Skills-Based Routing and its Operational Complexities

Service Engineering

Wharton's Call Center Forum

May 9, 2003

e.mail: avim@tx.technion.ac.il
Website: http://ie.technion.ac.il/serveng(2003)
Tool: http://4CallCenters.com (register & use)

Supporting Material (in Web-Site)

Gans, Koole, and M.: "Telephone Call Centers: Tutorial, Review and Research Prospects." Invited review to *MSOM*, 2002

Garnett and M.: "An Introduction to Skills-Based Routing and its Operational Complexities", Teaching Note, 2000; under revision.

Borst, M. and Reiman:. "Dimensioning Large Telephone Call Centers." Accepted to *OR*, 2002.

Atar, M. and Reiman: "Scheduling a Multi-Class Queue with Many Exponential Servers: Asymptotic Optimality in Heavy-Traffic." Submitted to <u>Annals Appl Prob</u>, 2002.

M. and Stolyar: "Scheduling Flexible Servers with Convex Delay Costs: Heavy-Traffic Optimality of the Generalized $c\mu$ -Rule." Under revision to *OR*, 2002.

Yahalom and M.: "Optimal Scheduling for a Multi-server Multiclass Non-preemptive Queueing System", in preparation.

Armony and M.: "Optimal Routing, Staffing and Networking in the QED (Halfin-Whitt) Regime: Homogenous Customers and Heterogeneous Servers", in preparation.

Contents

- Introduction to Skills-Based-Routing (SBR):
 Examples: CRM, Distributed Call Centers
 Truly a Multi-Disciplinary Challenge
- Focus: Agent Scheduling, Customer Routing and some Workforce Management (Staffing)
- Operational Regimes: Quality-Driven, Efficiency-Driven
 QED (Quality and Efficiency Driven; Haflin-Whitt)
- 4. Square-Root Staffing Laws: Scale Economies (Erlang)
- 5. Efficiency-Driven SBR: Index strategies in the General Case
- 6. QED SBR: Only special Cases (I, N, V, Upside-Down V)
- 7. Beyond Conventional Queueing Theory:

Abandonment, Retrials; Time-Varying Queues

NationsBank CRM:

What are the relationship groups?

- The groups
 - RG1 : high-value customers
 - RG2 : marginally profitable customers (with potential)
 - RG3 : unprofitable customer
- What does it mean for a customer in each group to be profitable? Customer Revenue Management

Wharton

NationsBank's Design of the Service Encounter

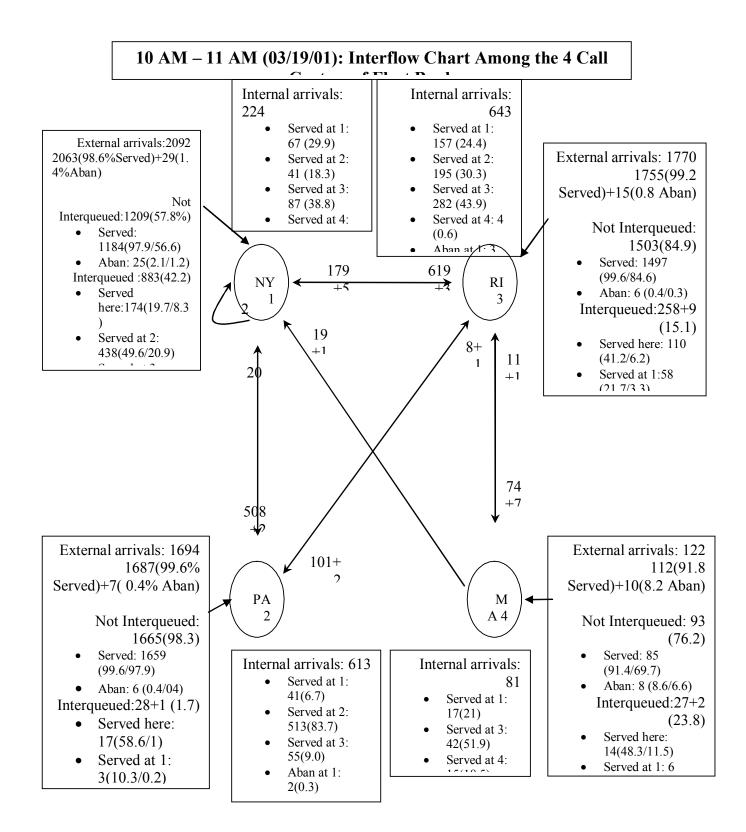
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Examples of Specifications: Assignable Grade Of Service (AGOS)

	RG1	RG2	RG3
VRU Target	70% of calls	85% of calls	90% of calls
Abandonment rate	< 1%	< 5%	< 9%
Speed of Answer	100% in 2 rings	80% in 20 seconds	50% in 20 seconds
Average Talk Time	no limit	4 min. average	2 min. average
Rep. Training	universal	product experts	basic product
Rep. Personalization	request rep / callback	FCFS	FCFS
Trans. Confirmation	call / fax	call / mail	mail
Problem Resolution	during call	within 2 business days	within 8 business days

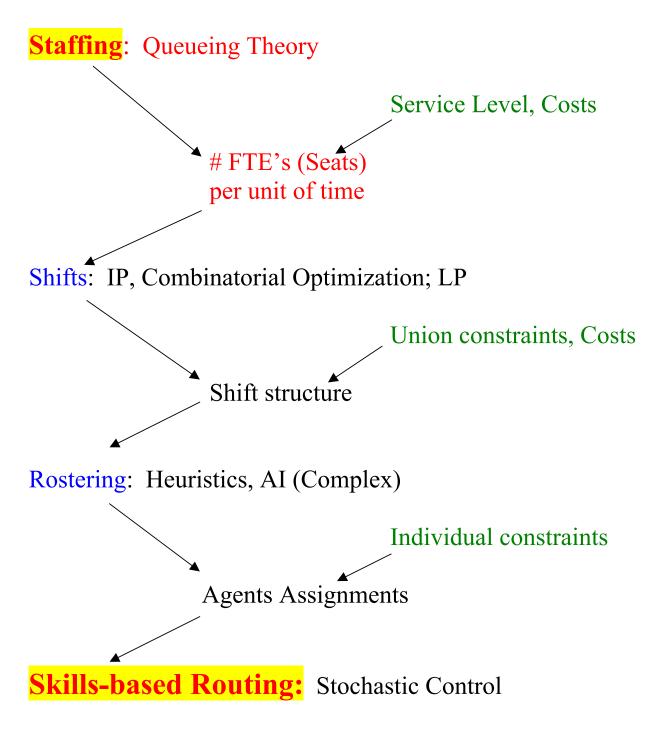
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Distributed Call Center: Member1



Workforce Management: Hierarchical Operational View

Forecasting Customers: Statistics, Time-Series Agents : HRM (Hire, Train; Incentives, Careers)



An Introduction to Skills-Based Routing

and its Operational Complexities

By Ofer Garnett and Avishai Mandelbaum Technion, ISRAEL

(Full Version)

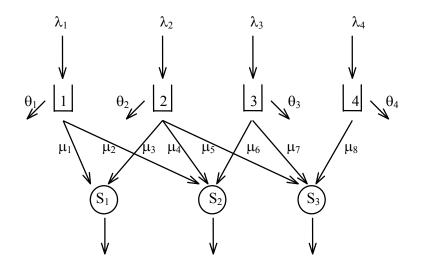
Contents:

- 1. Introduction
- 2. N-design with single servers
- 3. X-design with multi-server pools and impatient customers
- 4. Technical Appendix: Simulations the comutational effort

<u>Acknowledgement</u>: This teaching-note was written with the financial support of the Fraunhofer IAO Institute in Stuttgart, Germany. The authors are grateful to Dr. Thomas Meiren and Prof. Klaus-Peter Fähnrich of the IAO for their assistance and encouragement.

Introduction

Multi-queue parallel-server system = schematic depiction of a **telephone call-center**:



Here the λ 's designate arrival rates, the μ 's service rates, the θ 's abandonment rates, and the S's are the number of servers in each server-pool.

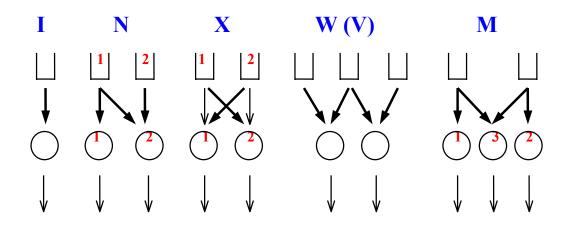
Skills-Based Design:

- Queue: "customer-type" requiring a specific type of service;
- Server-Pool: "skills" defining the service-types it can perform;
- Arrow: leading into a server-pool define its skills / constituency.

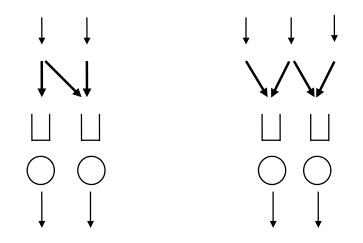
For example, a server with skill 2 (S2) can serve customers of type 3 (C3) at rate μ_6 customers/hour.

Customers of type 3 arrive randomly at rate λ_3 customers/hour, equipped with an impatience rate of θ_3 .

Some Canonical Designs - Animation



- I dedicated (specialized) agents
- N: for example,
 - C1 = VIP, then S2 are serving C1 to improve service level.
 - C2 = VIP, then S2 serve C1 to improve efficiency.
 - S2 = Bilingual.
- X: for example, S1 has C1 as Primary and C2 as Secondary Types.
- V: Pure Scheduling; Upside-down V: Pure Routing.



Major Design / Engineering Decisions

- Classifying customers into types (Marketing): Tech. support vs. Billing, VIP vs. Members vs. New
- 2. Determining server skills, incentives, numbers (HRM, OM, OR) Universal vs. Specialist, Experienced / Novice, Uni- / Multi-lingual
- Prerequisite Infrastructure MIS / IT / Data-Bases (CS, Statistics)
 CTI, ERP, Data-Mining

Major Control Decisions

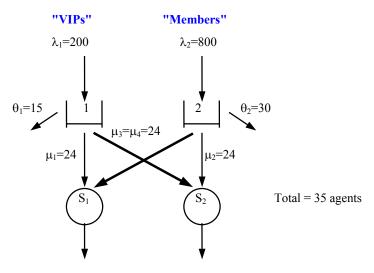
- 4. Matching customers and agents (OR)
 - Agent Scheduling: Whenever an agent turns idle and there are queued customers, which customer (if any) should be routed to this agent.
 - Customer **Routing**: Whenever a customer arrives and there are idle agents, which agent (if any) should serve this customer.
- 5. Load Balancing
 - Routing of customers to distributed call centers (eg. nation-wide)

Multidisciplinary Challenging Research

Skills-Based Routing: protocol for online matching of S's and C's.

- Prevalent: Static Priorities of customer types and agent skills
- Index-based: Dynamic Priorities via continuous review
- Threshold-based: Dynamic Management by Exception
- Others: discrete review, credit schemes (SLA), scripts; call backs

Example: Scripts for Staffing, Scheduling, Routing



Setup A : (X-design)

"VIP" servers : $S_1 = 20$

- If "VIP" queue not empty serve the "VIP" queue + all "Members" waiting more than 40 seconds, as a single FIFO queue.
- If "VIP" queue is empty, serve the first in the "Member" queue.

"Member" servers : $S_2 = 15$

- If "Member" queue not empty serve the "Member" queue + all "VIPs" waiting more than 6 seconds, as a single FIFO queue.
- If "Member" queue is empty, serve the first in the "VIP" queue.

Setup C : (V-design; feasible since servers are assumed equally skilled.) 35

Total servers:

- Serve as a FIFO queue, but "VIPs" enter the queue with a virtual 15 second wait (i.e. as if they had joined the queue 15 seconds earlier).

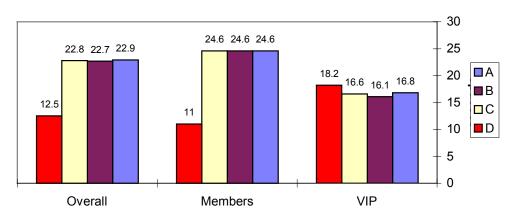


Chart 2 : 1000 Calls/hour - ASA

Chart 3 : 1000 Calls - Abandonment

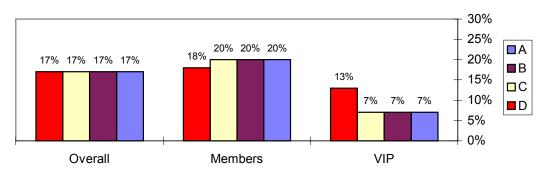
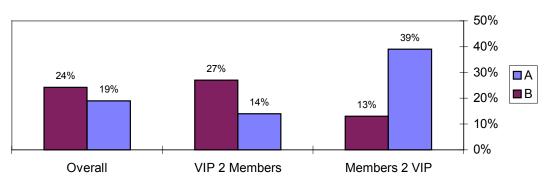
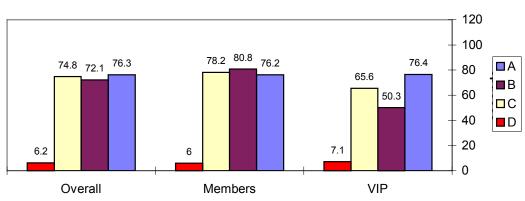


Chart 4 : 1000 Calls - Overflows





WHAT IF : 1500 Calls/hour - ASA



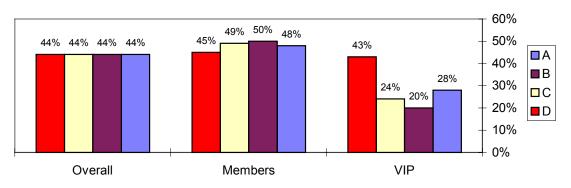
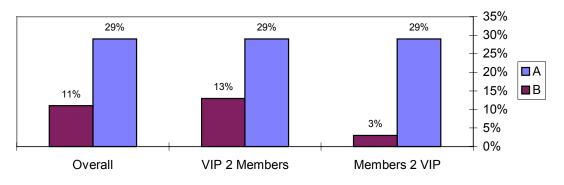


Chart 8 : 1500 Calls - Overflows

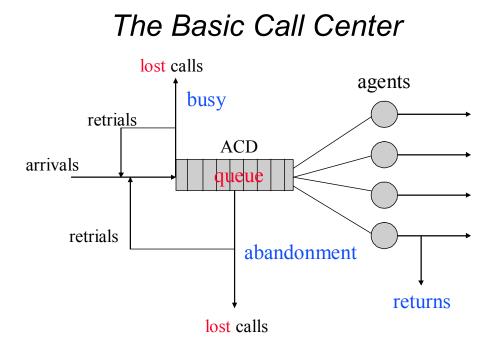


Reality

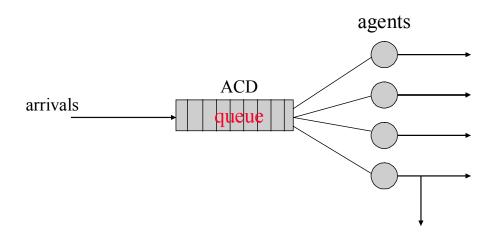
- Technology enables smart systems
- Reality becomes increasingly complex
- Solutions are urgently needed
- Theory lags significantly behind needs
- Ad-hoc methods: heuristics, simulation-based

Research Status

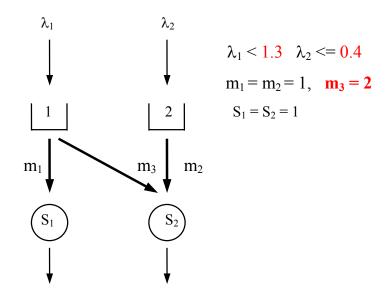
- Efficiency-driven SBR well understood and solved
- QED SBR is challenging and advancing
- Small yet significant models for theoretical insight
- Principles/Guidelines for design, staffing, control
- Implementation: fine-tuning of parameters, scale-up



Erlang-C = M/M/N

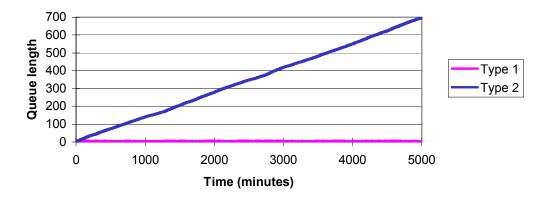


Static Priorities (Cross-Training): Some Subtleties

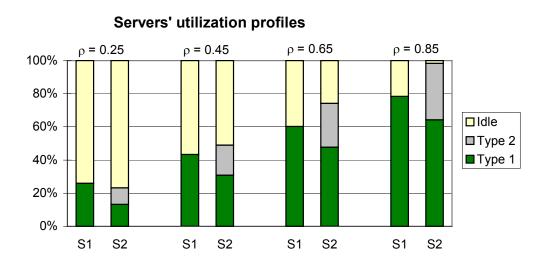


- C1 are VIP, hence S2 helps S1 by giving priority to C1 over C2.
- If both servers are idle Ci customers are routed to server Si

Queue length: S2 helps with VIP C1, Heavy Loading -



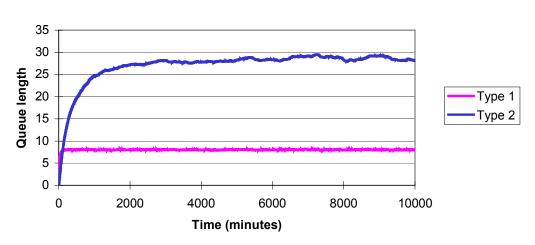
Q2 "explodes, while Q2 is negligibly small – why?



Instability: S2 overworked serving C1 and neglecting C2, while S1 is 20% idle.

To avoid "overzealous help", apply **Threshold control**:

S2 assists S1 only when Q1 is at or above a certain threshold



Queue Lengths: Threshold = 8 , Heavy Traffic

Both Q1 and Q2 are stable.

Now fine-tuning of the threshold value

Efficiency-Driven SBR - the "EASY" Case

Examples: Scarce agents, hence must be well utilized. Email-dominance, hence can delay response.

Classical special case: V-design

- Agent Scheduling: upon service completion, if

- 1. Same mean service times: serve the costliest queue (largest c)
- 2. Same delay costs: serve the shortest service (smallest m)
- 3. Generally: serve the largest c/m (= index).

General (N, X, W, M, ...) solution: Index Control is optimal

- Customer Routing: irrelevant, since essentially <u>all customers wait</u>.
- Agent Scheduling: upon service completion, the server chooses the queue with the largest <u>index</u> and serves its "oldest" customer.
- Index: marginal waiting-cost per unit of average service-time
 (Example: actual "waiting-time" of the "oldest" customer in queue)

However: well-managed telephone services are not (at least should not be) Efficiency-Driven !? What can be achieved

Copy of Summary Interval . Order PK

Date: 7/7/87 Split/Skill: Order PK

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Rough Performance Analysis

Peak 10:00 – 10:30 a.m., with 100 agents 400 calls

3:45 minutes average service time

Offered load $\mathbf{R} = \lambda \times E(S)$ = 400 × 3:45 = 1500 min./30 min. = 50 Erlangs

Occupancy $\rho = R/N$ = 50/100 = 50%

⇒ **Quality-Driven Operation** (Light-Traffic)

Above: R = 50, N = R + 50, \approx all served immediately. Rule of Thumb: $N = \lceil R + \delta R \rceil$, $\delta > 0$ service-grade.

Quality-driven: 100 agents, 50% utilization

 \Rightarrow Can increase offered load - but by how much?

Erlang-C	N=100	E(S) = 3:45 min.							
<u>λ</u> /hr	$\underline{\rho}$	$E(W_q) = ASA$	% Wait = 0						
800	50%	0	100%						
1000	62.5%	0	100%						
1200	75%	0	99.7%						
1400	87.5%	0:02 min.	88%						
1500	93.8%	0:15 min.	60%						
1550	96.9%	0:48 min.	35%						
1580	98.8%	2:34 min.	15%						
1585	<mark>99.1%</mark>	<mark>3:34 min.</mark>	12%						

⇒ Efficiency-driven Operation (Heavy Traffic)

Above: R = 99, N = R + 1, \approx all delayed. Rule of Thumb: $N = \lceil R + \gamma \rceil$, $\gamma > 0$ service grade.

Changing N (Staffing)

		I	E(S) = 3:45	
<u>λ</u> /hr	N	OCC	ASA	% Wait = 0
1585	100	99.1%	3:34	12%
1599	100	99.9%	59:33	0%
1599	<mark>100+1</mark>	98.9%	3:06	13%
1599	102	98.0%	1:24	24%
1599	105	<mark>95.2%</mark>	<mark>0:23</mark>	<mark>50%</mark>

⇒ New Rationalized Operation

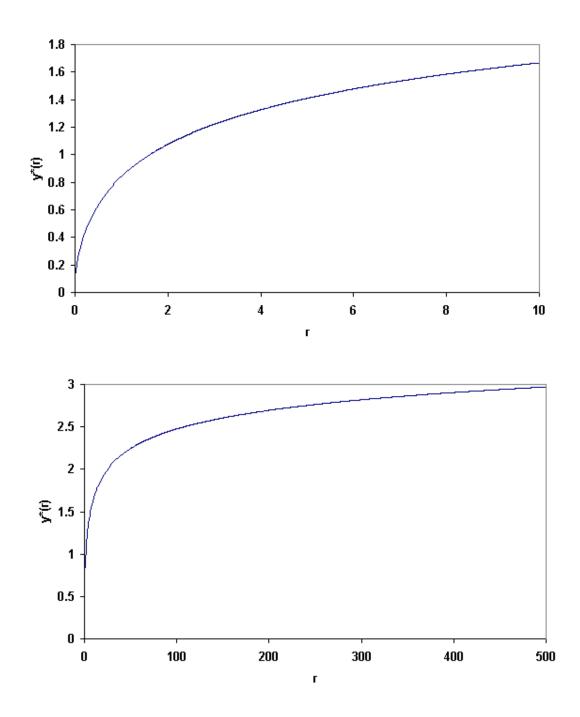
Heavy traffic, in the sense thatOCC > 95%;Light traffic,50% answered immediately

QED Regime = **Quality- and Efficiency-Driven Regime**

Above: R = 100, N = R + 5, 50% delayed.

 $\sqrt{\cdot} \text{ Safety-Staffing } \mathbf{N} = \left[\mathbf{R} + \beta \sqrt{\mathbf{R}}\right], \quad \beta > 0 \quad .$

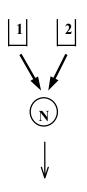
Square-Root Safety Staffing: $N = R + y^*(r)\sqrt{R}$ $r = \cos t \text{ of } \frac{delay}{(1-800)} / \cos t \text{ of } \frac{staffing}{staffing} (salary)$



<mark>V</mark>-Design: Pure <mark>Scheduling</mark>

N agents, fully flexible

C1 = VIP



Optimal Scheduling: Agent Reservation

- C1(=VIP) always served, if possible;
- C2 served only if # of idle agents exceeds a threshold.

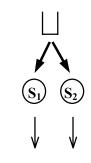
QED regime: $\sqrt{\cdot}$ Safety-Staffing, as before.

Threshold Size (relative to N) determines Service Levels:

- Large: C1 is Q-served, C2 is E-served
- Small: C1 and C2 indistinguishable QED
- Moderate: C1 is Q-served, C2 is QED

Upside-Down-V Design: Pure Routing

Homogeneous Customers Heterogeneous Agents: **S1 = Faster**



Optimal Routing: "Slow-Server" phenomenon

- S1(=Fast) always employed, if possible;
- S2(= Slow) employed if # in queue exceeds a threshold.

QED regime: $\sqrt{\cdot}$ Safety-Staffing for S1+S2.

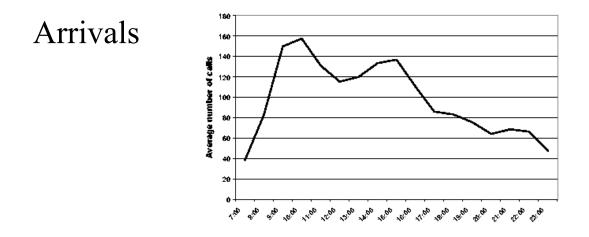
- No threshold needed: just have all servers work

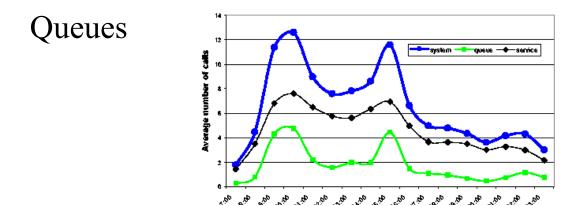
when possible, ensuring that the "fast" get the priority.

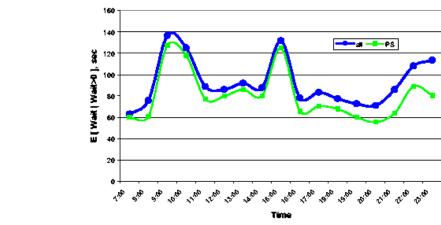
- Can do also detailed staffing: how many S1 and S2.
- Distributed call centers: similar

But N-Design active challenging research

Beyond Erlang-C: Predictable Variability







Waiting

Erlang-A: (Im)Patience

1 Common Performance

3/04/99 637 0:19 219 0:26 1:57 92:05 0 4310:06 8.7 6 3/05/99 849 0:06 113 60:05 1:35 179:58 0 429:43 11.3 8 3/07/99 1213 0:12 358 0:18 1:42 280:22 0 5592:23 13.2 7 3/07/99 1213 0:12 358 0:18 1:46 226:20 0 4830:15 11.5 7 3/08/99 631 0:26 382 0:33 1:57 150:50 0 3743:04 7.9 4 3/10/99 570 0:40 70:47 1:52 1:48:41 0 3379:04 6.7 3 3/10/99 572 0:23 222 0:28 1:41 243:06 0 3046:00 7.9 5 Witch Name: FDC/HAMPDEN Date: 7:00 pm WED MAR 10, 1999 5 Skill: 430 0:22 479 0:31 2:08 100:16 0 4213:22 <td< th=""><th>AY</th><th>1: 37 e: !BA</th><th>AUTH1</th><th></th><th></th><th></th><th>A</th><th>ccept</th><th>able</th><th>Service</th><th>Level</th><th>30</th></td<>	AY	1: 37 e: !BA	AUTH1				A	ccept	able	Service	Level	30		
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BCMS SKILL REPORT Witch Name: FDC/HAMPDEN Skill: 33 Date: 7:01 pm WED MAR 10, 1999 Skill Name: GA Authorization Acceptable Service Level: 30 AVG AVG AVG TOTAL % IN ACD SPEED ABAND ABAND TALK AFTER FLOW FLOW AUX/ AVG SERV ACD SPEED ABAND ABAND TALK AFTER FLOW FLOW AUX/ AVG SERV AVY CALLS ANS CALLS TIME TIME CALL IN OUT OTHER STAFF LEVI 0/04/99 1248 0:27 61 0:42 1:57 330:04 0 0 6035:35 13.0 82 0/05/99 1521 0:14 37 0:20 1:58 353:48 0 6035:35 13.0 82 0/06/99 2388 0:20 130 0:34 2:10 550:16 0 6369:58 14.4 76 0/08/99 925 0:18 50 1:00 1:53 191:06 0 <th< td=""><td>JMMARY</td><td>10963</td><td>0:19</td><td>3788</td><td>0:22</td><td>1:55</td><td>2019:24</td><td>0</td><td>0</td><td></td><td></td><td>65</td></th<>	JMMARY	10963	0:19	3788	0:22	1:55	2019:24	0	0			65		
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Switch Name: FDC/HAMPDEN

Date: 7:02 pm WED MAR 10, 1999