Data-Based
Service Engineering (Science, Management)
in Call Centers, Hospitals, . . .

Avishai Mandelbaum

Technion, Haifa, Israel

http://ie.technion.ac.il/serveng

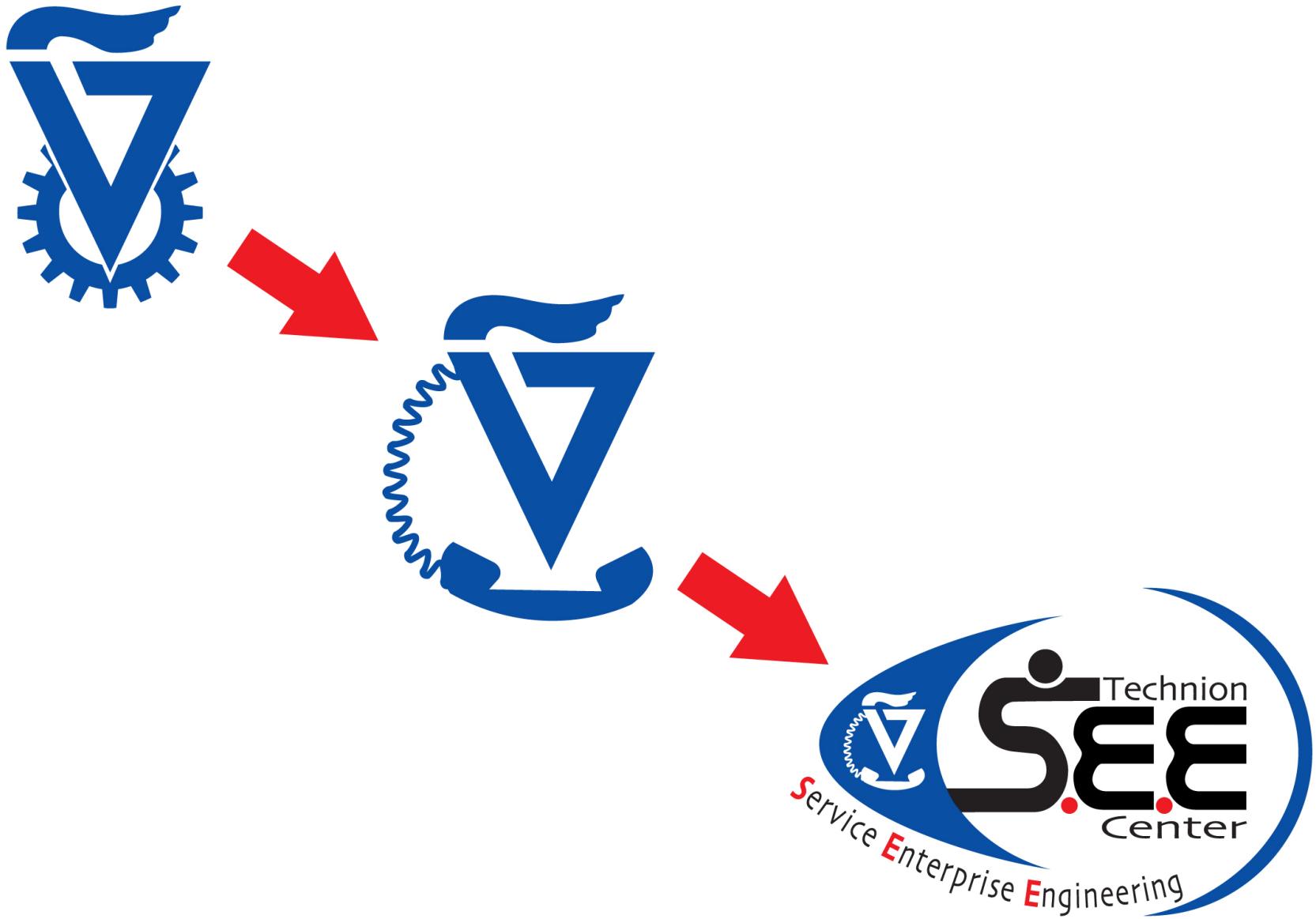
16th IE&M Conference, Tel-Aviv, March 2010

Research Partners

- **Students**:
  Aldor*, Baron*, Carmeli, Feldman, Garnett*, Gurvich*, Khudiakov*, Maman*, Marmor, Reich, Rosenshmidt*, Shaikhet*, Senderovic, Tseytlin*, Yom-Tov, Zaied, Zeltyn*, Zohar*, Zviran, . . .
- **Empirical/Statistical Analysis**:
  Brown, Gans, Zhao; Shen; Ritov, Goldberg; Allon, Bassamboo, Gurvich; Armony, . . .
- **Theory**:
  Armony, Atar, Feigin, Gurvich, Jelenkovic, Kaspi, Massey, Momcilovic, Reiman, Shimkin, Stolyar, Wasserkrug, Whitt, Zeltyn, . . .
- **Industry**:
  IBM Research (OCR: Carmeli, Vortman, Wasserkrug, Zeltyn), Rambam Hospital, Hapoalim Bank, Mizrahi Bank, Pelephone Cellular, . . .
- **Technion SEE Center / Labaratory**:
  Feigin; Trofimov, Nadjharov, Gavako, Kutsyy; Liberman, Koren, Rom; Research Assistants, . . .

The Technion SEE Center / Laboratory

Data-Based Research & Teaching



History, Resources (Downloadable)

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  http://ie.technion.ac.il/Labs/Serveng
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- **Technion IE&M** = Outsourcing Knowledge (Research, Practice)

  e.g. Search Google Scholar for <**Call Centers**>:
  First 5 entries originated at the Technion.

The Case for Service Science / Engineering

- **Service Science / Engineering** (vs. Management) are emerging **Academic Disciplines**. For example, universities (world-wide), IBM (SSME, a là Computer-Science), USA NSF (SEE), Germany IAO (ServEng), ...

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  - Hospitals
  - Justice
  - Transportation
  - ...

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- **What Can Be Done** vs. **How To** (*Pause for a Commercial*)

Expanding the Scientific Paradigm

Service Engineering vs. **Industrial** Engineering

Human Complexity

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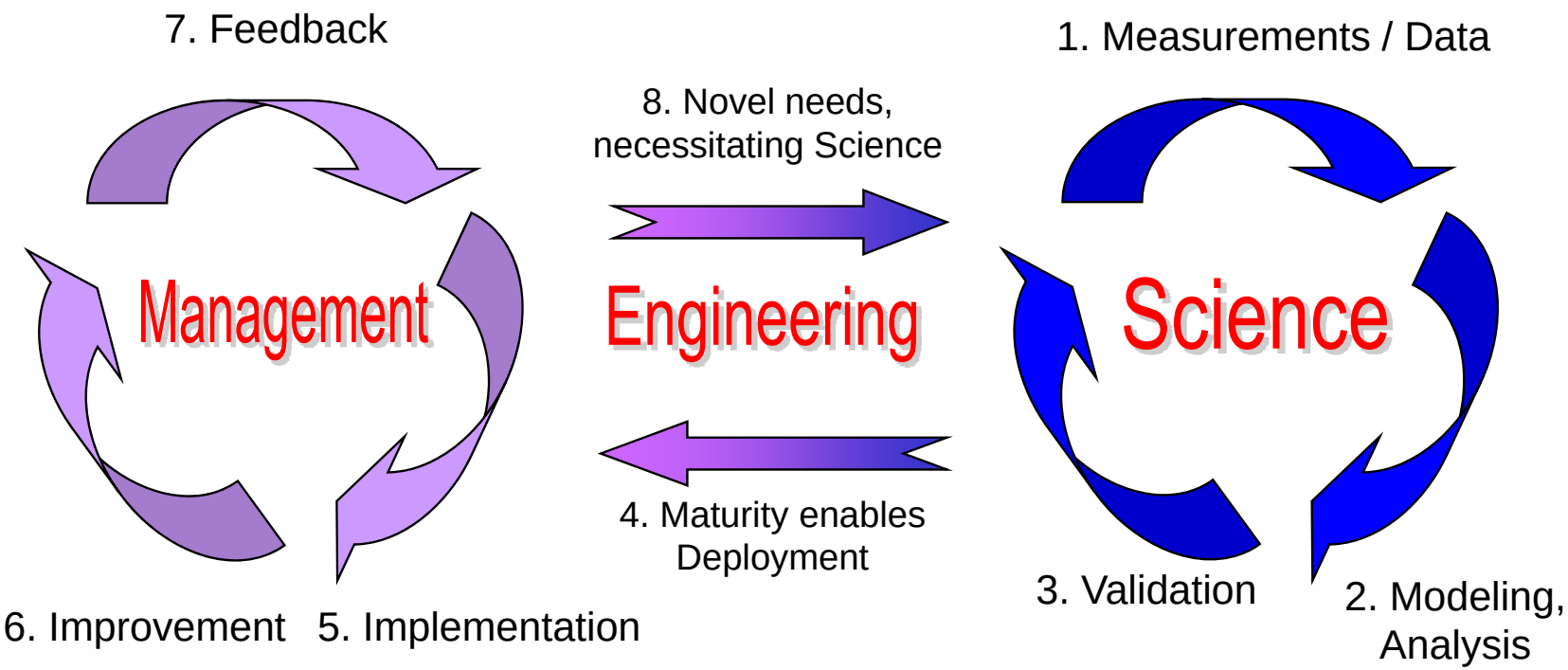
Service Engineering vs. **Industrial** Engineering

Human Complexity $\Rightarrow$ **Scientific Paradigm** (Physics ... Economics) and beyond (with IBM Research):



Started with Call Centers, Expanded to Hospitals

Call Centers - U.S. (Israel) Stat.

- $200 – $300 billion annual expenditures (0.5)
- 100,000 – 200,000 call centers (500)
- “Window" into the company, for better or worse
- Over 3 million agents = **2% – 4% workforce** (11K)

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Healthcare - similar and unique challenges:

- Cost-figures far more staggering
- Risks much higher
- ED (initial focus) = hospital-window
- Over 3 million nurses

Call-Center Environment: Service Network

Call-Centers: “Sweat-Shops of the 21st Century"

ER / ED Environment: Service Network

Acute (Internal, Trauma)

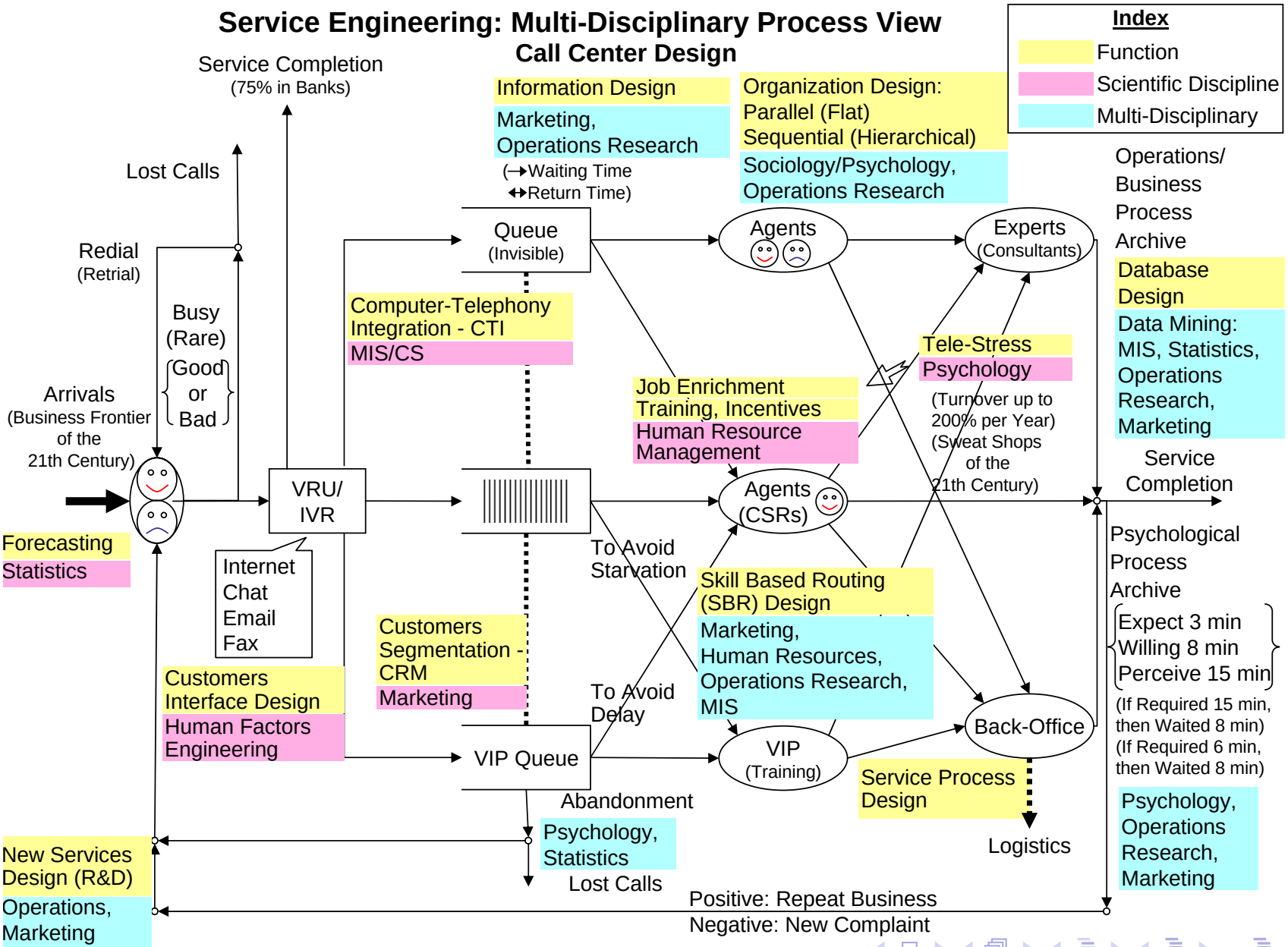
Walking

Multi-Trauma

ED-Environment in Israel

ED-Queue in a “Good" Beijing Hospital

Call-Center: Multi-Disciplinary ServEng View



Skills-Based Routing in Call Centers

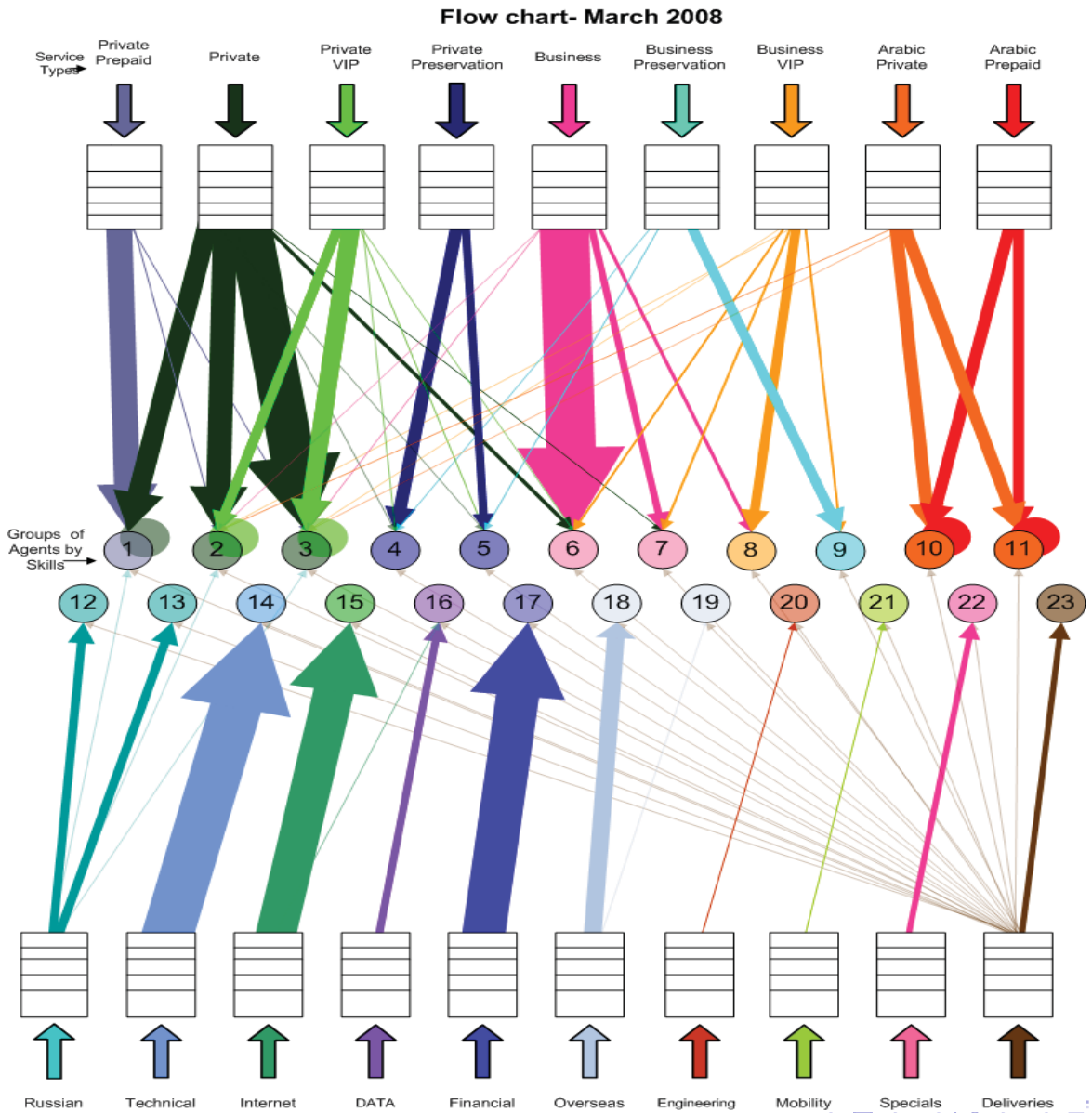
EDA and OR, with I. Gurvich and P. Lieberman

Mktg. ⇒

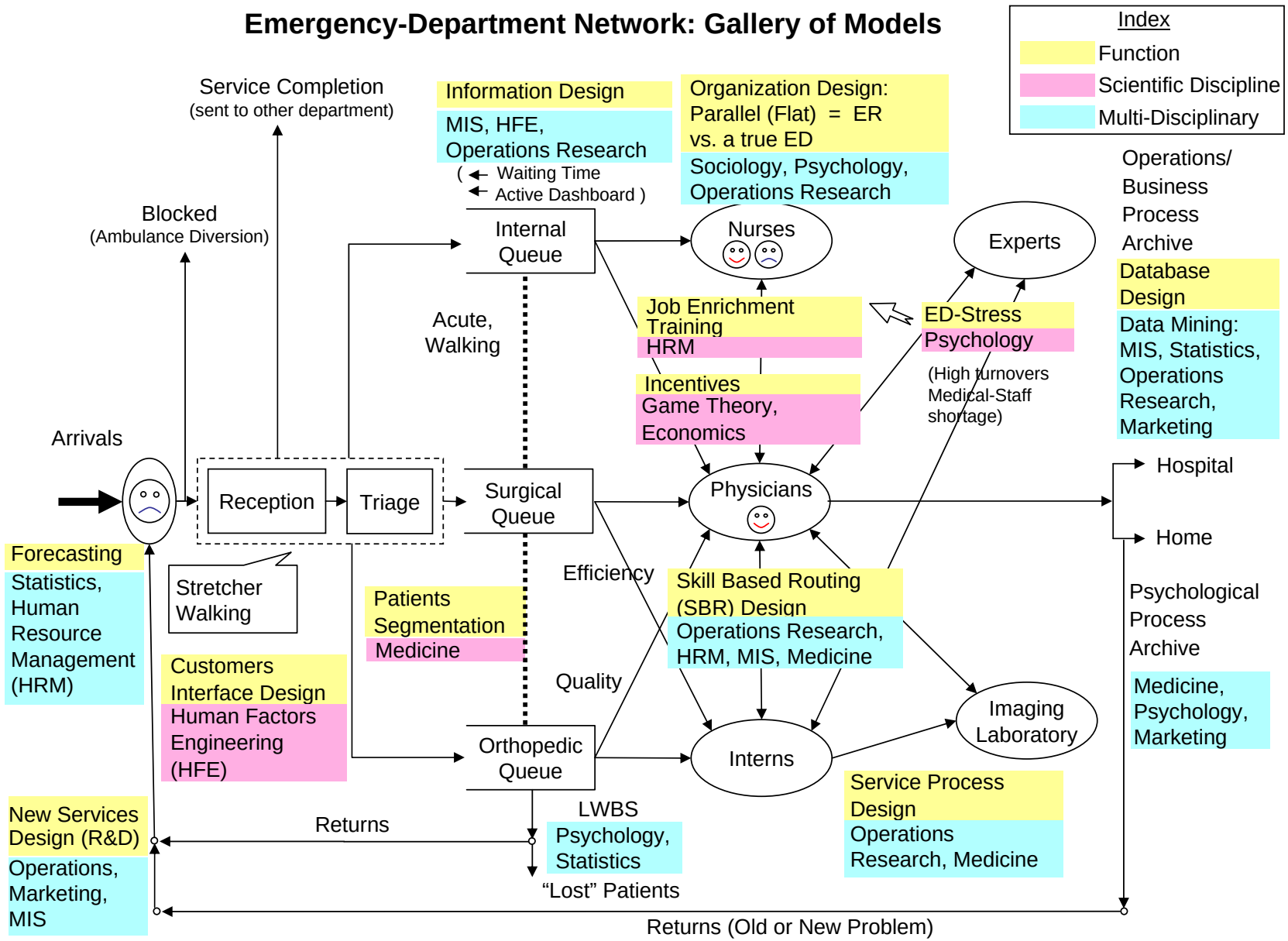
OR ⇒

HRM ⇒

MIS ⇒



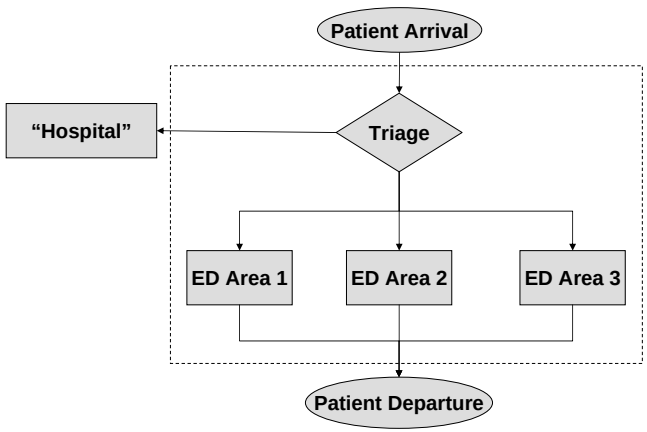
Emergency-Dept.: Multi-Disciplinary ServEng View



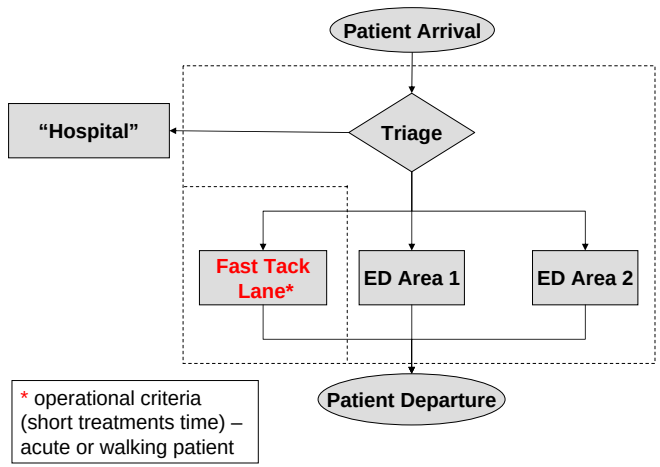
ED Design, with B. Golany and Y. Marmor (PhD)

Routing: Triage (Clinical), Fast-Track (Operational), . . . (via DEA)

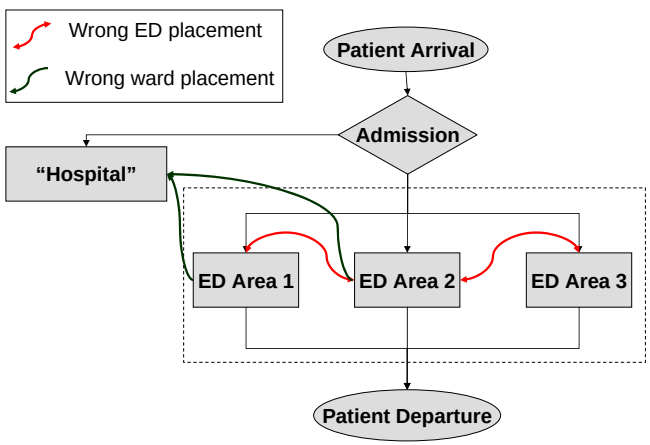
e.g. Fast Track most suitable when elderly dominate



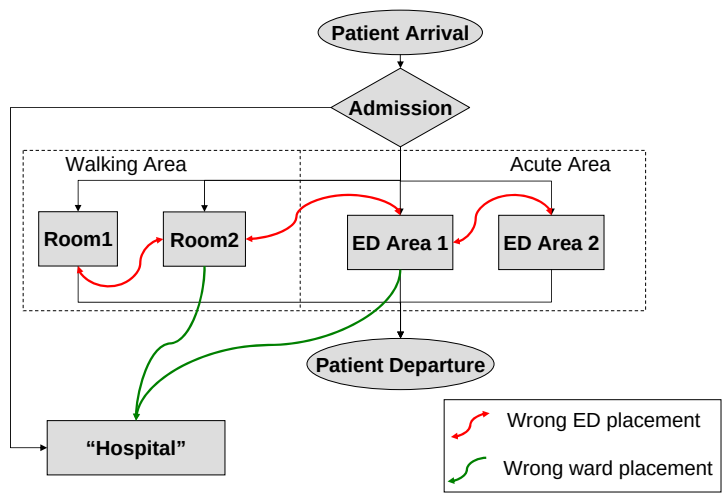
(a) Triage Model



(b) Fast-Track Model



(c) Illness-based Model



(d) Walking-Acute Model

ED-to-IW Routing: A Hospital Bottleneck

Israeli Large Hospital (1/5/06 to 30/10/08, excluding 1-3/07)

	Ward A	**Ward B**	Ward C	Ward D
ALOS (days)	6.37	**4.47**	5.36	5.56
Avg Occupancy Rate	97%	**95%**	86%	92%
Avg # Patients per Month	206	187	210	210
Standard bed capacity	45	30	44	42
Avg # Patients /Bed/Month	4.57	**6.25**	4.77	4.77
Returns (within 3 months)	15.4%	15.6%	16.2%	14.8%

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- The “fastest" + smallest **Ward B** subject to highest **workload** = **bed-occupancy, bed-turnover (flux)**: **unfair !**
- Calls for ED-to-IW routing, which is both **efficient and fair** (w/ **Tseytlin** (M.Sc.), Tseytlin & **Momcilovic**, Tseytlin & **Zviran**): **Markov exact, QED approx. (natural), partial information**.

On “Fairness" in Hospitals (“Justice-Table")

- **Patients Fairness** (prevalent): Least delays, hence higher priority to “faster" wards.
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- **Bed-Occupancy = Bed-Turnover $\times$ ALOS**, by **Little’s Law**.

Fair & Efficient ED-to-IW Routing

- **Tunable Routing**, customized to preferences,
  with **Y. Tseytlin** and **P. Momcilovic**:

  Route to ward with **highest (weighted) idleness-ratio**, i.e.

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- Last, but not least - Workload is both **Operational + Cognitive**: 5 minutes taking temperature vs. 5 minutes saving life.

  e.g. Two Maternity Wards perceive unfairness, hence psychological:

  - Ward 1: complications **before** birth
  - Ward 2: complications **after** birth
  - **Fair routing** of **normal** births? (Just starting, with **A. Rafaeli**)

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Averages Prevalent (and could be useful / interesting).

But I need data at the level of the **Individual Transaction**:
For each service transaction (during a phone-service in a call center, or a patient's visit in a hospital, or browsing in a website, or . . .), its **operational history** = time-stamps of events .

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- Expanding:
  - Hospitals, via **RFID**, with **B. Carmeli, S. Israelit, Y. Marmor**
  - Operational + Financial + Contents (Marketing, Clinical)
  - Internet, chat (multi-media)

Prerequisite II: Models (The Fluid View)

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Flow Design and Control: Transportation (Fluid) Network




The Fluid View: Labor-day Queueing at Niagara Falls

Stochastic Individualism **Averaged** out by the **LLNs** (Scale)

Fluid Models: Preparing for Mass-Casualty Events

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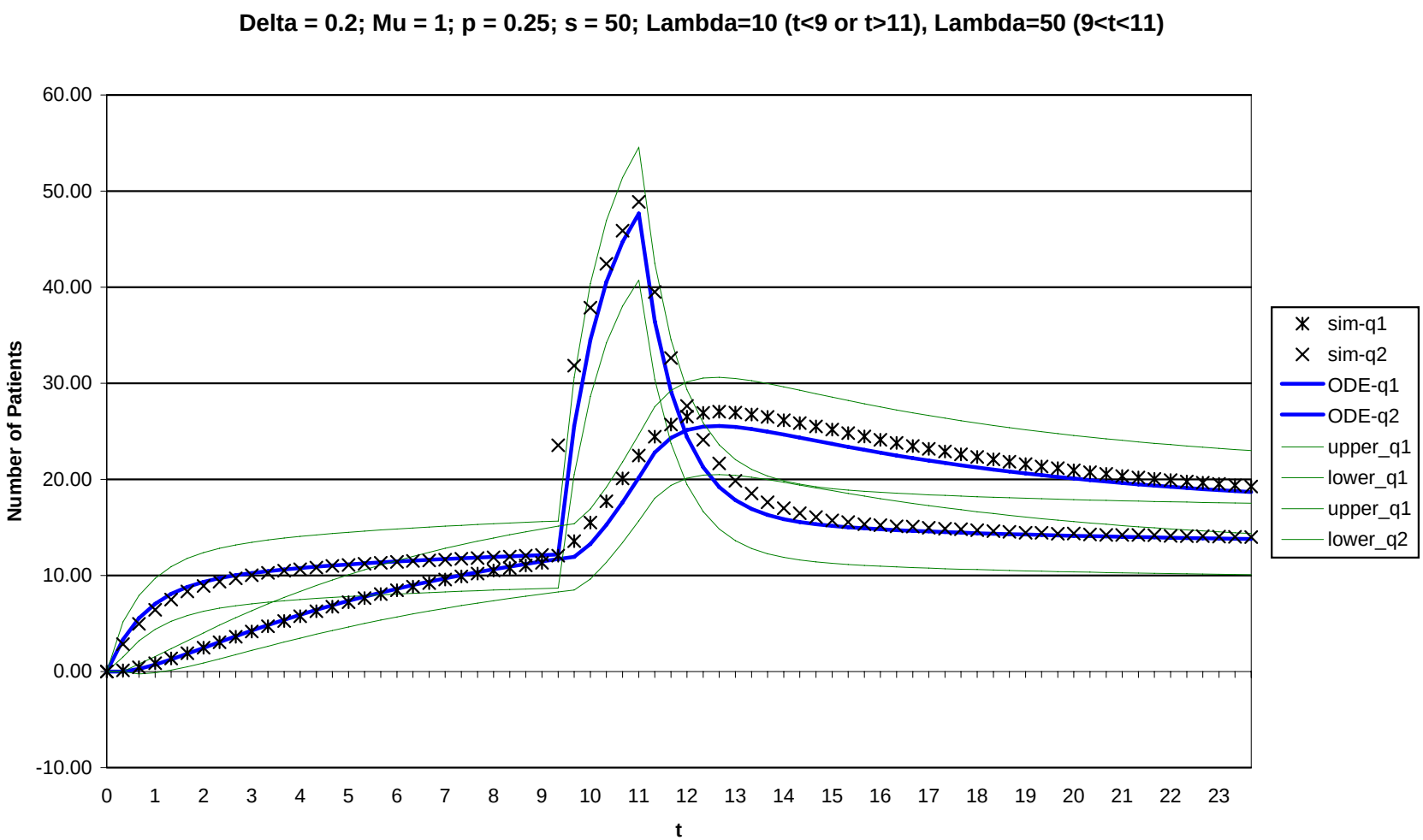
e.g. Erlang-R = **R**eEntrant Patients, with **G. Yom-Tov** (PhD).

5-fold Rise in Inflow-Rate, between 9am -11am:



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e.g. **Single-server** queue (M/M/1) in **Heavy-Traffic**:
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and, moreover, a significant fraction are not delayed in queue. (For example, in well-run call-centers, **50%** served "immediately", along with over **90%** agents' utilization, is not uncommon) **?** **QED**

Operational Regimes: Conceptual Framework

R: **Offered Load** not too small.

def. ***R*** = Arrival-rate $\times$ Average-Service-Time

e.g. ***R*** = 25 calls/min. $\times$ 4 min./call = **100**

N = #Agents **?**

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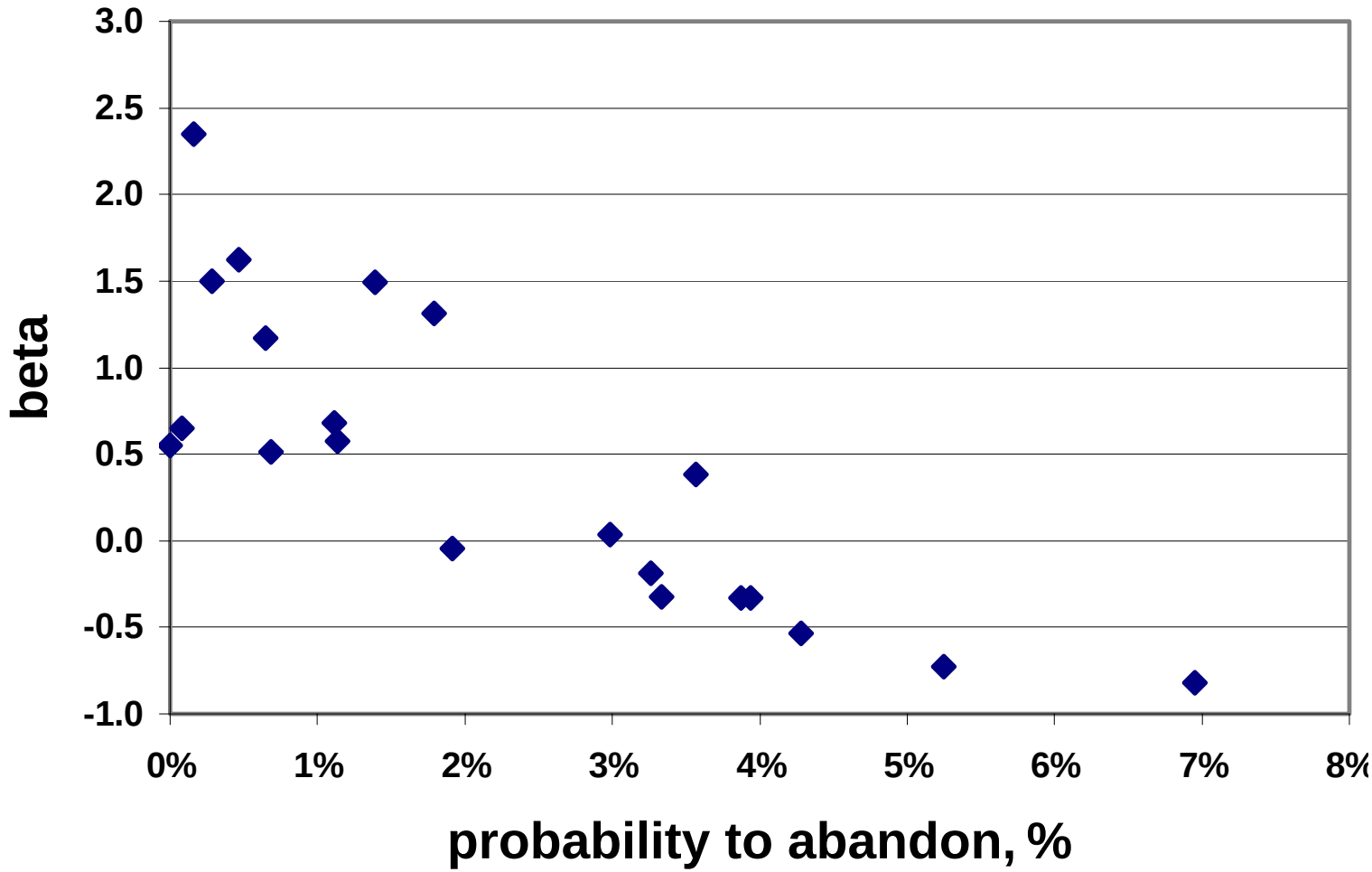
QED Regime: $N \approx R + \beta\sqrt{R}$, $-1 < \beta < +1$ (e.g. $N = 100$)

- Erlang 1913/24, Halfin & Whitt 1981, Garnett et. al.
- %Delayed between 25% and 75%
- Wait one-order below service-time (sec vs. min); 1-5% Abandon

QED: Practical Support

QOS parameter $\beta = (N - R)/\sqrt{R}$ vs. %Abandonment



Operational Regimes: Rules-of-Thumb, with **S. Zeltyn**

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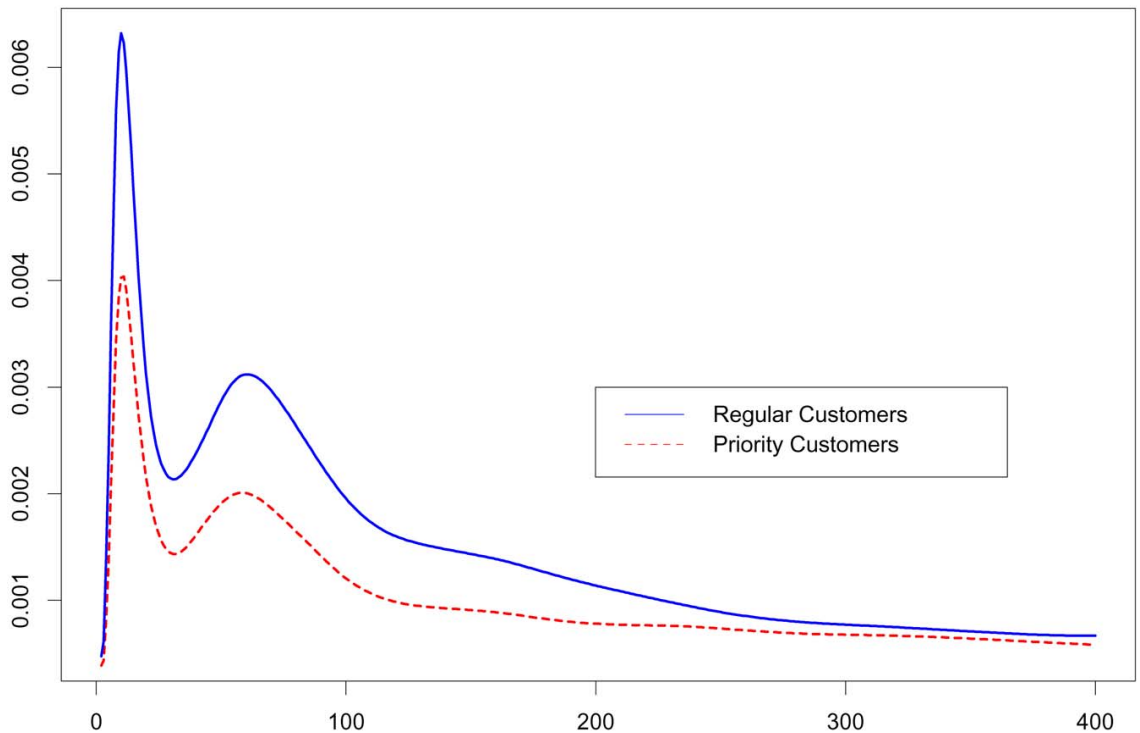
WFM: How to determine specific staffing level $\boldsymbol{N}$? e.g. β.

(Im)Patience while Waiting (Palm 1943-53)

Irritation $\propto$ Hazard Rate of (Im)Patience Distribution
Regular over VIP Customers – Israeli Bank



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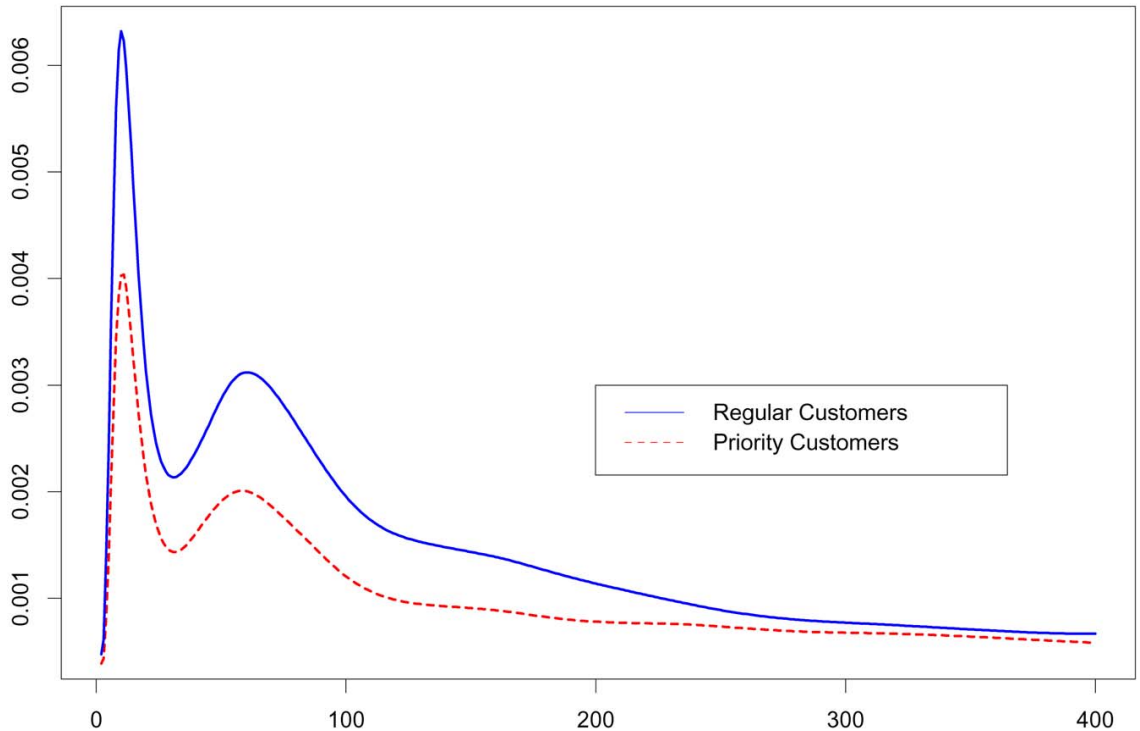

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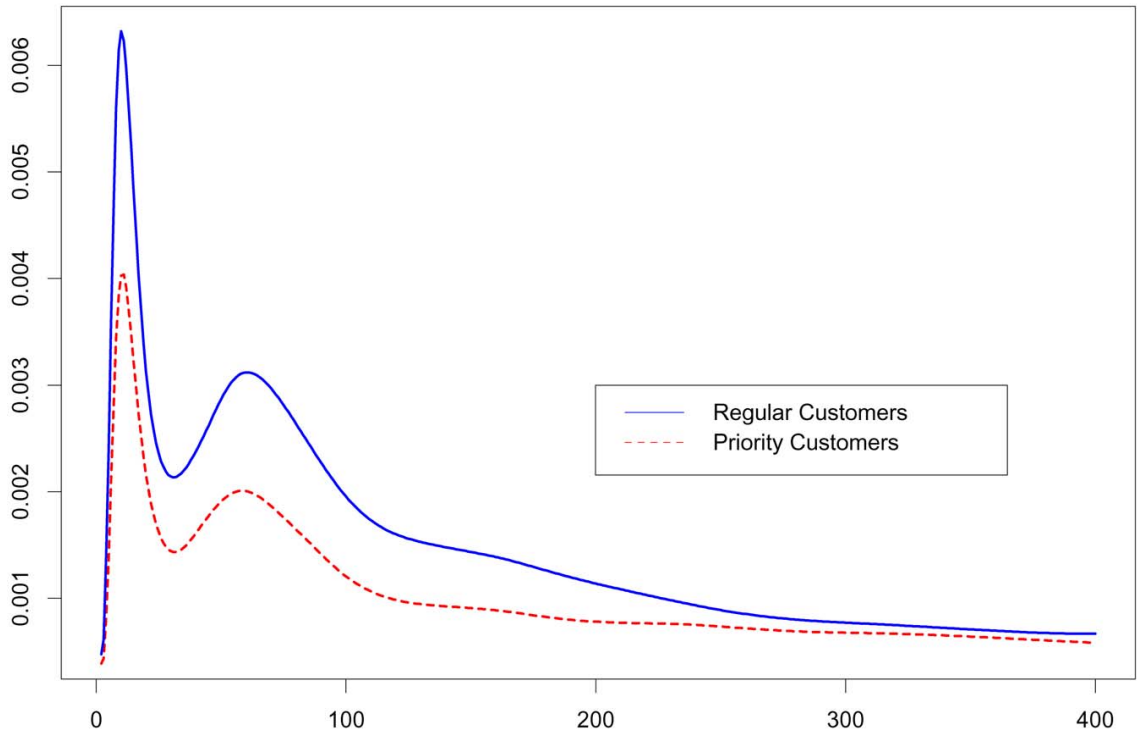

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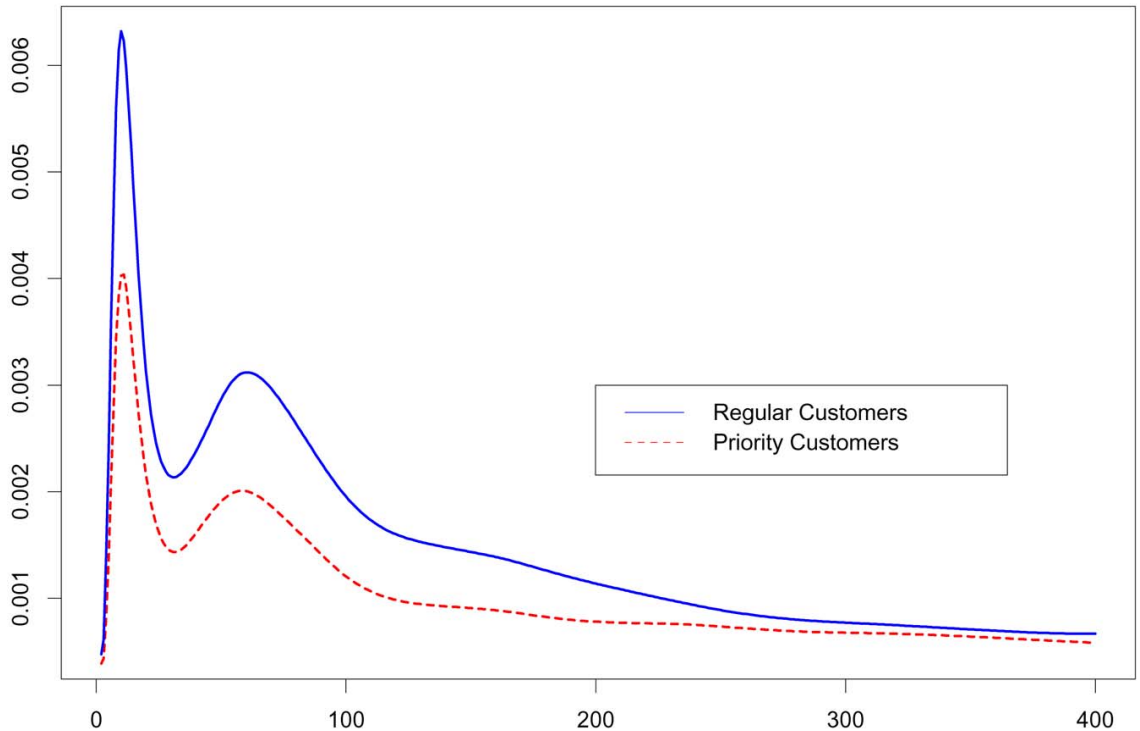

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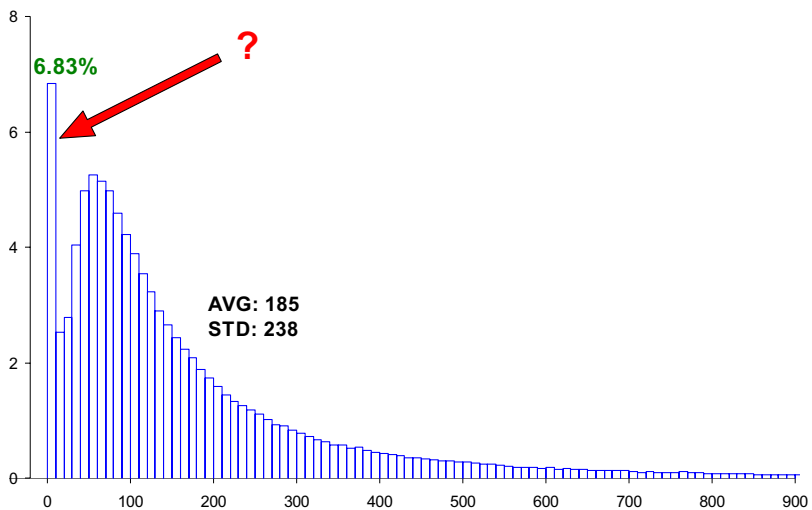
- **Peaks** of abandonment at times of **Announcements**
- **VIP** are **more patient** (Needy)

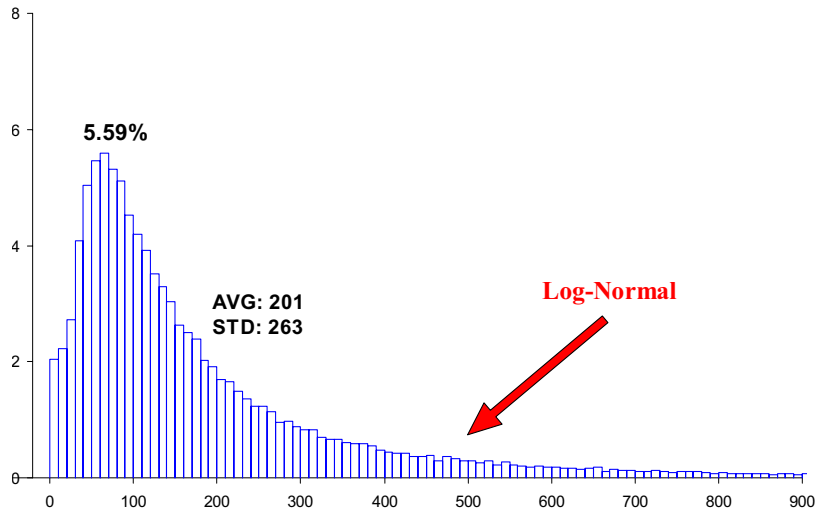
Beyond Averages: The Human Factor

Histogram of Service-Time in a (Small Israeli) Bank

January-October



November-December



- 6.8% Short-Services:

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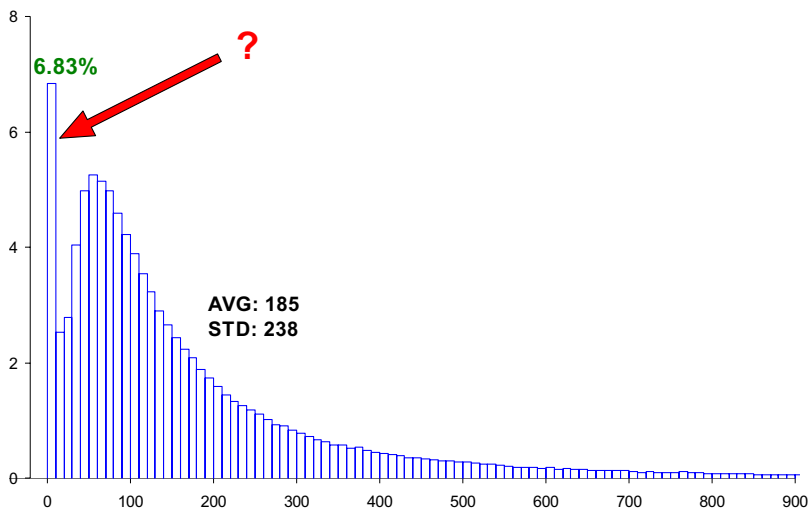

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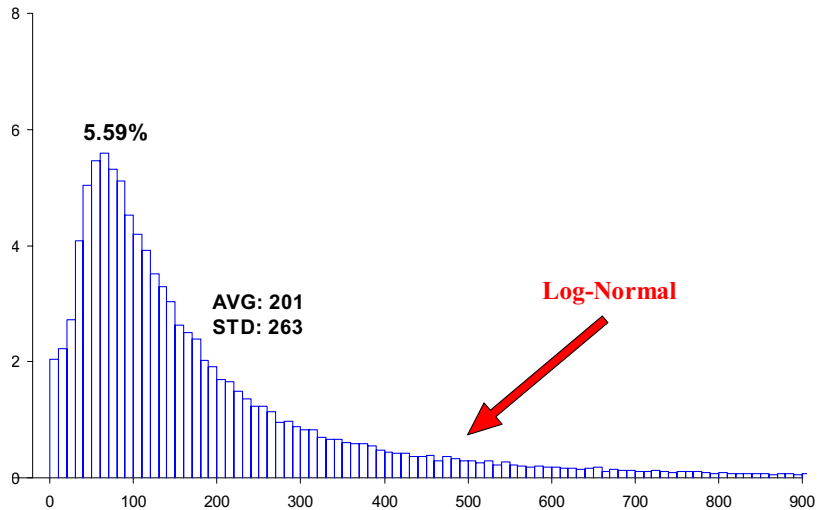
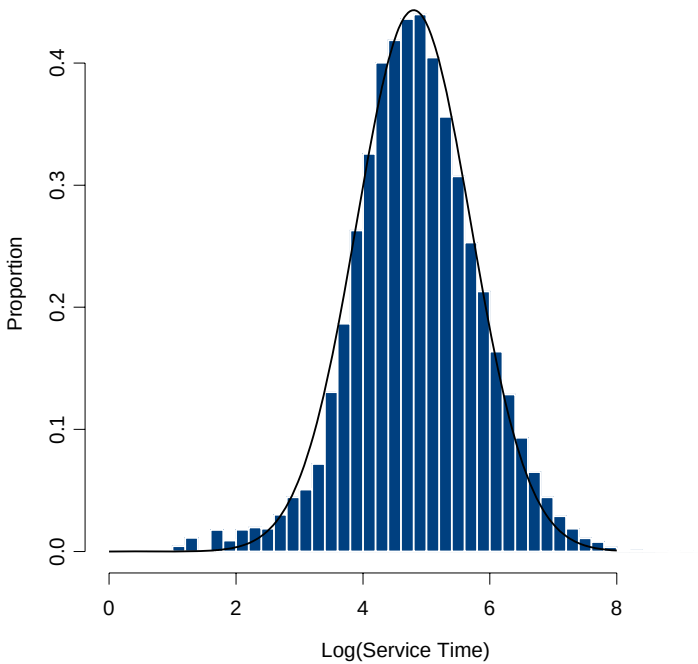


- **6.8% Short-Services:** Agents' "Abandon" (improve bonus, rest), lead by **incentives**
- **Distributions** must be measured (in seconds)
- **LogNormal** service times common in call centers

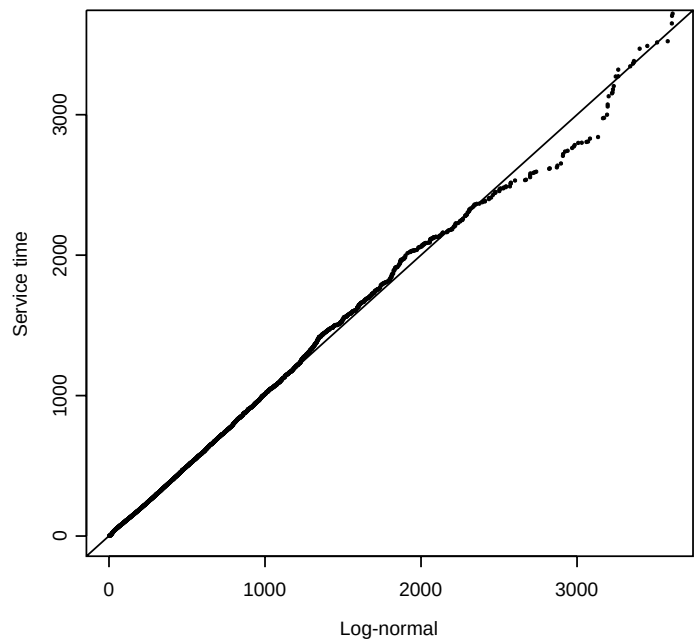
Validating LogNormality of Service-Times

Israeli Call Center, Nov-Dec, 1999

Log(Service Times)



LogNormal QQPlot

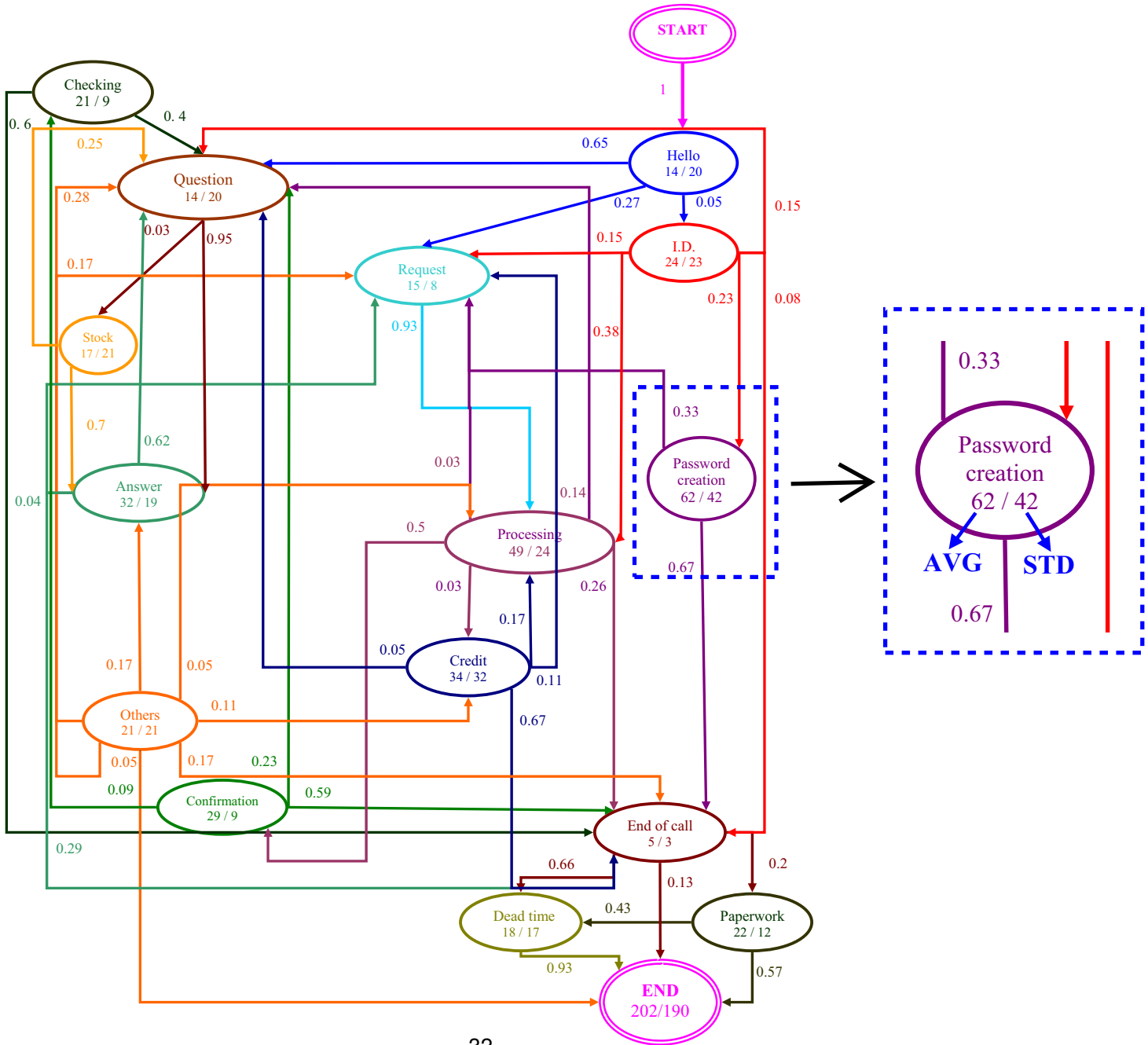


- **Practically Important**: (mean, std)(log) capture Service-Times
- **Theoretically Challenging**: Why LogNormal ?
- Simple-model of a complex-reality? The **Service Process:**

The (Telephone) Service Process: Phase-Type Model

Retail Service (Israeli Bank)

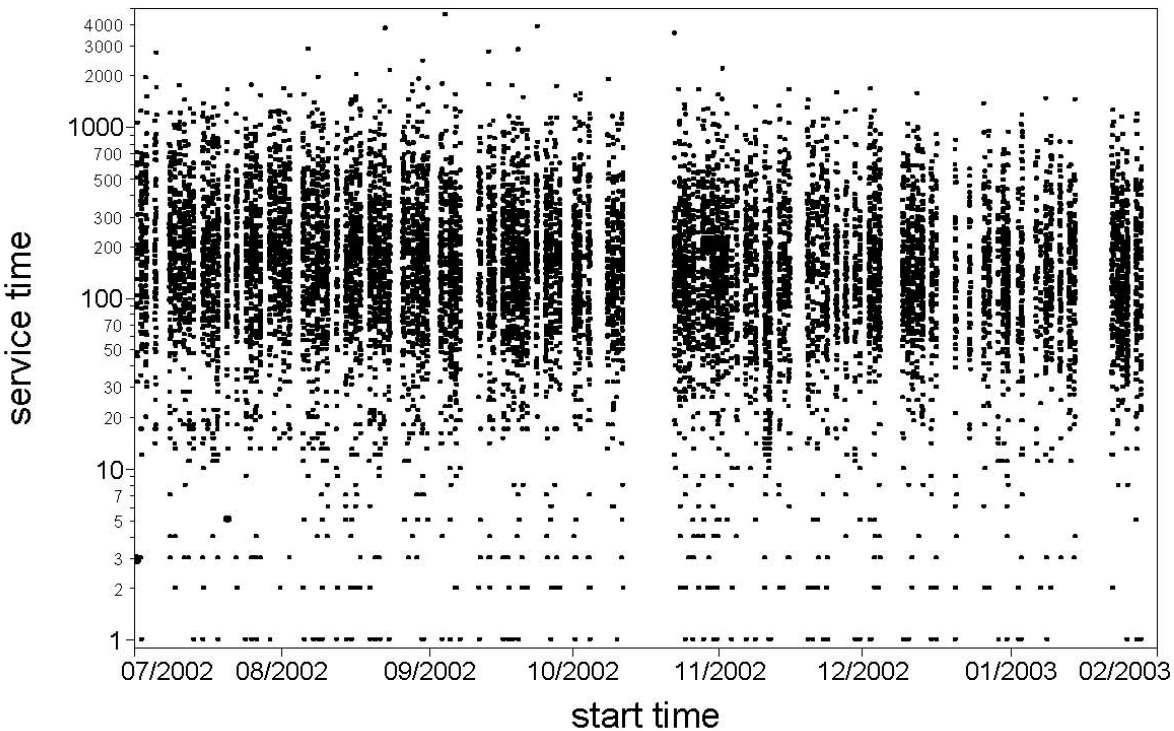
Work Design (Time Study)



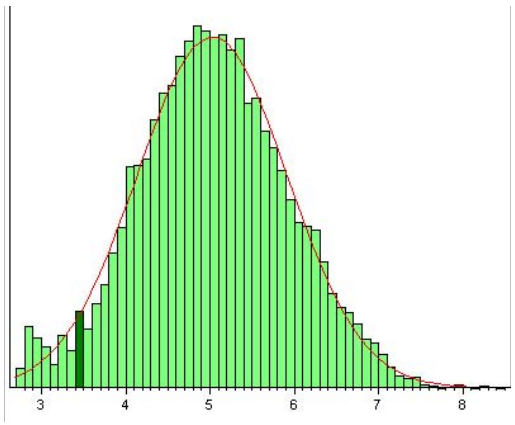
Individual Agents: Service-Time, Variability

Agent 14115

Service-Time Evolution: 6 month



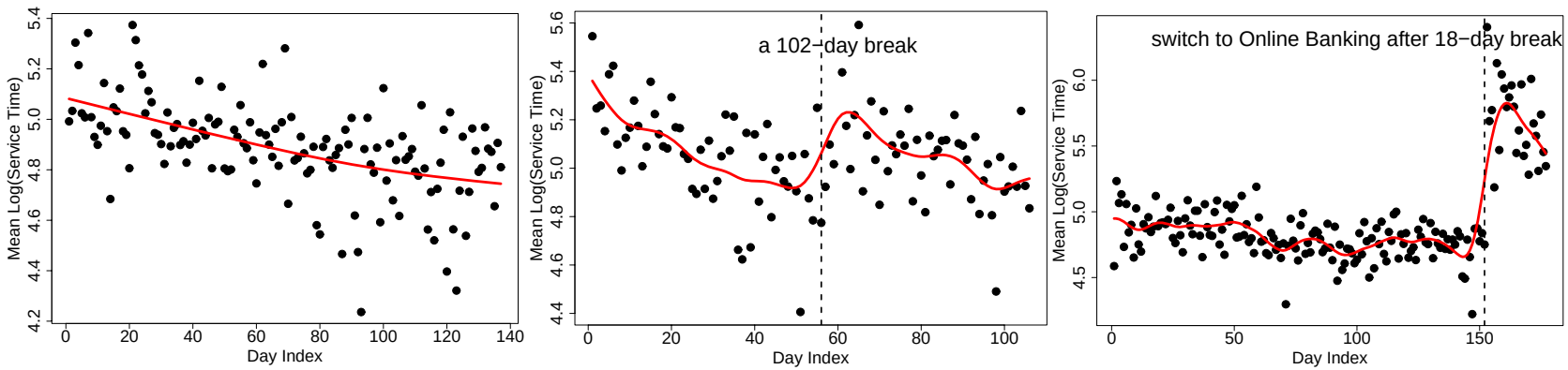
Log(Service-Time)



- **Learning**: Noticeable decreasing-trend in service-time
- **LogNormal** Service-Time, individually and collectively

Individual Agents: Learning, Forgetting, Switching

Daily-Average Log(Service-Time), over 6 months
Agents 14115, 14128, 14136



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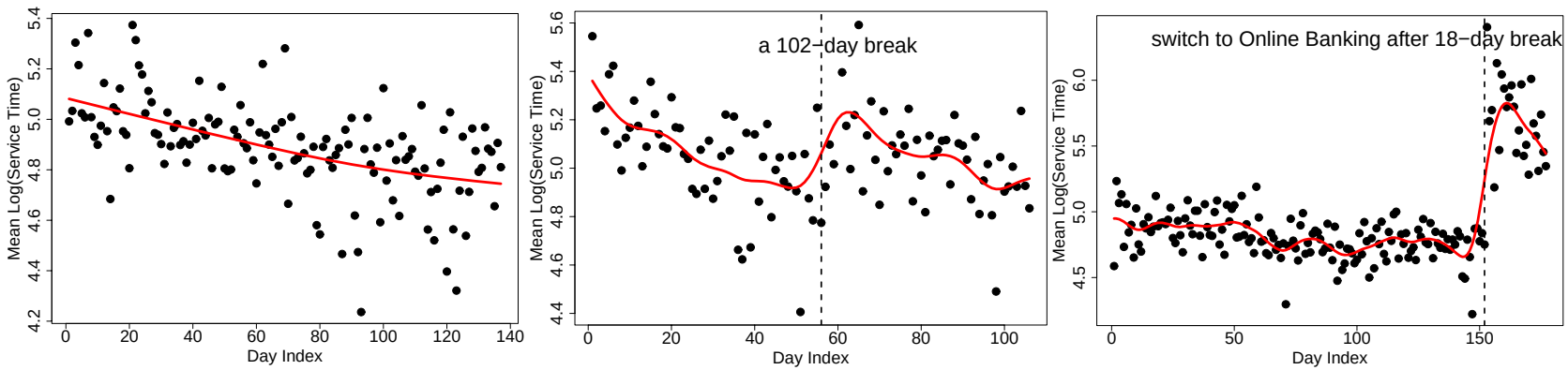
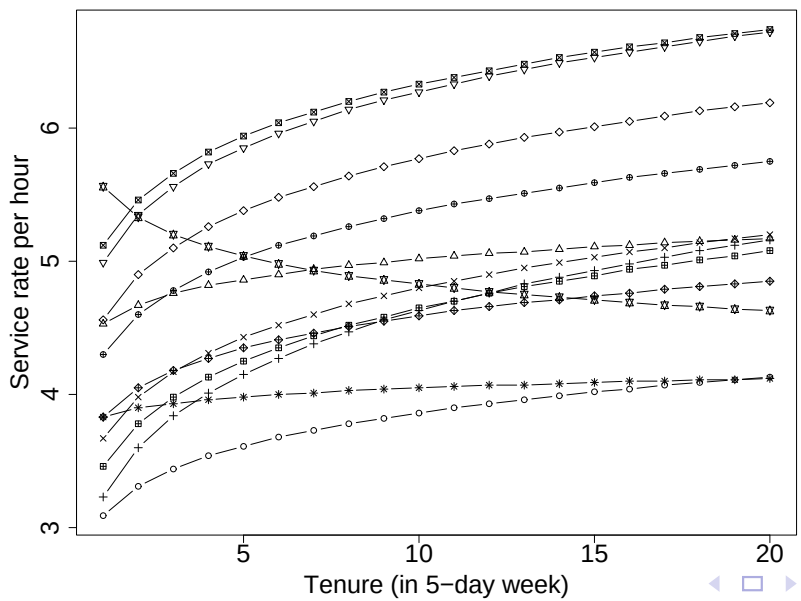


Weakly Learning-Curves for 12 Homogeneous(?) Agents



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In large call centers:
+One Second to Service-Time implies **+Millions** in costs, annually

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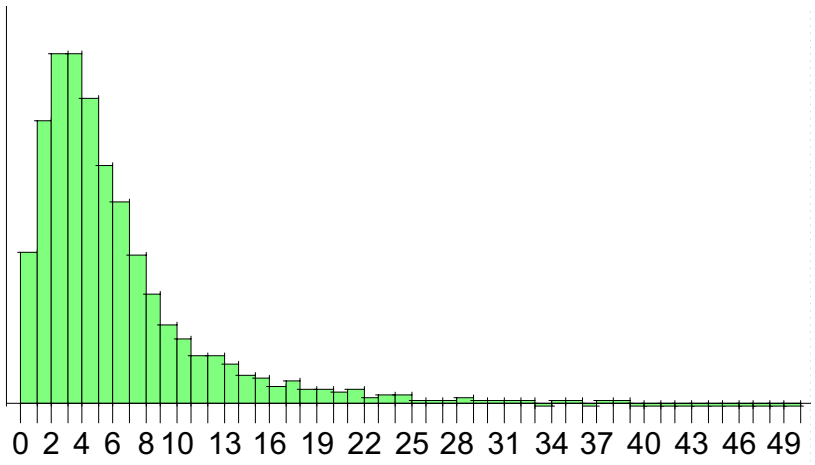
- **IVR Process Model**: **75% services**, same method, easier data

Beyond Averages: Length-of-Stay in a Hospital

Israeli Hospital, in Days: LN



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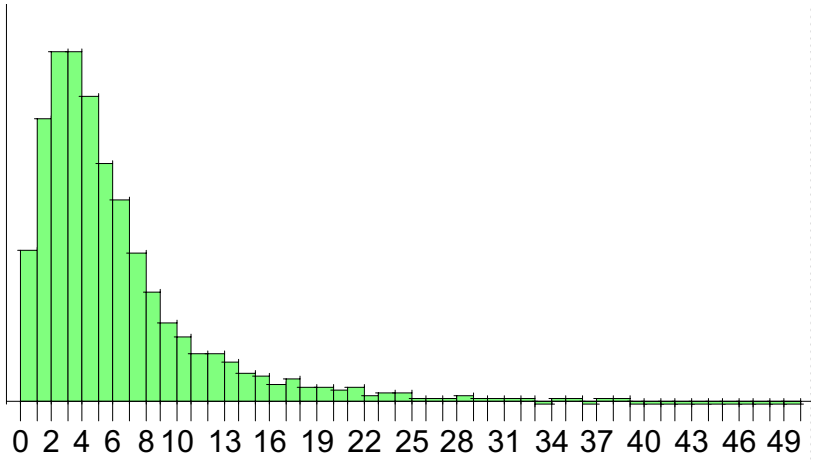
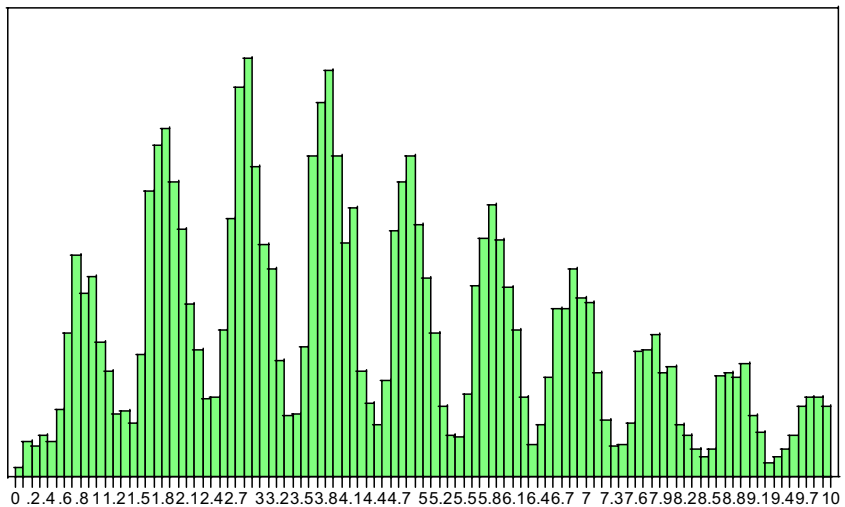
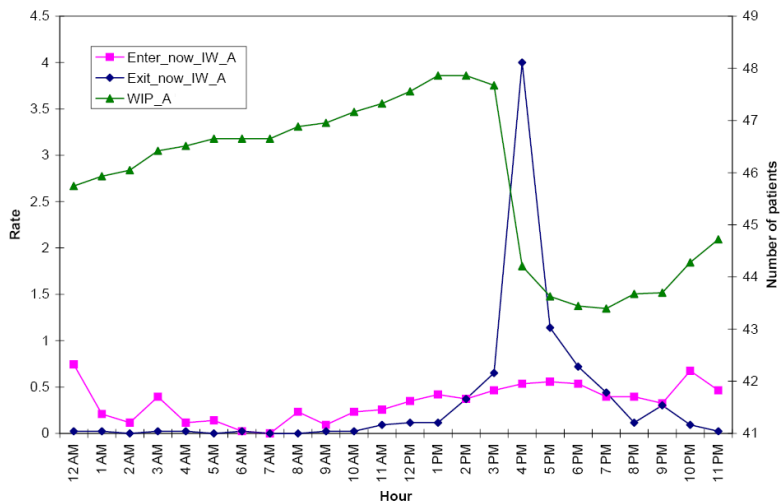


Israeli Hospital, in Hours

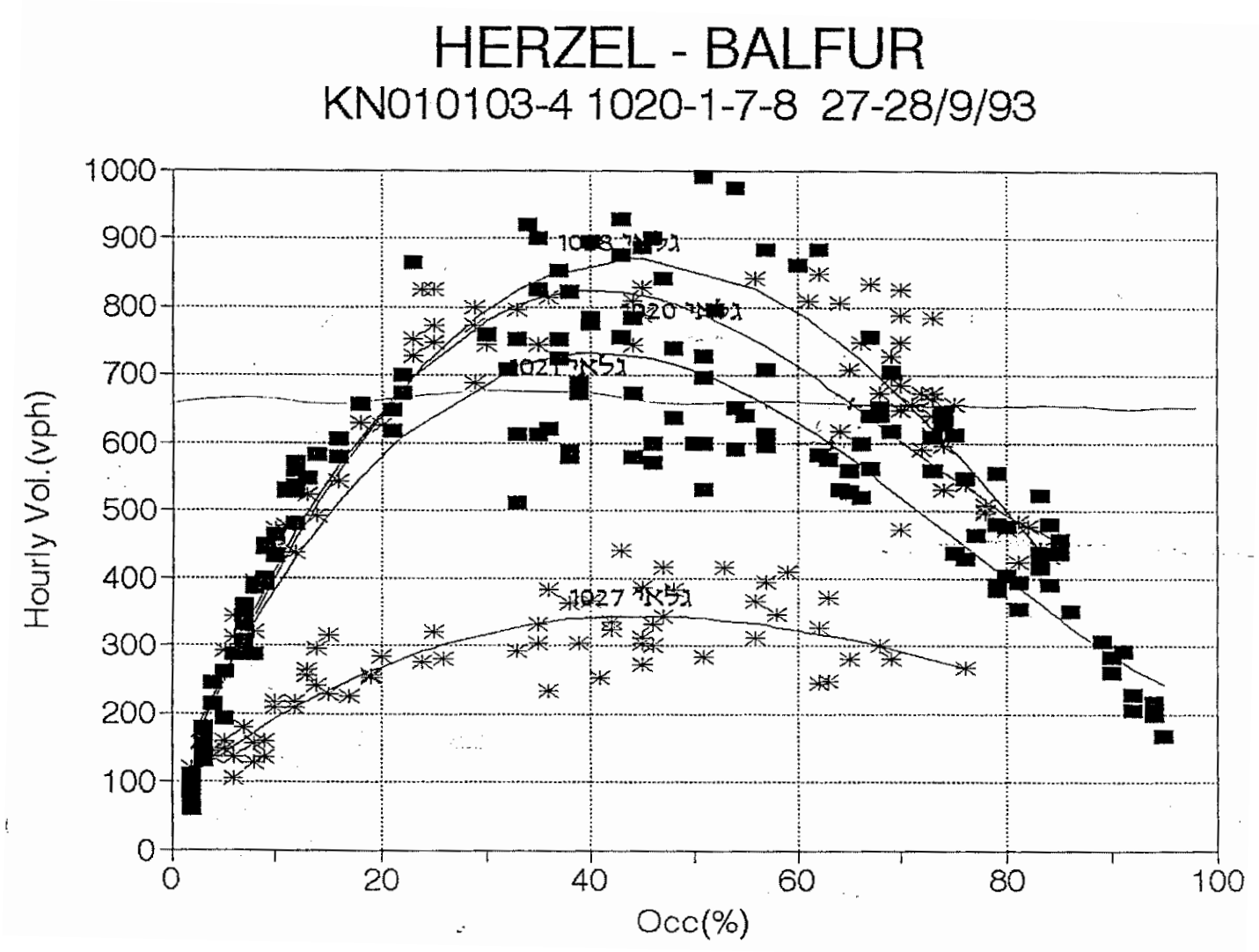


Explanation: Releases around 3pm



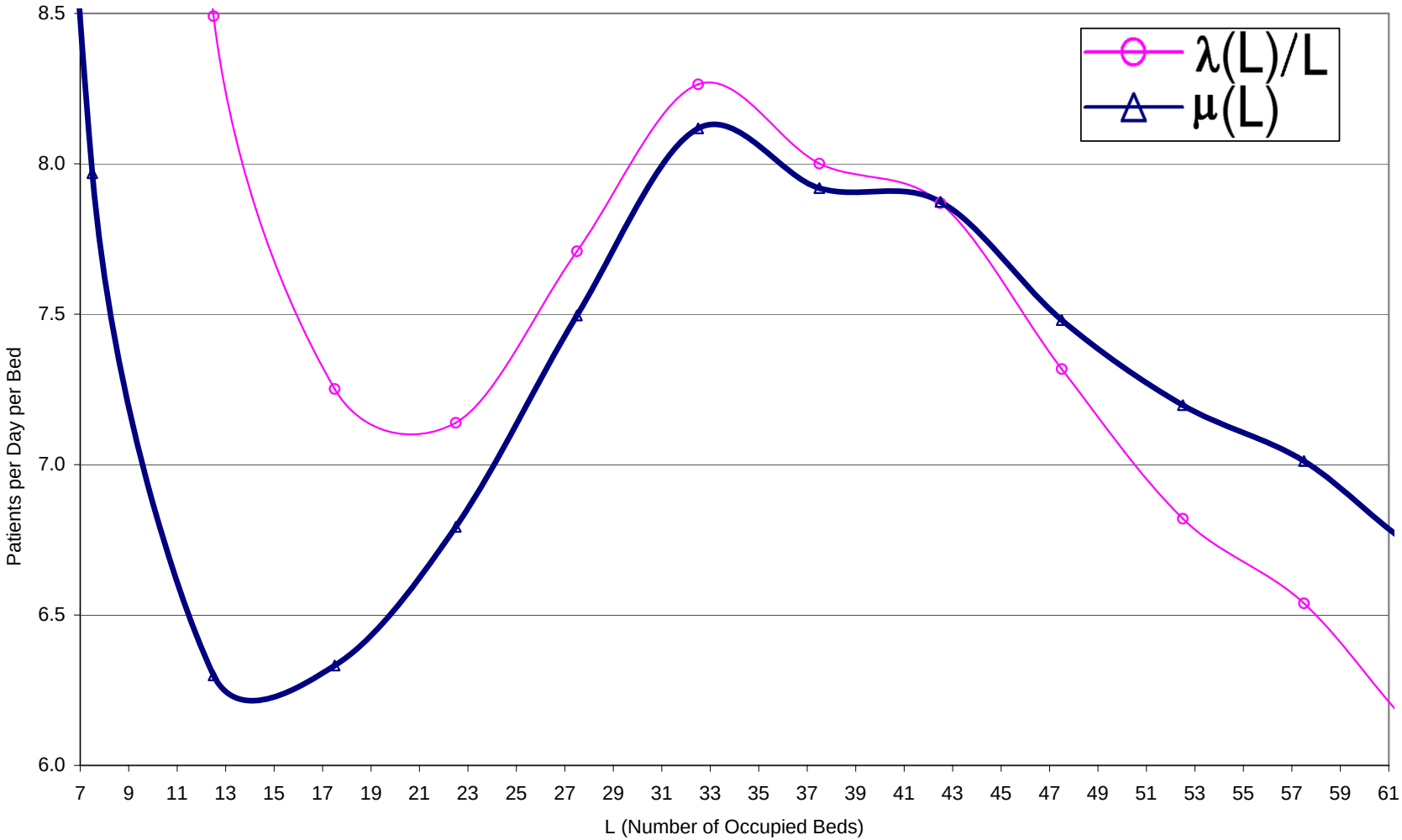
Transportation: Throughput (Flow) vs. Occupancy

Free-Flow → Critical-Occupancy → Congestion (Human)



ED: Throughput (Flow) vs. Occupancy (Human)

Congestion-Dependent Flow-Rates: Light, Regular, Heavy



Empirical Analysis of an ED:

Y. Marmor (PhD), **Y. Tseytlin** (MSc), **G. Yom-Tov** (PhD), **Mor Armony**.

The Technion SEE Center / Laboratory

Data-Based Service Engineering