$ modeled by adding employee types
  - $m > \lambda$
  - $i = 1, \ldots, \lambda$ indicate hiring/training stages
- Hiring lead time
  - $\mu_i = 0$
  - W_i may be 0
- Training lead time
  - μ_i may be 0
  - $W_i > 0$

Numerical Analysis

- Modeling of different CSR classes
- Modeling of the stochastic elements

Compare

- Optimal policy: state-dependent
  - recognize different employees have different capacities
  - take into account the stochastic elements
- Heuristic: headcount policy
  - check only the total number of employees
  - assume everyone has the same (average) capacity
  - take into account the stochastic elements
- Heuristic: LP-based
  - recognize different employees have different capacities
  - use average learning and turnover rates

Example Problem: Slow and Fast CSRs

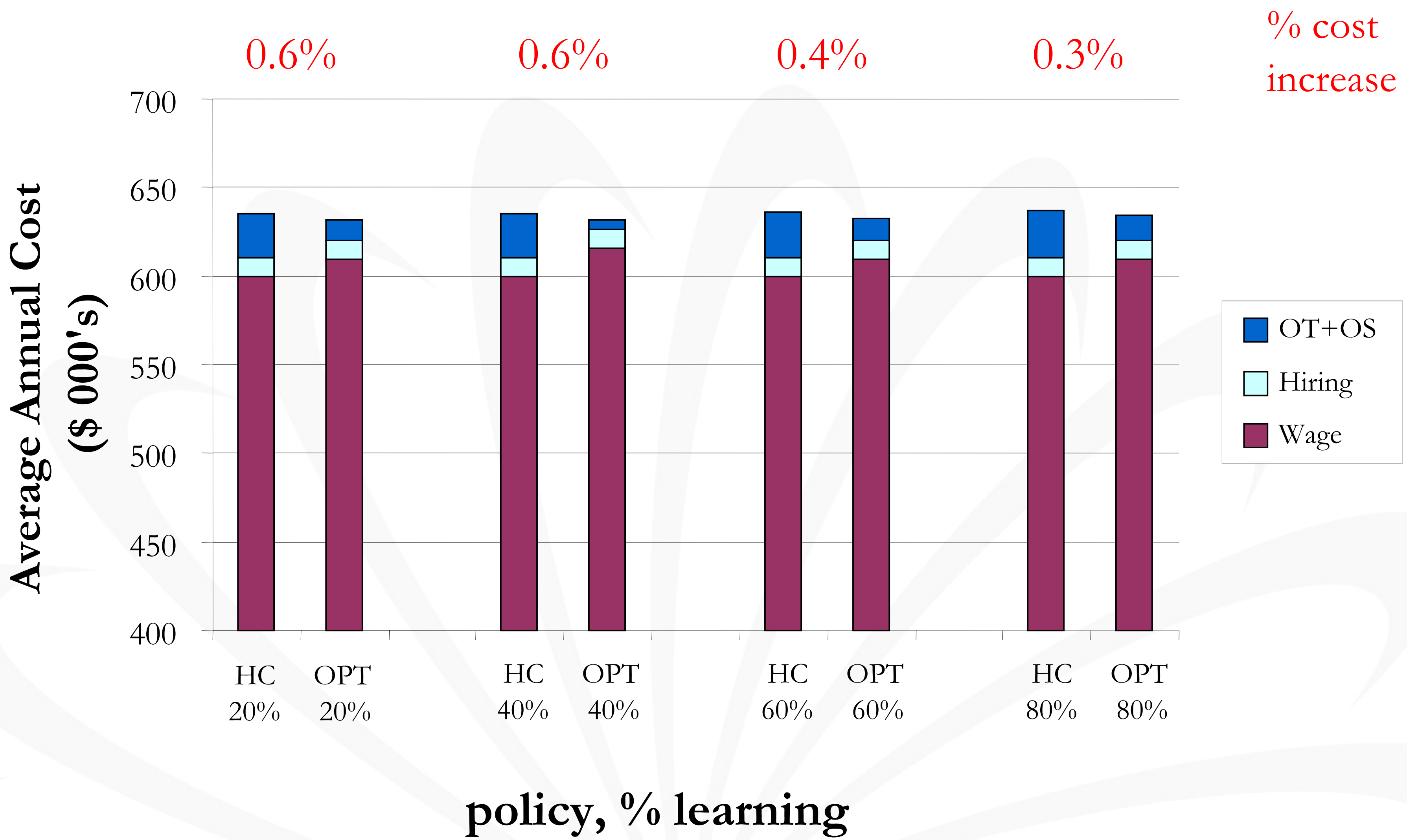
- CSR turnover
  - slow CSRs: 48% yearly (15% per quarter)
  - fast CSRs: 34% yearly (10% per quarter)
- CSR learning: slow and fast CSRs
  - CSR becomes fast after one quarter of experience
  - % speedup with learning: 20%, 40%, 60%, 80%
- Call volume
  - Demand: 250,000 per quarter
  - CSR capacity: 10,000 per quarter on average
  - Overtime as % of regular time: 10%, 20%, 30%

Costs Used for Examples

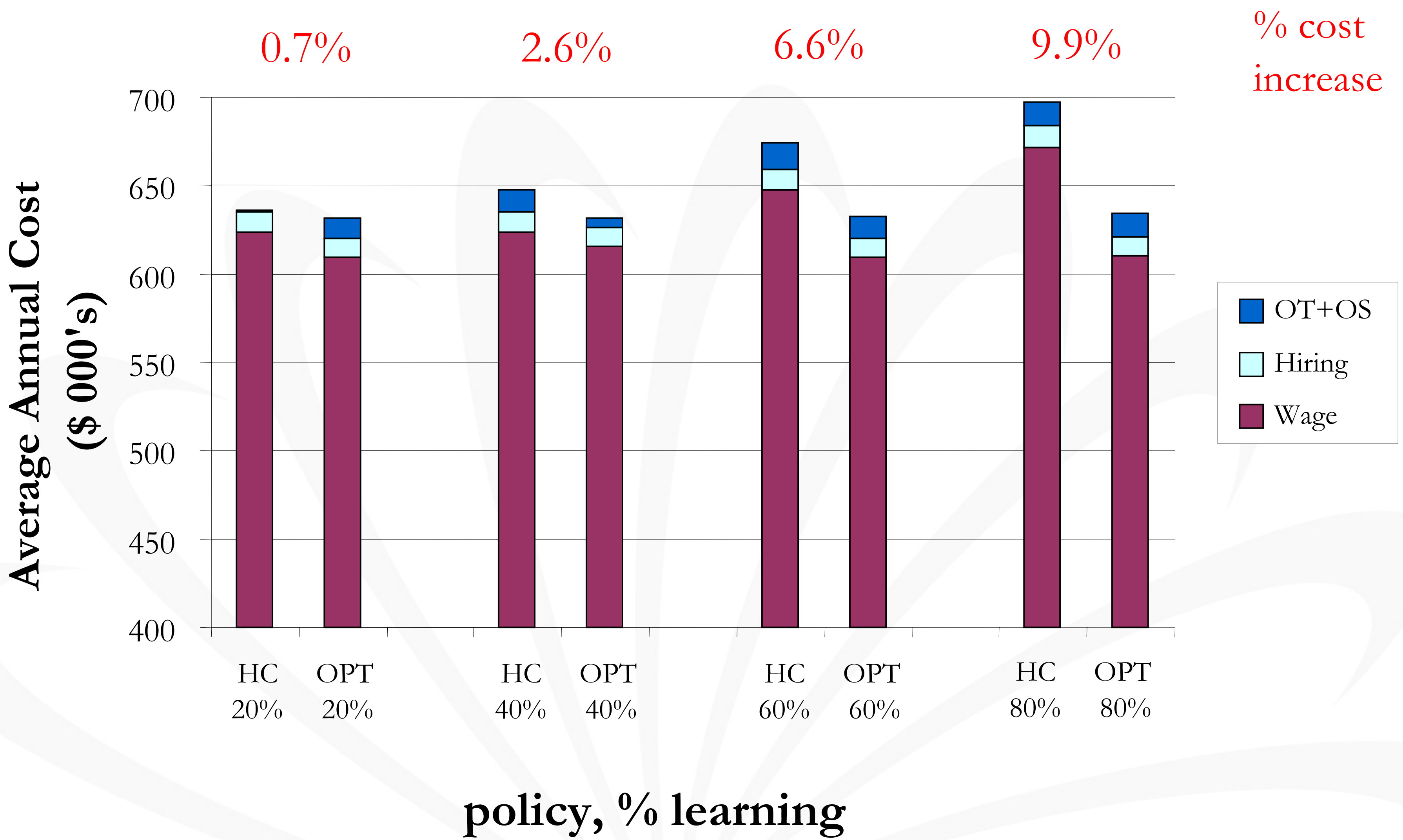
Wage is capacity neutral, for an avg. capacity of 10,000 per quarter:

- Base wage: $4,500, benefits: $1,000 (22.2%)
- Overtime: 1.5 times base wage rate
- Outsource cost: 1.8, 18, 36, 91, 182 times base wage rate

Optimal v.s. Headcount: Ample Overtime

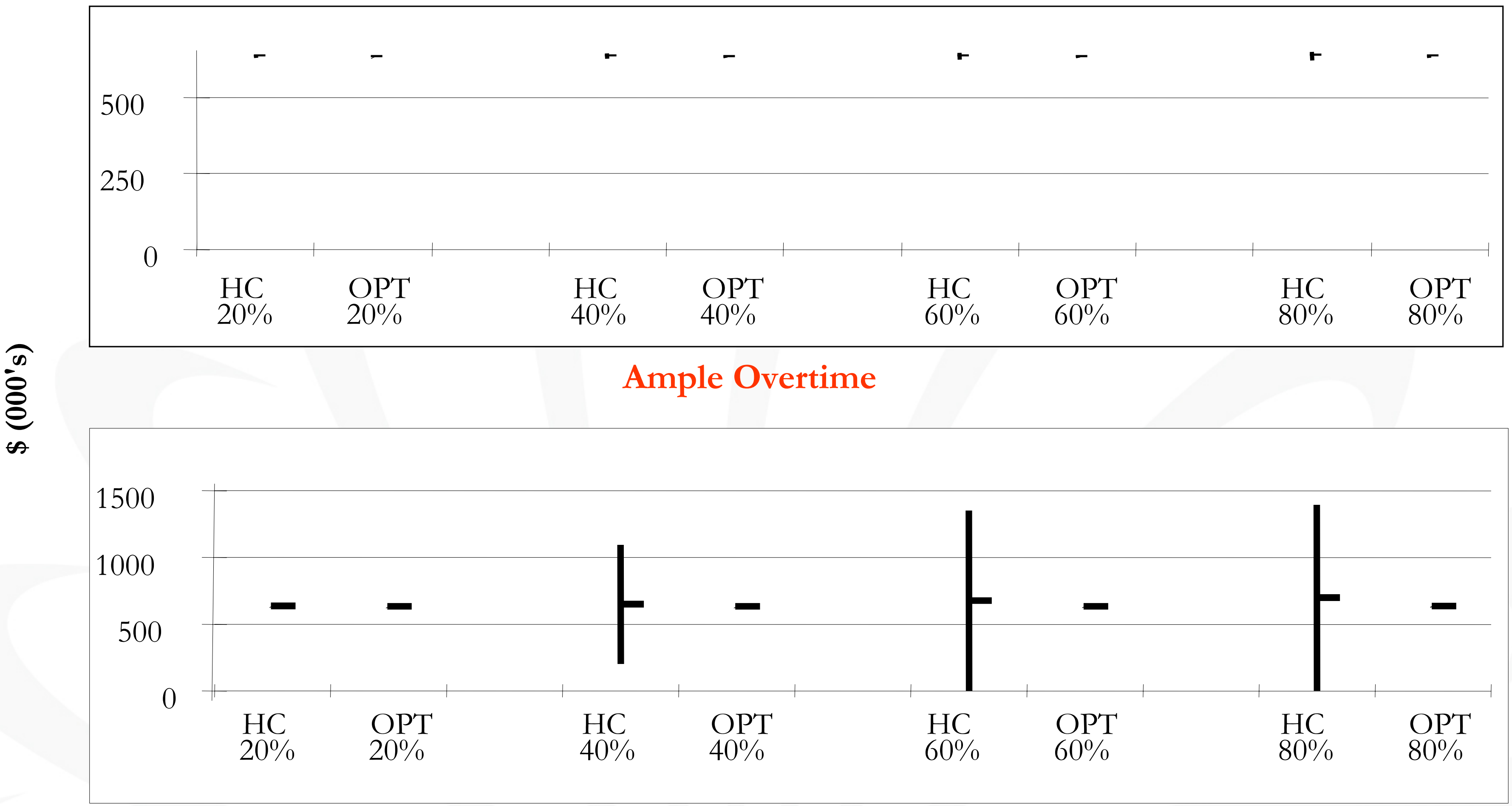


Optimal vs Headcount: Limited Overtime



Cost Variability

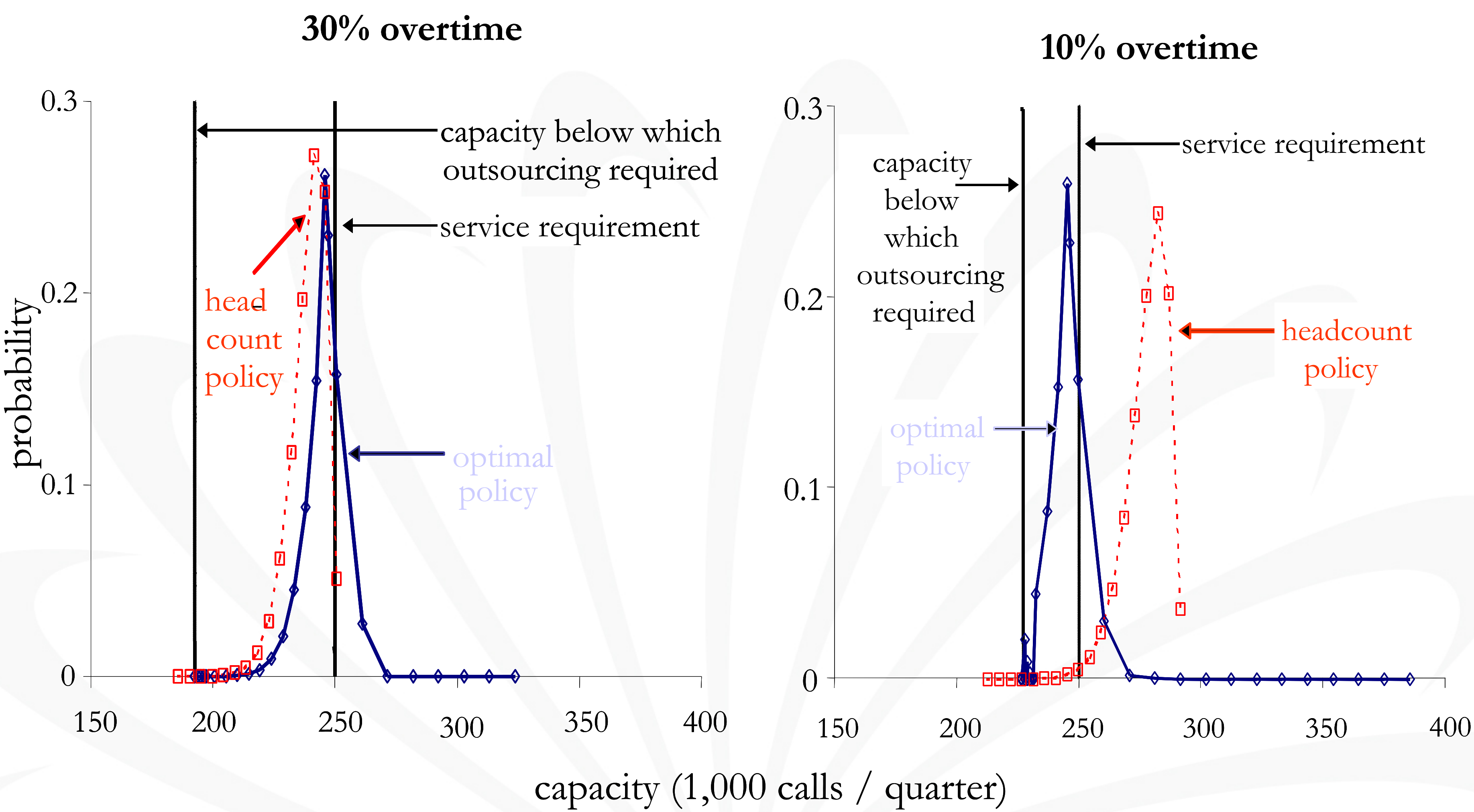
Average Cost +/- 1 Standard Deviation



Limited Overtime

Optimal vs. Headcount

Distribution of Regular Time Capacity



Our Findings

- When spare capacity is cheap
  - simpler hiring schemes do well
  - less need to track employees carefully

$\Rightarrow$ heuristics that ignore learning

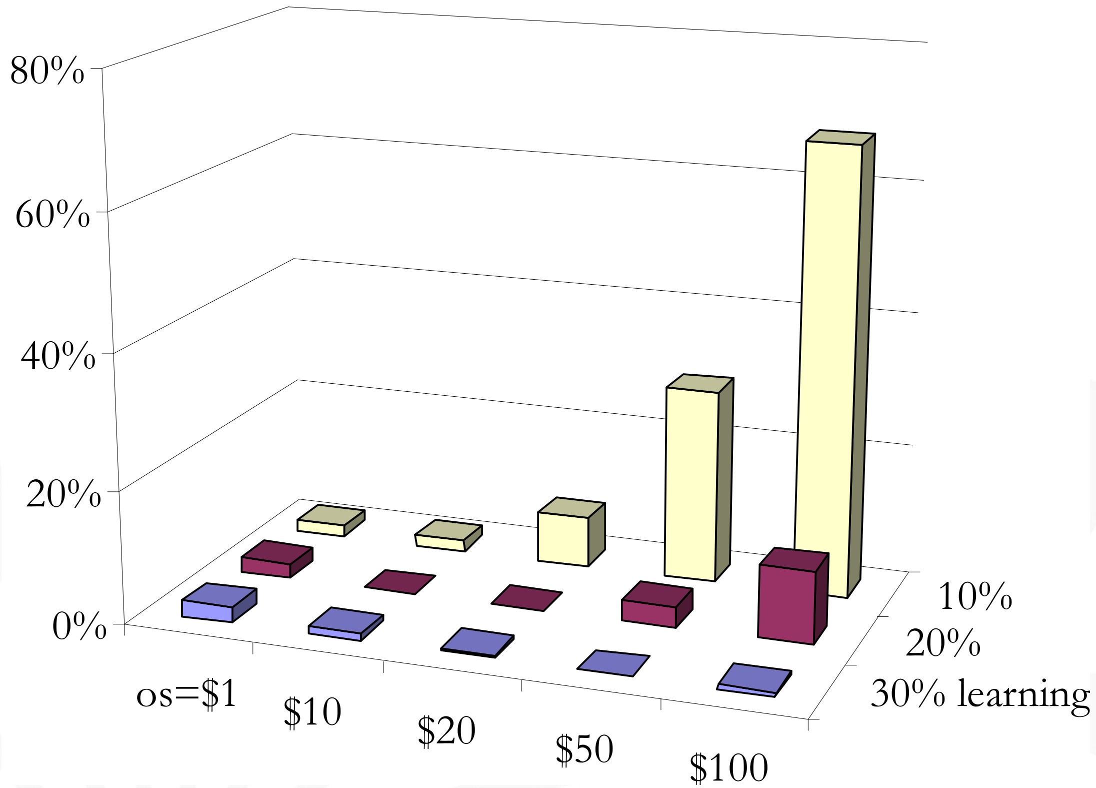
- When spare capacity is tight
  - simpler hiring schemes can do poorly
  - value to tracking employees carefully

$\Rightarrow$ more complex approaches: DP, IPA

Optimal vs. LP Heuristic

- W/O training LT: LP does very well

- When there is a one-period leadtime: LP capacity often falls short



Our Findings

- LP heuristic performs well, when …
  - … training is fast -- LP can wait to observe the number of employees available and hire accordingly
  - … training takes time, but overtime is ample, or OS (or service failure) is cheap -- OT and OS can cover capacity shortfall when turnover is higher than average
  - The optimal "base level" structure simplifies calculation

- LP performs poorly, when …
  - … overtime is limited and OS (or service failure) is expensive
  - If MDP is too complicated to use, then at least add some "buffer capacity" in conjunction with LP

Summary

- A new framework to study employee staffing problems
  - DP approach, allows randomness in the system
  - Natural incorporation of the scheduling and routing problem
  - Optimal policy and structural properties
- Numerical results show when it is worthwhile to more carefully monitor system capacity