Engineering, then Management, now
Data Science:

3 (4?) Stories of Intrapreneurship at the Faculty of Industrial Engineering & Management Technion

Avishai Mandelbaum

IE&M & SEELab, Technion
http://ie.technion.ac.il/Labs/ServEng/

- Caveat: I am an expert in neither **Entrepreneurship** nor **Innovation**
- But my faculty (school), Industrial Engineering & Management, carries within Technion the flag of “Management” (hence also the E&I Flag)
- And I happen to be the present Dean of IE&M
- Hence accepted the invitation/challenge

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- Hence accepted the invitation/challenge, encouraged by (my observation)
  - **Management & Engineering – each is changing in the direction of the other (research, teaching, practice)** - if so, my experience possibly relevant:
    - Managers forced to become more "**analytic**": BI, big-data, …
    - Engineers forced to "**manage**": data-based research (A-journals), teaching (e.g. case studies, reversed/active class-room), team work and personal E&I (within individual career-paths)

3 Stories:

Technion (50's; State of Israel "born" in 1948)
Industrial Engineering & Management (IE&M): born as Faculty & Profession

Personal (90's; BSc=Math + CS, MSc = Stat, PhD = OR; 1st job = BusSchool)
Service Engineering: Research, Teaching, Management Support

IE&M (Ongoing, both "IE" and "M" in flux)
Data Science & Engineering (DS&E): BSc, Research (Culture)

4th Story?

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… and perhaps we are now creating the 4th story?

Story 1: Industrial Engineering & Management (IE&M)

1958 - "Born" at Technion, as a Department (and a Profession), by fusing

- *Manufacturing/Industrial Engineering*, from Mechanical Engineering
- *Behavioral Sciences (Psychology, Sociology)*, from General Studies
- *Industrial Relations & Human-Resource Management*, also from GS
- *Operations Research* = newly established theme (included Statistics, Economics)

Founders: Prof's **Pinchas (Paul) Naor**, Shmuel (Sam) Eilon, Sebastian Littauer.

IE&M: Brief History

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Vision: All disciplines join and cross-nurture while still maintaining scholarly/academic legitimacy, via **Areas: *all* educating IE&M's while each awarding own MSc & PhD**

1968 - Faculty (approx. School, or large department)

- Later more areas: Economics, *Statistics* (70s), *Information Systems* (80s);
- … and focus themes: *Economics & Computation*, *Service Engineering*, *Entrepreneurship*, *Innovation*, …

IE&M: Brief History

"**Product**": System/Industrial **engineers**, w/ sound **scientific** education, trained also in the functions of **management** (human resources, economics, marketing, finance, accounting)

IE&M: Brief History

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Program in the 70's: Industrial Management, turned later into MBA (now 3 programs), which is a main reason for <u>not</u> having a Business School at Technion

IE&M: Founders' Vision Materializes

Most versatile and one of the largest of its kind world-wide

- Profession constantly in high demand
  - 11,000+ IE&M Technion alumni
  - 13 IE&M programs in Israel (research universities, colleges)
  - 1000 IE&M's graduated in Israel last year (500, 500)

- **World-class research institute**
  - 50+ researchers, many world-class (editorial boards, prizes, …)
  - Guests, postdocs, ...
  - Alumni that are leading researchers in leading universities

IE&M: Founders' Vision Materializes

- **Versatility (Flexibility, Adaptability) = our strength**

  - 6 areas w/ critical mass in each: IE, OR, Stat, InfoSys, BehavSc+Management, Econ
  - 13 Research Laboratories: Optimization, Business Intelligence, SEE,…

  - Focus themes:

    Robust Optimization

    Behavioral Economics,

    Economics & Computation,

    IS, Information Retrieval, NLP, Project Mgt/Edu, Stochastics, Game Theory,

    Service Engineering, …

Story 2: Service Engineering (& Science)

Background: Math, CS, Stat, OR; Management, Engineering

History:

• 80's (PhD)	TQM	Quality	Math, Statistic
• 90's (Israel)	BPR	**Processes**	OR, IE
• 00's (SEE)	CRM	**Customers**	**Service-Engineering**, IS
• 10's	BI/BD	**Data**	with all above

(Looking back: Did what I liked and fortunate that others liked as well)

Scope of the Service Industry

Guangzhou Railway Station, Southern China

Research Partners

Students:

Aldor, Baron Yonit, Carmeli-Yuviler Nitzan, Carmeli Boaz, Chen Hong, Cohen Izik, Feldman Zohar, Garnett, Gurvich, Khudiakov, Koren, Maman, Marmor, Reich, Rosenshmidt, Shaikhet, Senderovic, Tseytlin, Yom-Tov, Zaied, Zeltyn, Zychlinski, Zohar Eti, Zviran, …

Theory:

Armony, Atar, Azriel, Cohen Izik, Gurvich, Feigin, Gal, Huang Junfei, Jelenkovic, Kaspi, Massey, Momcilovic, Reiman, Shimkin, Stolyar, Trofimov, Wasserkrug, Whitt, Yom-Tov, Zeltyn, Zhang Jiheng, Zhang Hanqin, …

Exploratory Data Analysis, Data Sources, Statistics, Projects:

Brown, Gans, Shen Haipeng, Zhao Linda; Zeltyn; Ritov, Goldberg; Gurvich, Huang Junfei, Liberman; Liu Nan, Ye Han; Armony, Marmor, Tseytlin, Yom-Tov; Gorfine, Ghebali; Tezcan; Kim Song-Hee, Won Chul Cha; He Shuangchi, Sim Melvyn; Feigin, Azriel; Rafaeli, Yom-Tov, …

Industry:

Mizrahi Bank, Fleet Bank, Rambam Hospital, IBM Research, Hapoalim Bank, Pelephone Cellular, Samsung Hospital, Dana Farber Cancer Institute, LivePerson, …

Technion SEE Laboratory (SEELab):

Feigin; Trofimov, Nadjharov, Gavako; Kutsy; Senderovic, Carmeli; Liberman, Koren, Plonsky;
Research Assistants, Visitors, Postdocs, …

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), ...

- Models that explain fundamental phenomena, which are **common** across applications:
  - **Call Centers**
  - **Hospitals**
  - **Transportation**
  - Justice, Fast Food, Police, Internet, . . .

- Simple models at the Service of Complex Realities (Human)
  Note: Simple yet rooted in **deep analysis**.

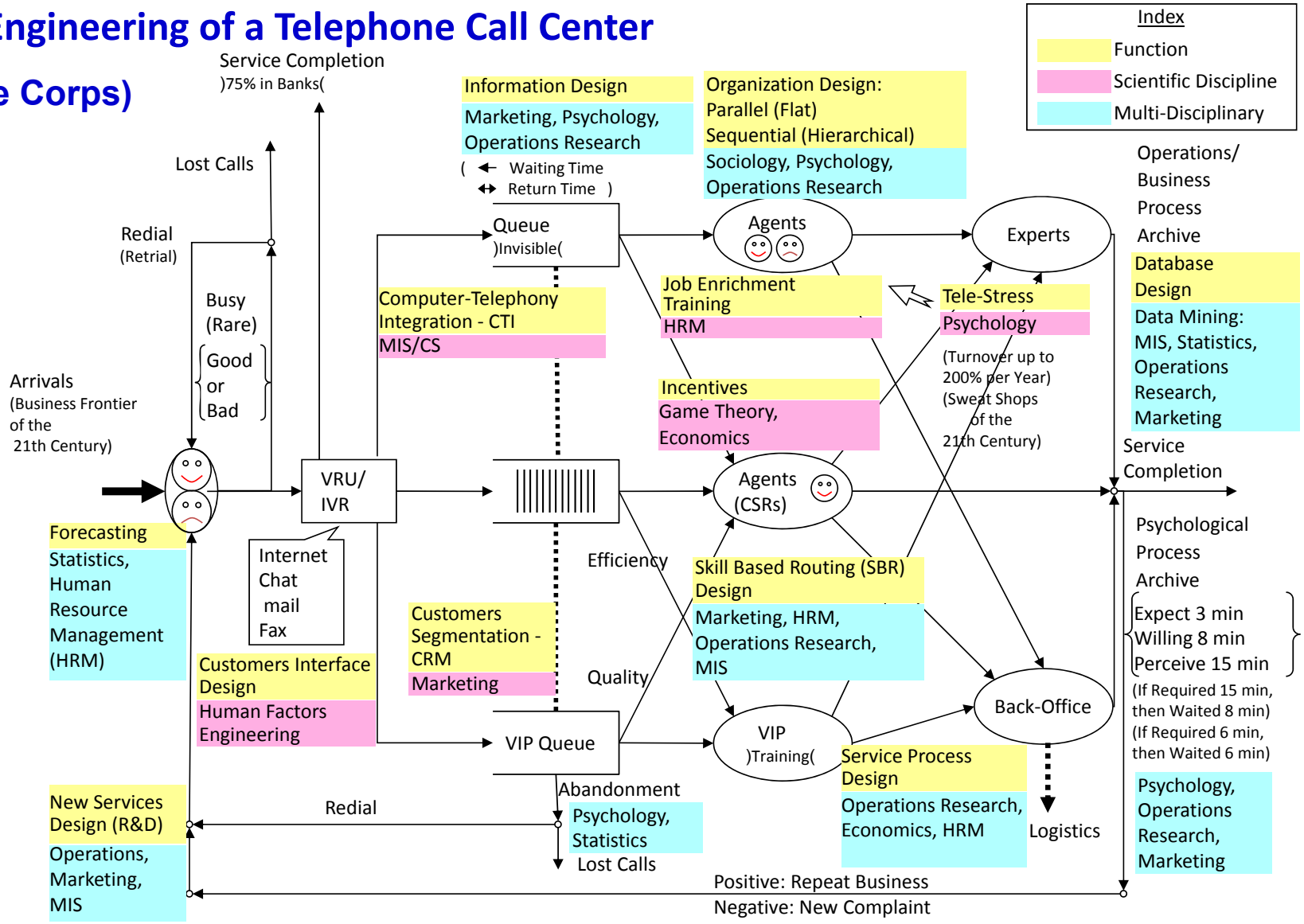
Call-Center Environment: Service Network

= "Fruit-flies of Hospitals": fast, low-stake, no IRB, . . .

yet highly relevant

Service Engineering of a Telephone Call Center

(Esprit de Corps)

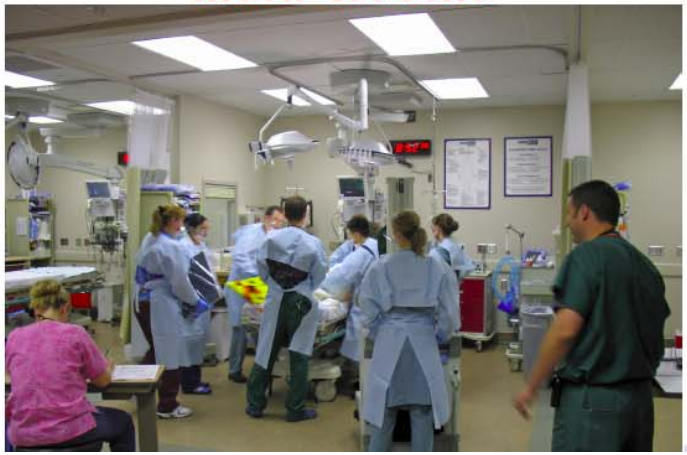


ER / ED Environment: Service Network

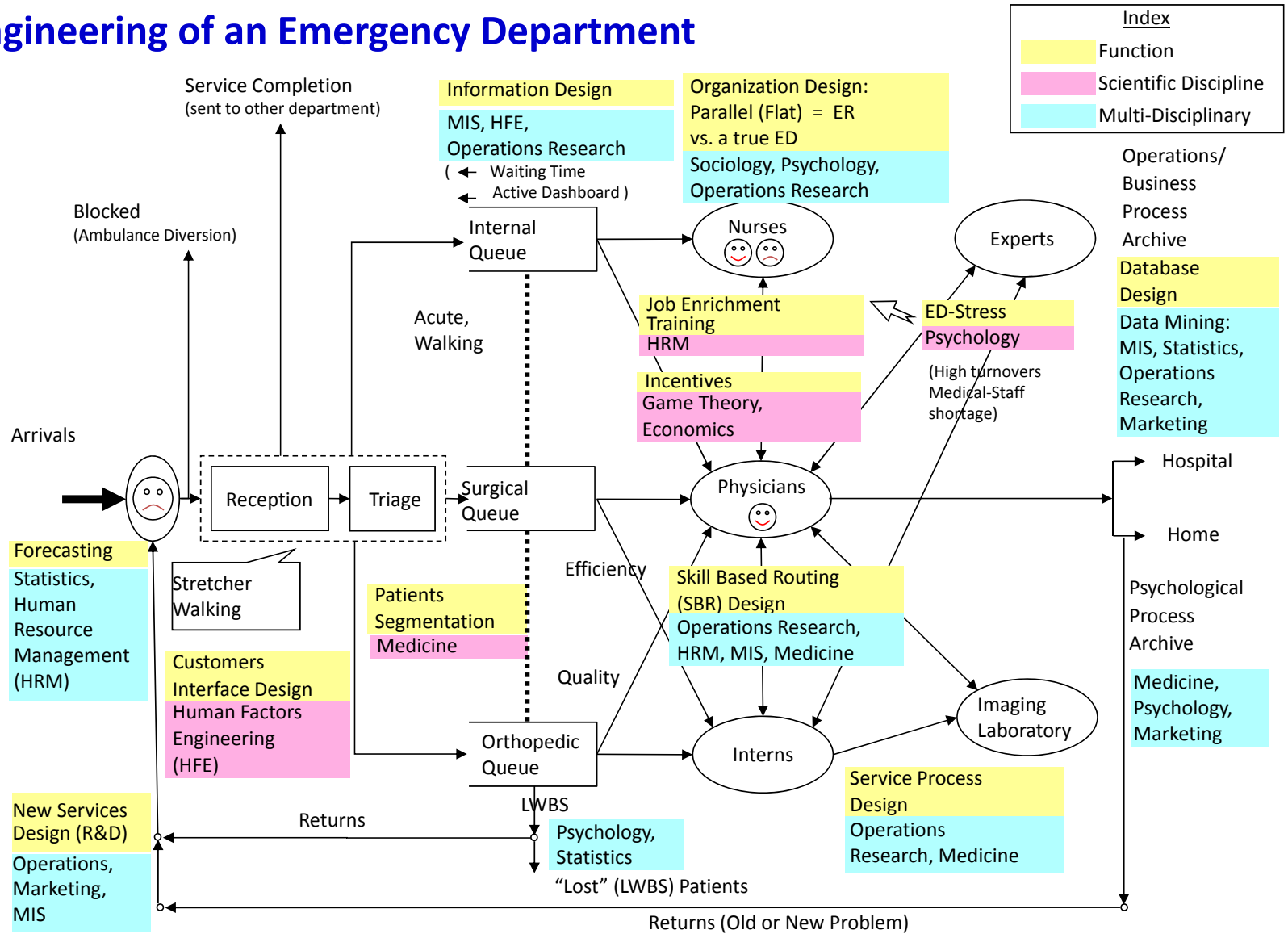
Acute (Internal, Trauma)

Walking

Multi-Trauma



Service Engineering of an Emergency Department



Technion SEE Lab
Service Enterprise Engineering / Science

2007-

Donation: Hal and Inge Marcus

Founders: Feigin P., Mandelbaum A.

Researches: Valery Trofimov, Ella Nadjharov, Igor Gavako, …

- **Students**
- **Guests**

SEELab: Environment for graphical EDA in real-time

Detailed **operational histories** (customers, servers), e.g.

1. *Bank Anonymous : **1 year, 350K calls by 15 agents** - in 2000, which paved the way to:

2. *U.S. Bank : **2.5 years, 220M calls, 40M by 1000 agents**
3. Israeli Cellular: **2.5 years, 110M calls, 25M calls by 750 agents**
4. Israeli Bank: **from January 2010, daily-deposit at a SEESafe**
5. Service Engineering **internet site**: click-stream data (2 years)

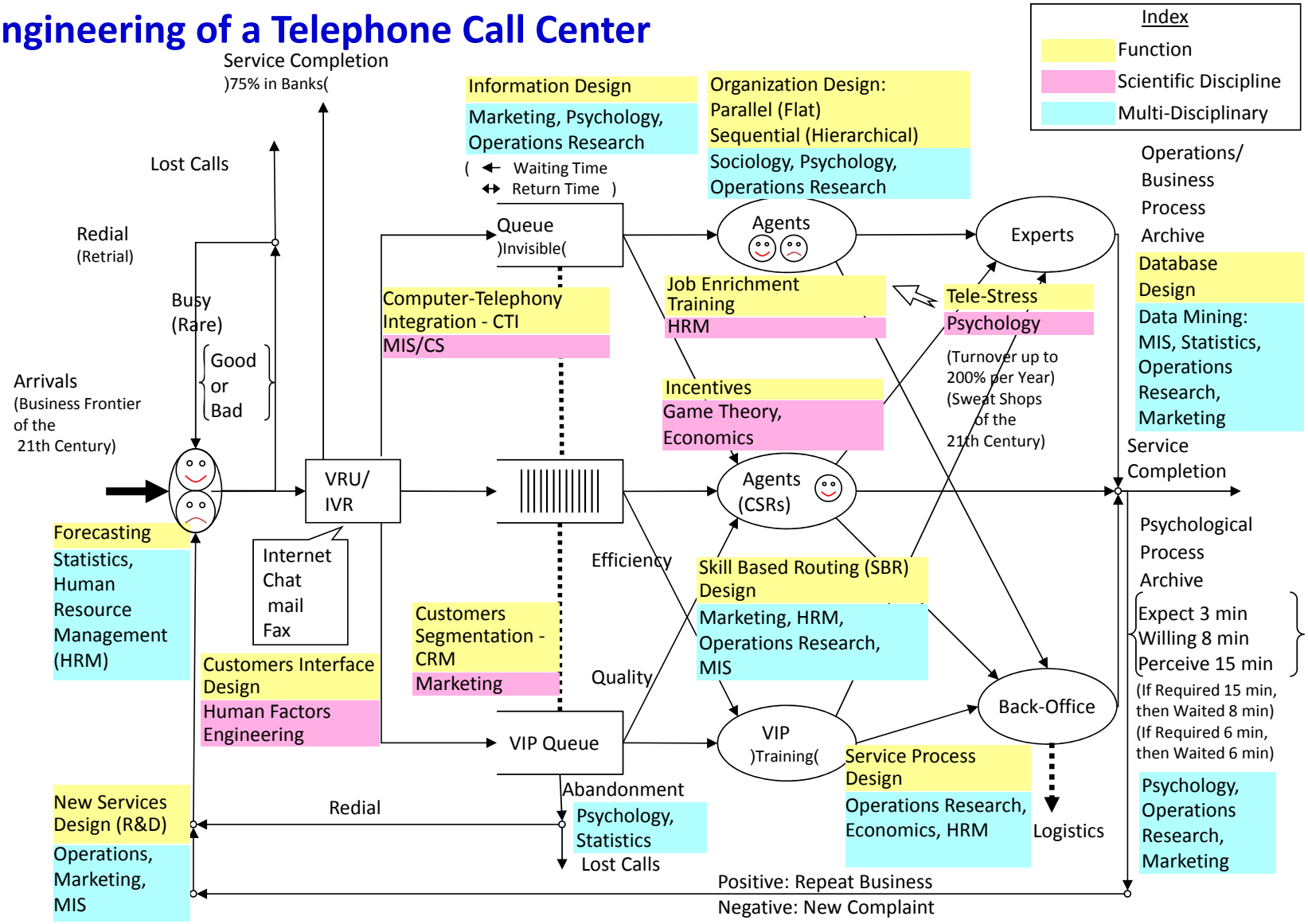
6. *Home (Rambam) Hospital : **4 years, 1000 beds**, inter-ward flow

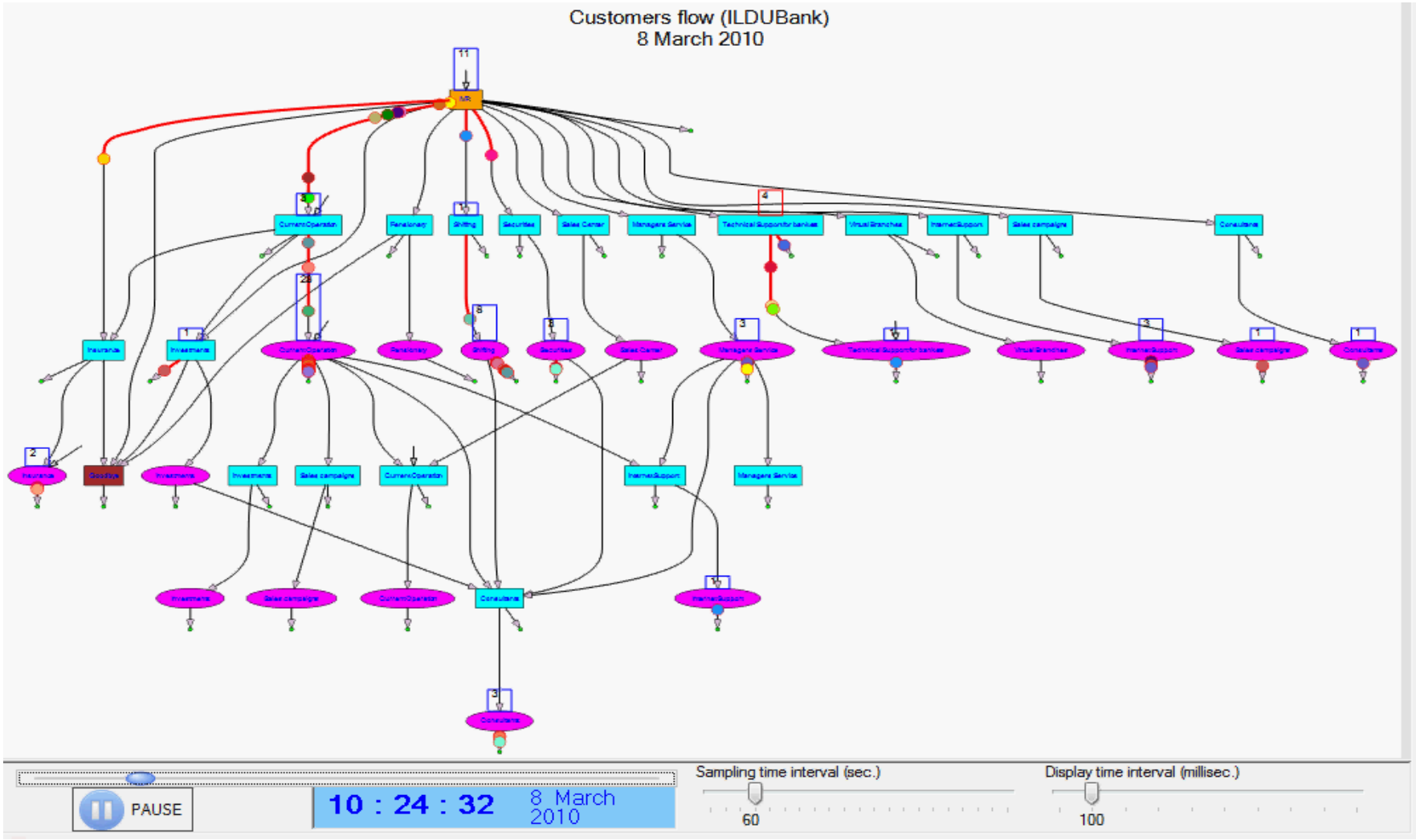
7. **Emergency Department** (ED) patient flow:
   - 5 EDs in Israel: 1-2 years, **late David Sinreich**, ED arrivals & LOS
   - ED in Seoul: 2 months, **K. Song-Hee & W. Cha**, pilot
   - ED in XY: 2 years, pilot

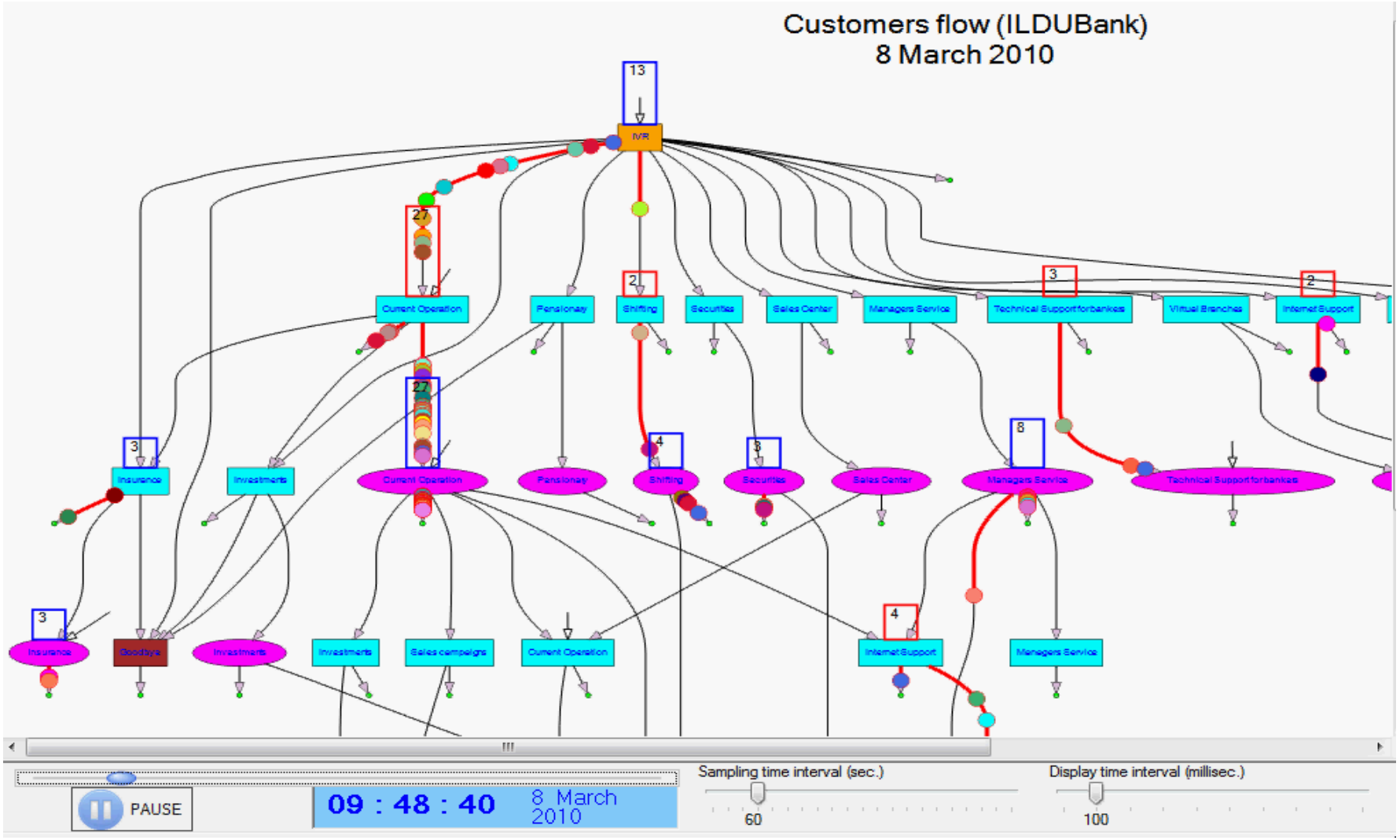
8. **Hospital RTLS (Real-Time Location System):**
   - **250K events/day: 1000 patients, 350 staff (1500 tagged entities)**
   - Infrastructure: **900 readers (sensors), many floors**

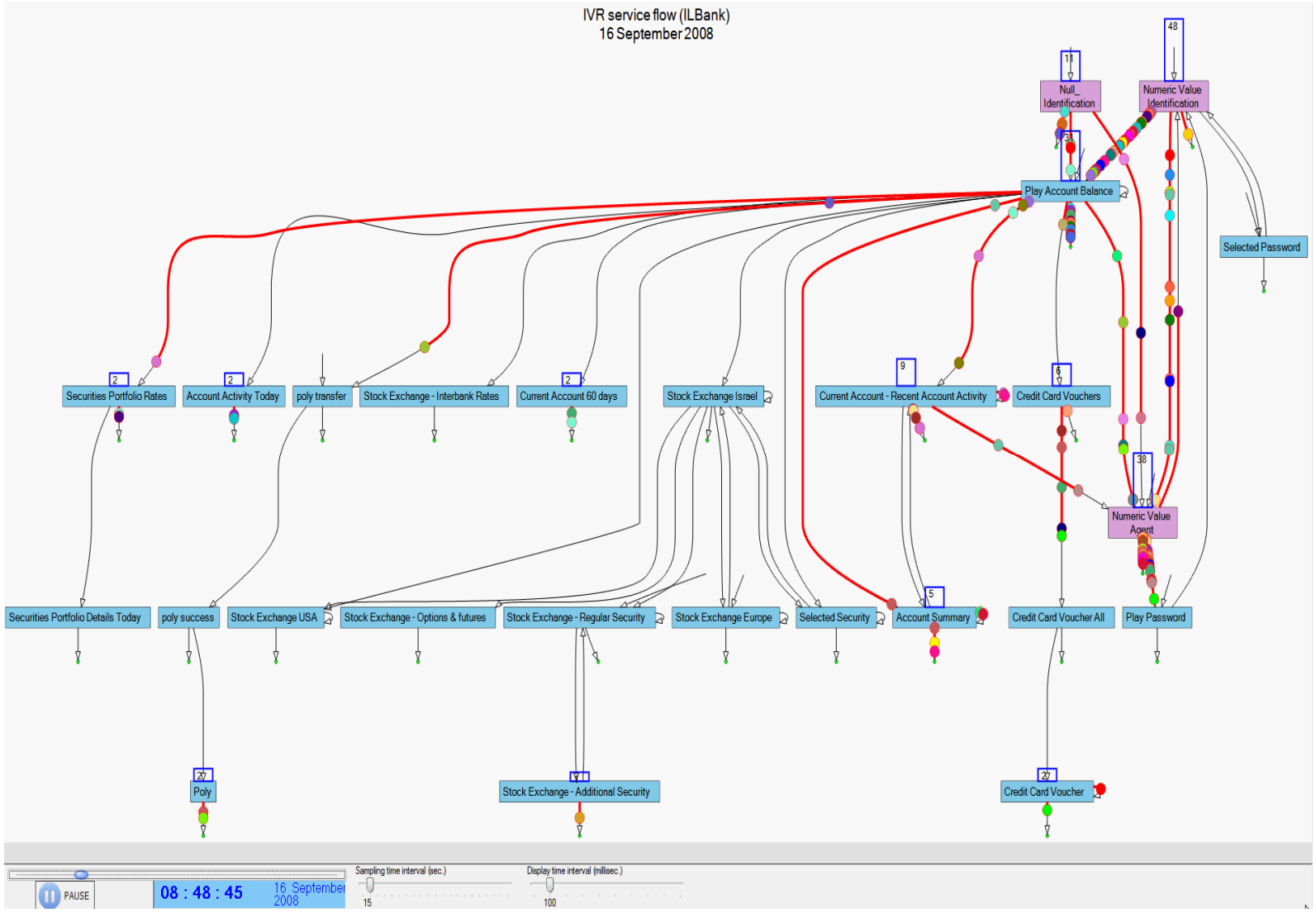
***Open & Free for research and teaching**

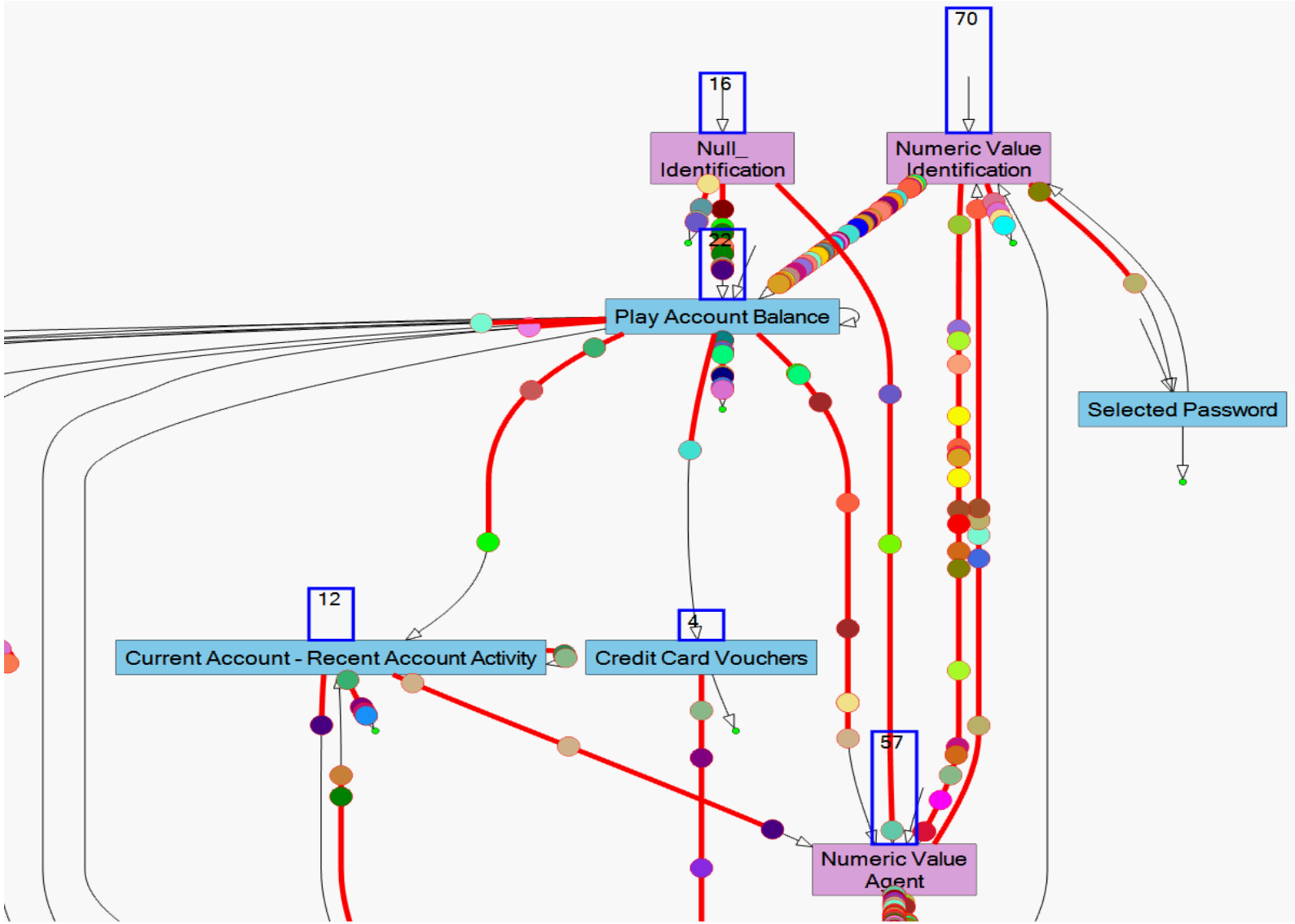
Service Engineering of a Telephone Call Center




Customers flow (ILDUBank)
8 March 2010
PAUSE
10 : 24 : 32
8 March 2010
Sampling time interval (sec.)
60
Display time interval (millisec.)
100

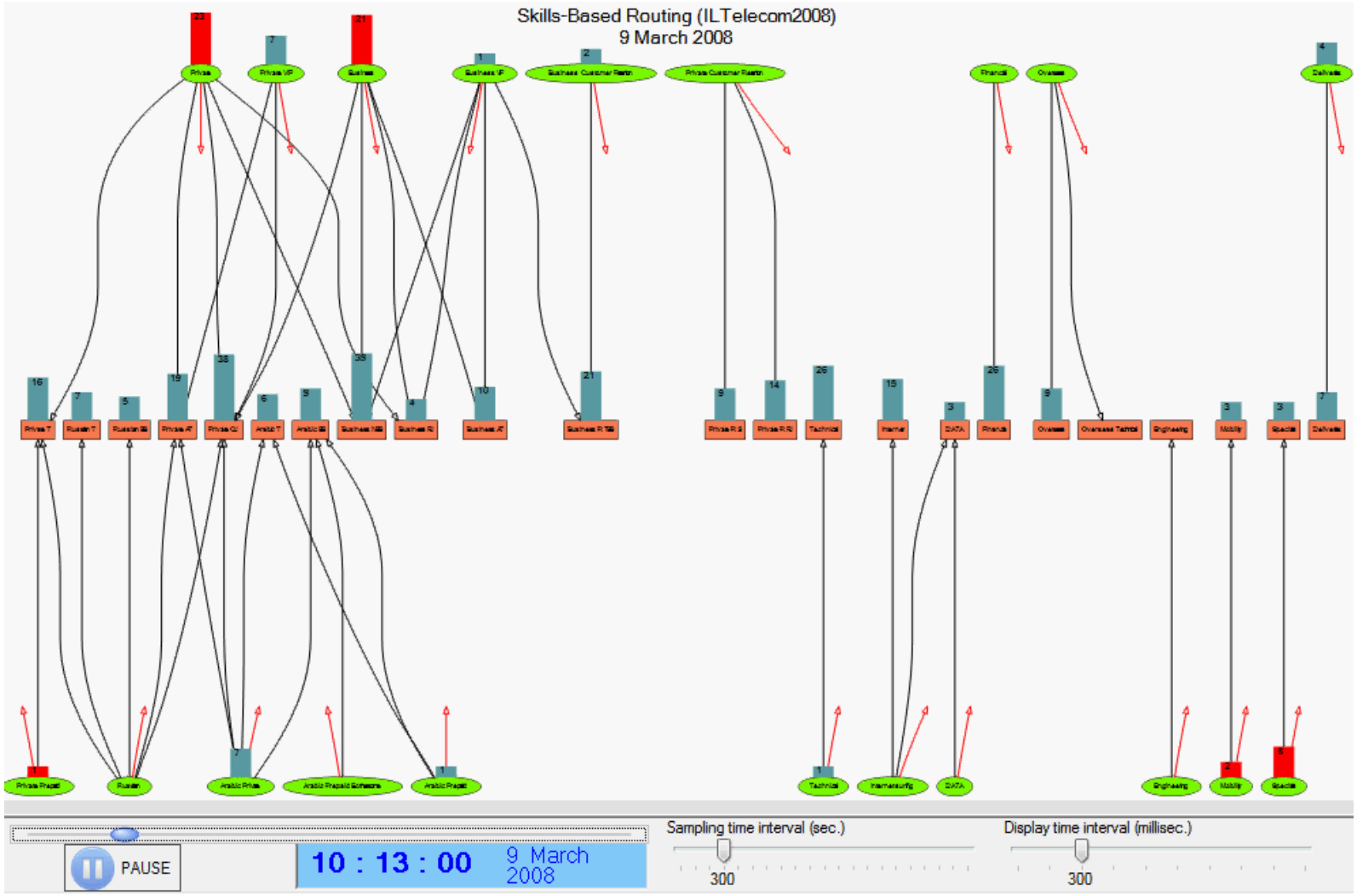

Customers flow (ILDUBank)
8 March 2010
IVR
Current Operation
Pensionay
Shifting
Securities
Sales Center
Managers Service
Technical Supportforbankes
Virtual Branches
Internet Support
Insurance
Investments
Goodbye
Sales campaigns
PAUSE
09 : 48 : 40
8 March 2010
Sampling time interval (sec.)
60
Display time interval (millisec.)
100

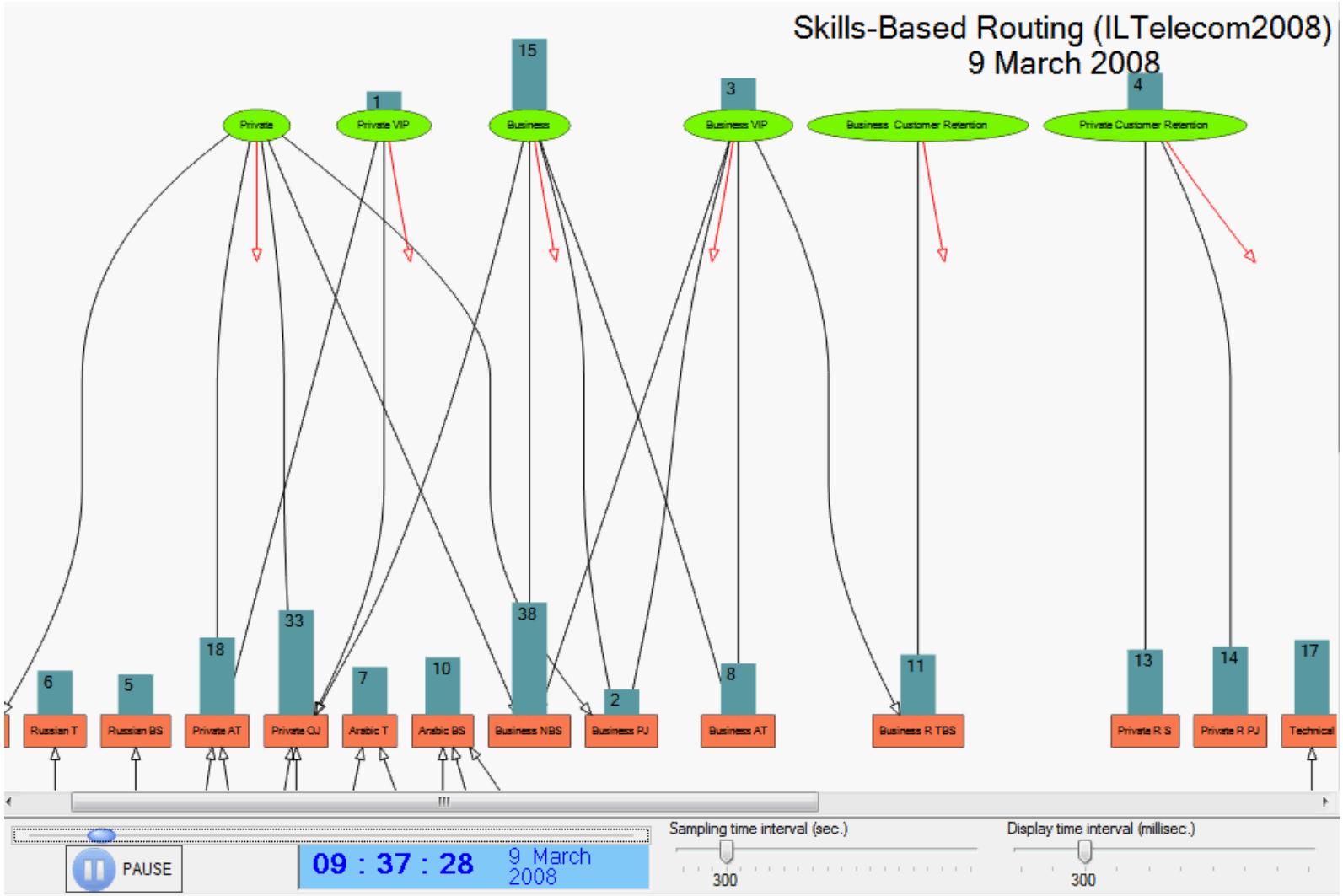

IVR service flow (ILBank)
16 September 2008
Null_ Identification
Numeric Value Identification
Play Account Balance
Selected Password
Securities Portfolio Rates
Account Activity Today
poly transfer
Stock Exchange - Interbank Rates
Current Account 60 days
Stock Exchange Israel
Current Account - Recent Account Activity
Credit Card Vouchers
Numeric Value Agent
Securities Portfolio Details Today
poly success
Stock Exchange USA
Stock Exchange - Options & futures
Stock Exchange - Regular Security
Stock Exchange Europe
Selected Security
Account Summary
Credit Card Voucher All
Play Password
Poly
Stock Exchange - Additional Security
Credit Card Voucher
PAUSE
08 : 48 : 45
16 September 2008
Sampling time interval (sec.)
15
Display time interval (millisec.)
100


70
16
Null_
Identification
Numeric Value
Identification
22
Play Account Balance
Selected Password
12
Current Account - Recent Account Activity
4
Credit Card Vouchers
57
Numeric Value
Agent

Use Case: Skills-Based Routing in a Call Center

- **Customer Classes**
  - Marketing segregates customers according to their needs and/or importance – this determines customer priorities
- **Agent Skills**
  - Human-Resources Management assigns agent skills according to capabilities, experience (training) – this determines agent constituencies
- **Matching Class & Skill (Demand and Supply)**
  - Operations-Researchers develop matching algorithms so that customers don't wait long for an agent (service-level) and agents don't wait long for a customer (efficiency)
- **Information Infrastructure** (IS/CS)
- **Data Management** (Statisticians)


Skills-Based Routing (ILTelecom2008)
9 March 2008
PAUSE
10 : 13 : 00
9 March 2008
Sampling time interval (sec.)
300
Display time interval (millisec.)
300

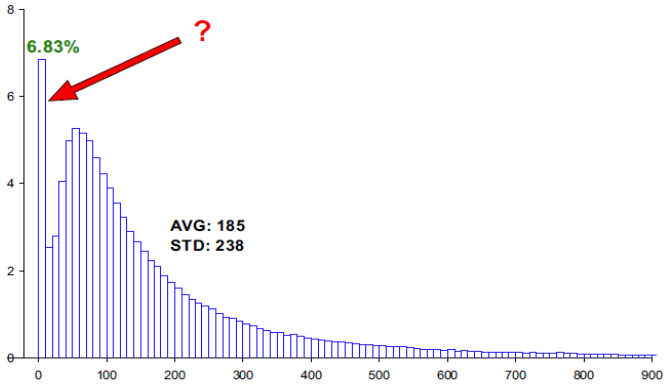

Skills-Based Routing (ILTelecom2008)
9 March 2008
Private
Private VIP
Business
Business VIP
Business Customer Retention
Private Customer Retention
Russian T
Russian BS
Private AT
Private OJ
Arabic T
Arabic BS
Business NBS
Business PJ
Business AT
Business R TBS
Private R S
Private R PJ
Technical
PAUSE
09 : 37 : 28
9 March 2008
Sampling time interval (sec.)
300
Display time interval (millisec.)
300

Building Blocks of a Model: Service Durations

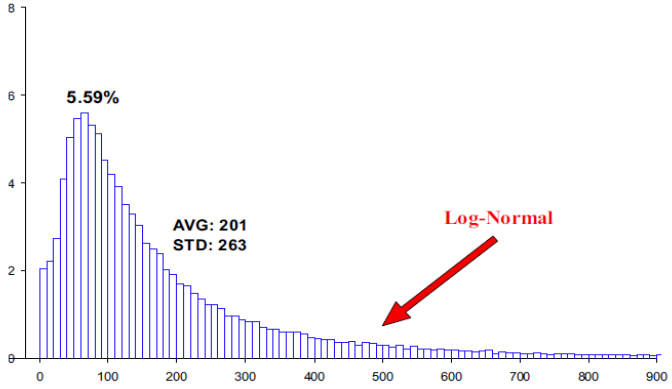
Histogram of Service-Duration in an Israeli Call Center, 1999

Why short services? Why LogNormal?

January-October



November-December

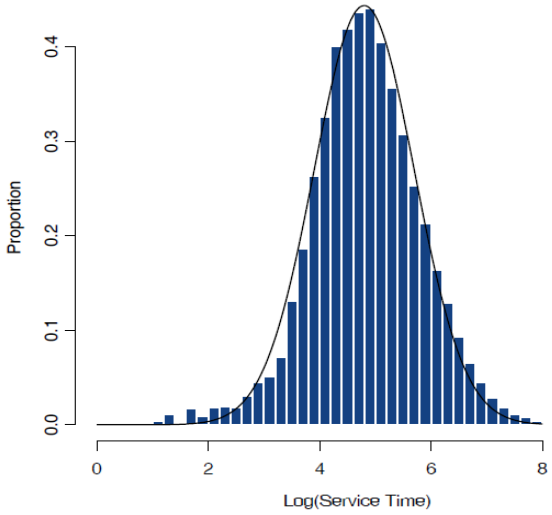


- January-October: **6.8% Short-Services** ($\leq$ 10 seconds) ?
- November-December: **LogNormal** durations (common) ?

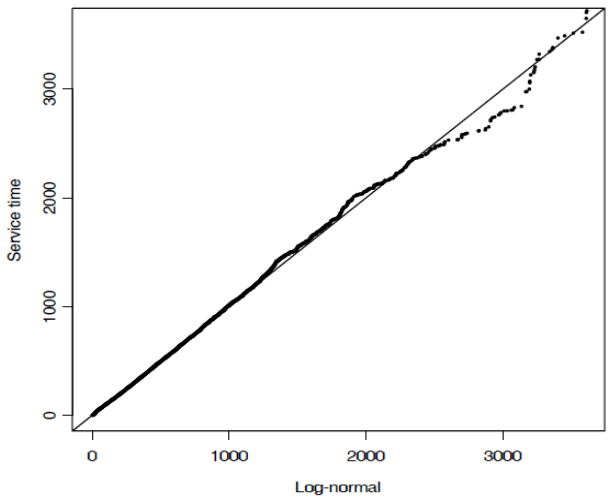
Durations: Phone Calls (Surprises)

Israeli Call Center, Nov–Dec, 1999

Log(Service Times)

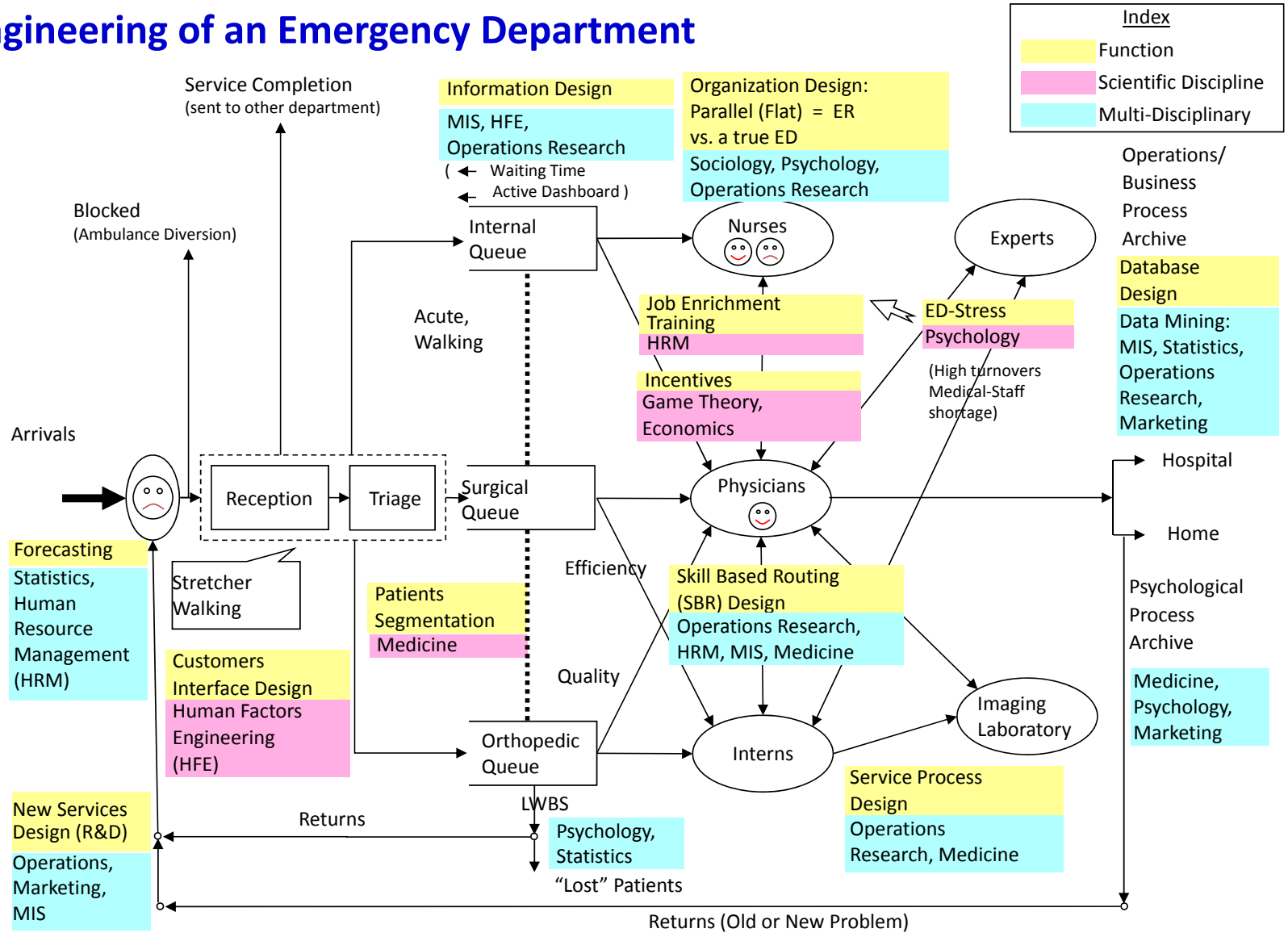


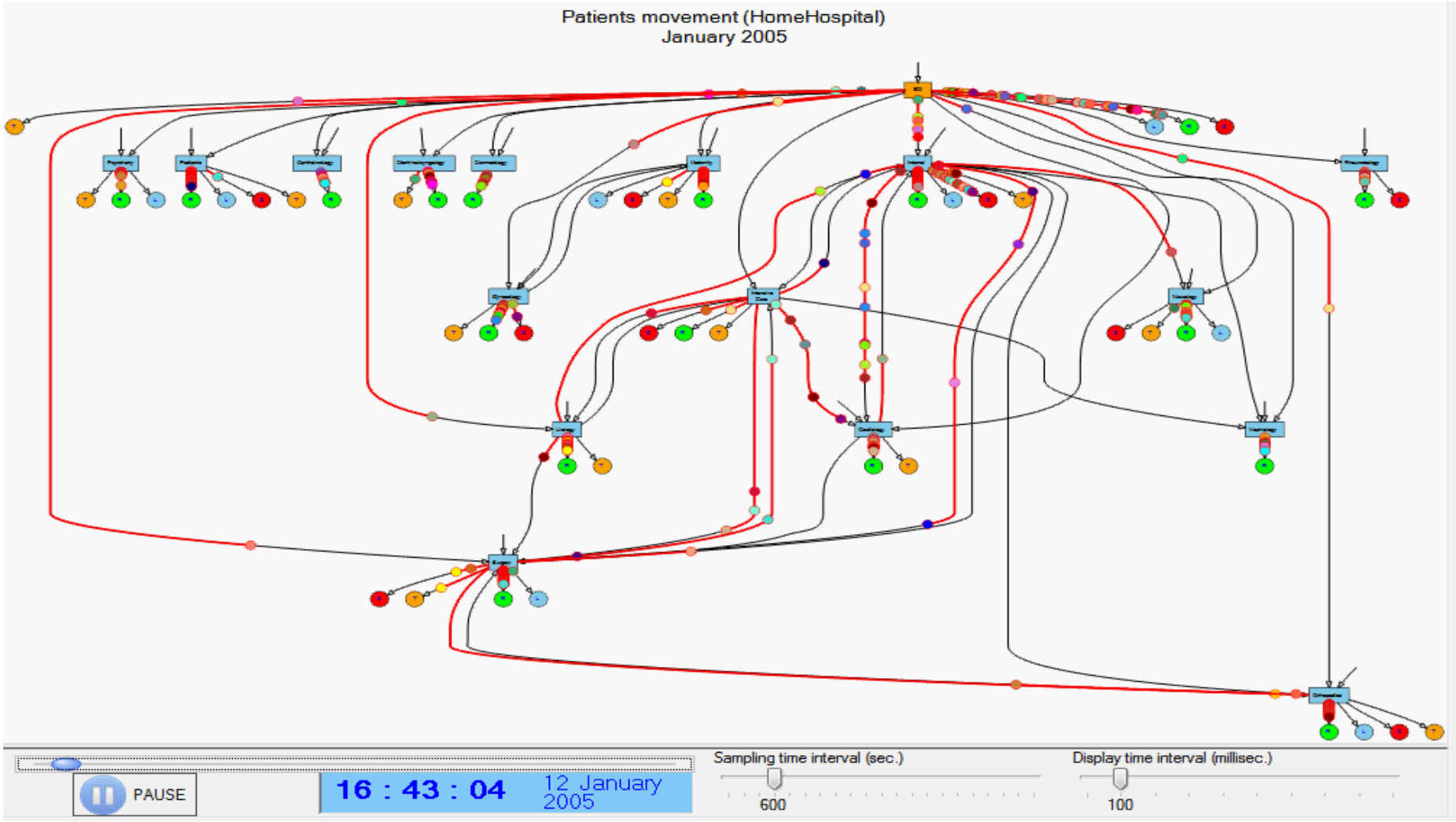
LogNormal QQPlot

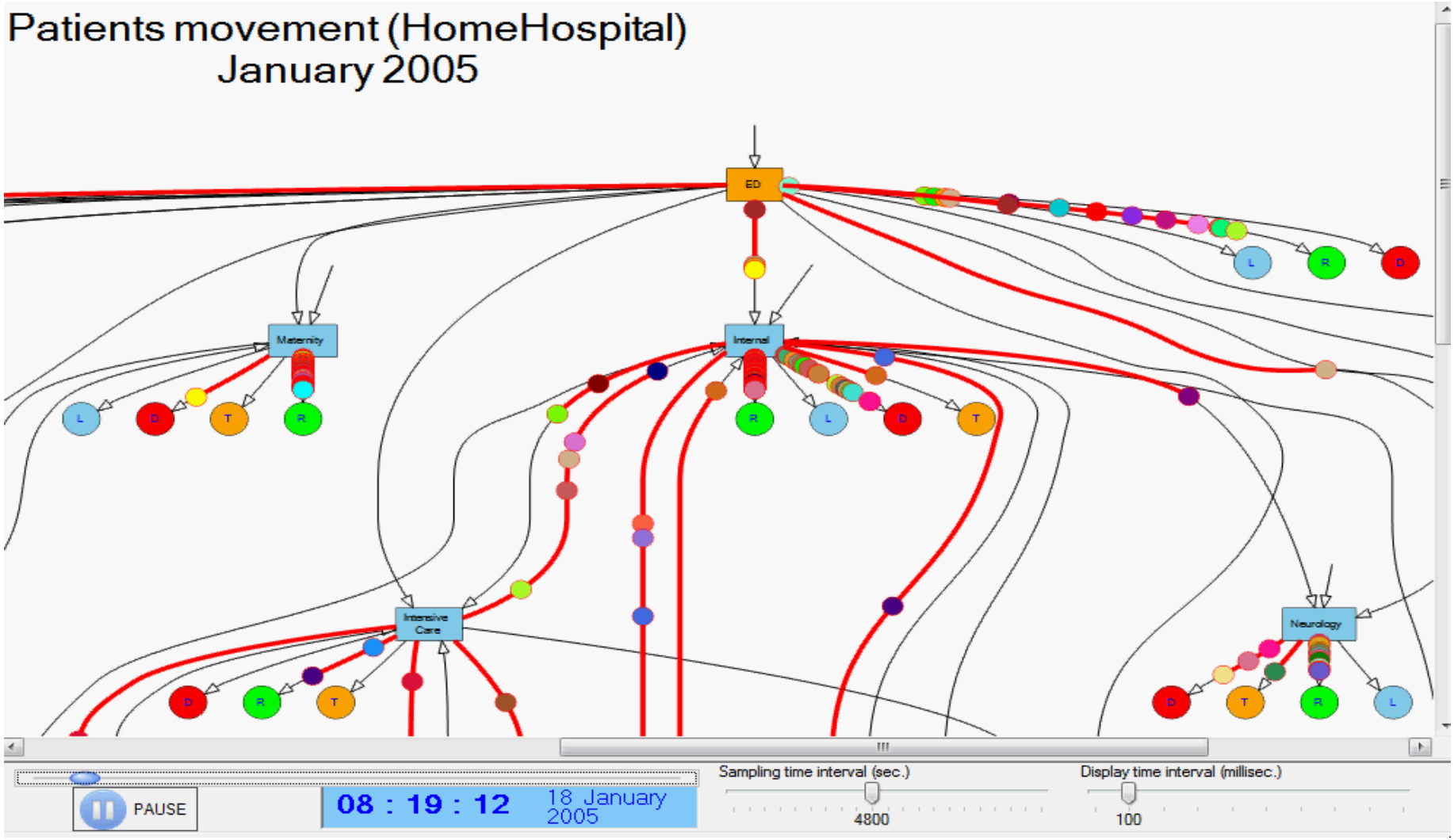


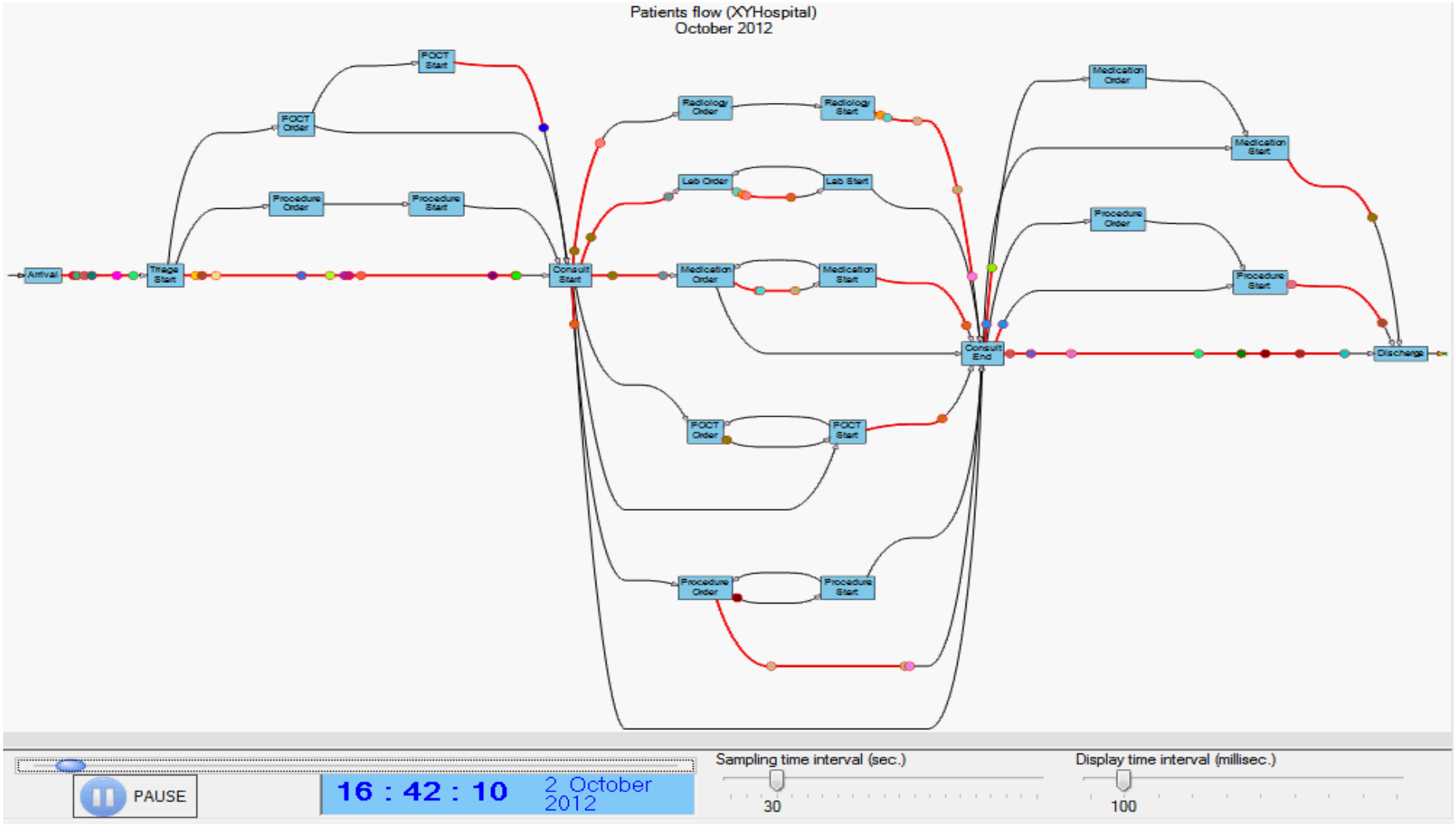
- **Practically Important**: (mean, std)(log) characterization
- **Theoretically Intriguing**: Why LogNormal ? Naturally multiplicative but, in fact, also **Infinitely-Divisible** (Generalized Gamma-Convolutions)

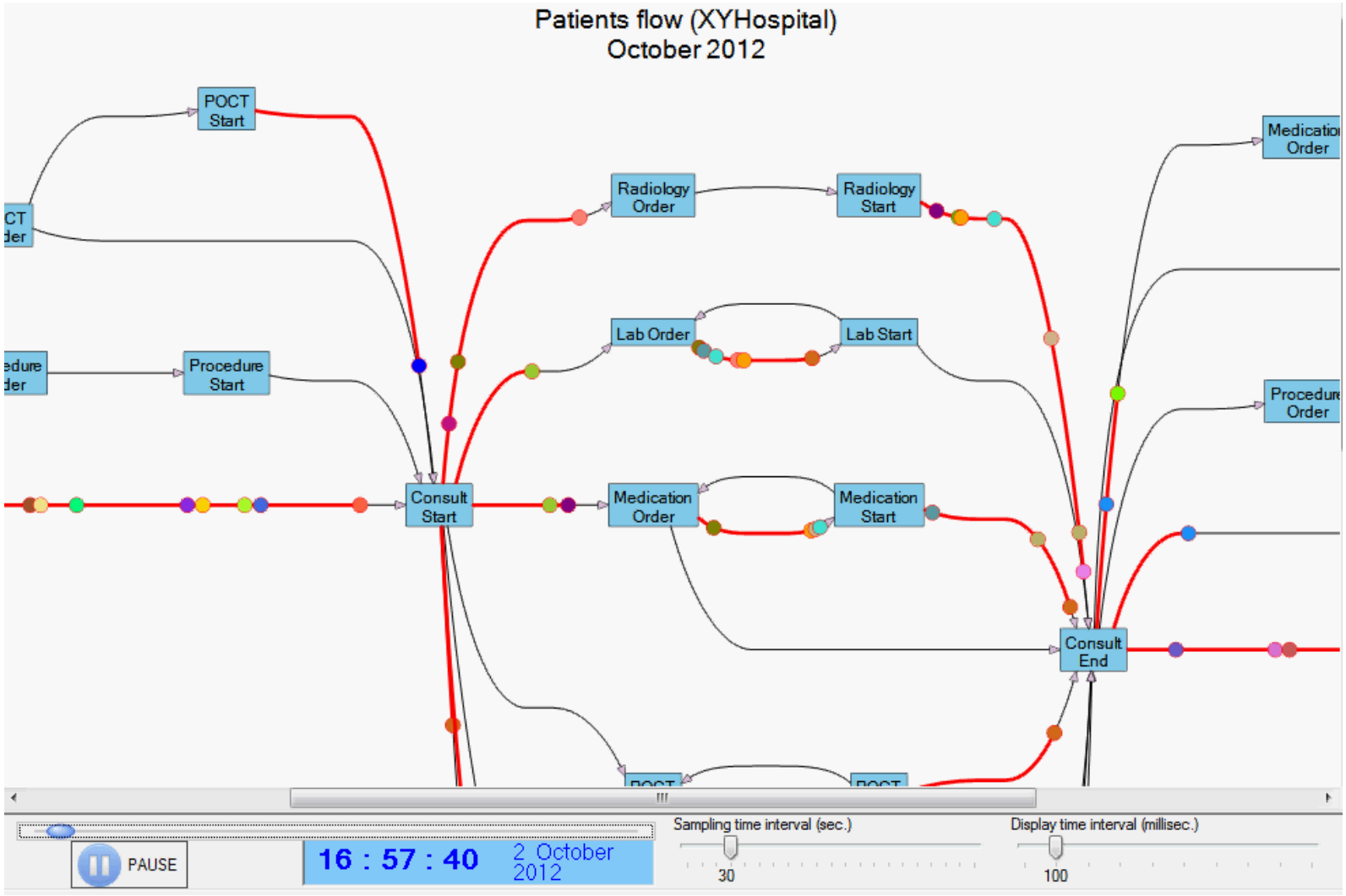
Service Engineering of an Emergency Department



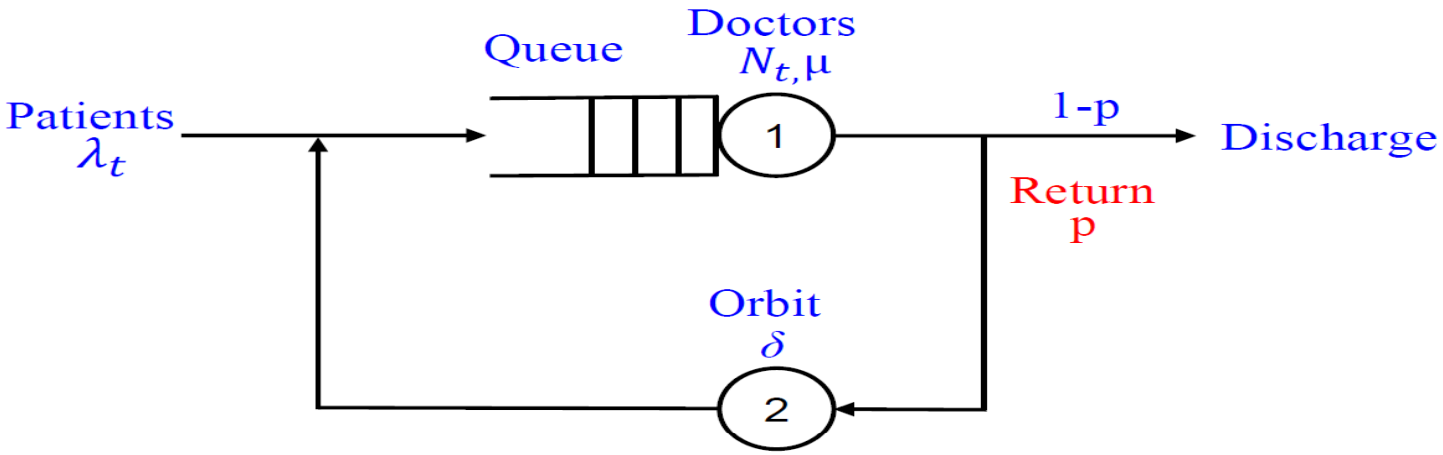

Patients movement (HomeHospital)
January 2005
PAUSE
16 : 43 : 04
12 January 2005
Sampling time interval (sec.)
600
Display time interval (millisec.)
100


Patients movement (HomeHospital)
January 2005
ED
Maternity
Internal
Intensive Care
Neurology
L
D
T
R
PAUSE
08 : 19 : 12
18 January 2005
Sampling time interval (sec.)
4800
Display time interval (millisec.)
100


Patients flow (XYHospital)
October 2012
Arrival
Triage Start
POCT Order
POCT Start
Procedure Order
Procedure Start
Consult Start
Radiology Order
Radiology Start
Lab Order
Lab Start
Medication Order
Medication Start
POCT Order
POCT Start
Procedure Order
Procedure Start
Consult End
Medication Order
Medication Start
Procedure Order
Procedure Start
Discharge
PAUSE
16 : 42 : 10
2 October 2012
Sampling time interval (sec.)
30
Display time interval (millisec.)
100


Patients flow (XYHospital)
October 2012
POCT Start
Radiology Order
Radiology Start
Lab Order
Lab Start
Procedure Start
Consult Start
Medication Order
Medication Start
Consult End
PAUSE
16 : 57 : 40
2 October 2012
Sampling time interval (sec.)
30
Display time interval (millisec.)
100

Erlang-R ↔ Fluid Model



Functional Strong Law of Large Numbers, for a 2-station QNet. BUT

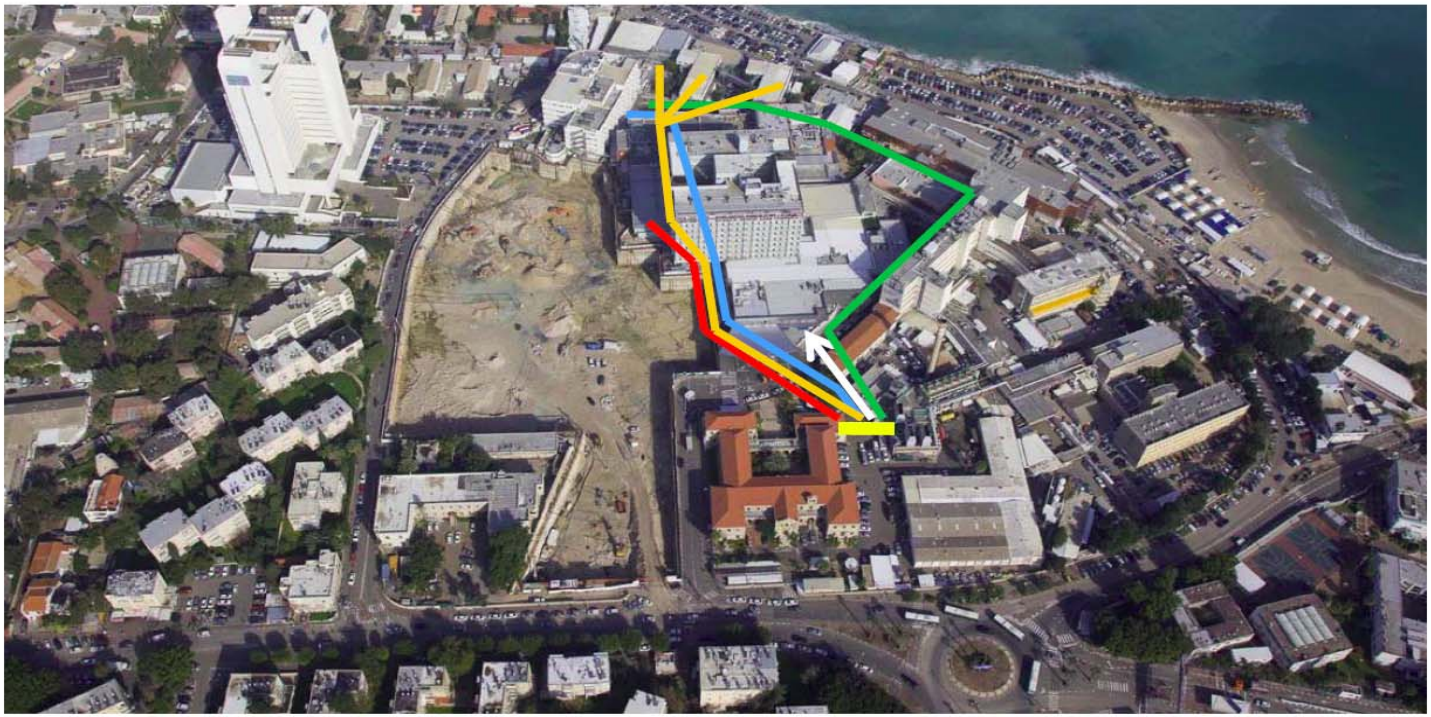
FNet = ODE: derived **directly** (no QNet), spreadsheet "solution"

$$\frac{d}{dt} q_t^1 = \lambda_t - \mu \cdot (q_t^1 \wedge N_t) + \delta \cdot q_t^2$$

$$\frac{d}{dt} q_t^2 = p \cdot \mu \cdot (q_t^1 \wedge N_t) - \delta \cdot q_t^2$$

eg. RFID-Based Data: Mass Casualty Event (MCE)

Drill: Chemical MCE, Rambam Hospital, May 2010



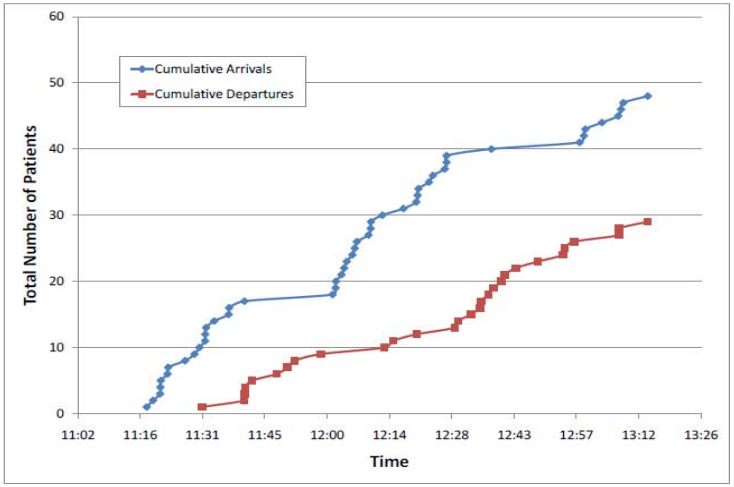
Focus on **severely wounded** casualties ($\approx$ 40 in drill)

Note: 20 observers support real-time control (helps validation)

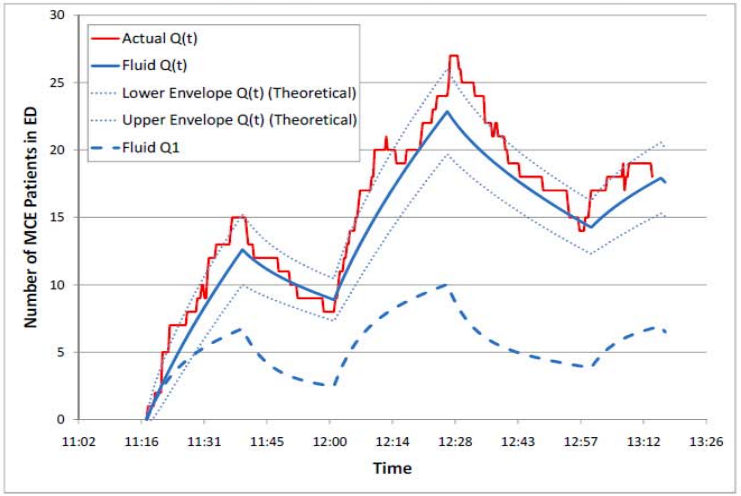
FNet vs. Data :Erlang-R value

Chemical MCE Drill (Israel, May 2010, 11:00-13:00)

Arrivals & **Departures** (RFID)



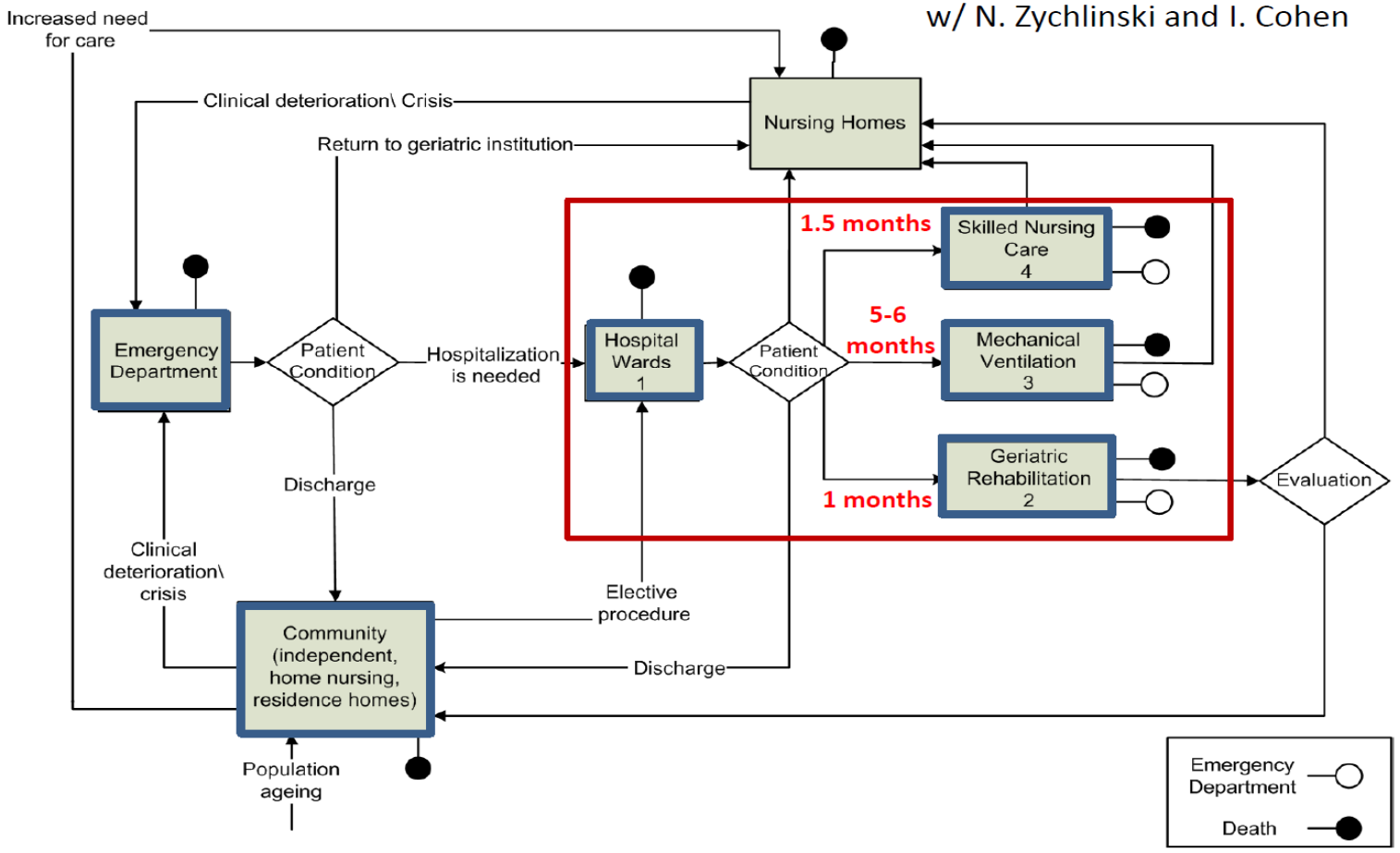
Erlang-R (**Fluid** , **Diffusion**)



- **Recurrent/Repeated** services in Chemical MCE: injection every 15/30/60 min
- **Fluid** = ODE
- **Diffusion** (confidence band), via F. Central Limit Theorem: Usefully narrow

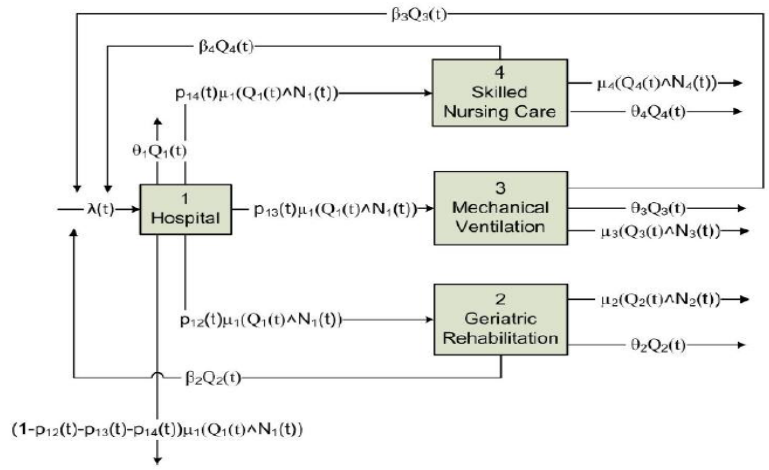
Patient Flow: ED to Wards to Nursing/Geriatric Institutions

w/ N. Zychlinski and I. Cohen



A Fluid Model

Stations 2,3 and 4



$$\dot{Q}_2(t) = (p_{12}(t)\mu_1 \cdot (Q_1(t) \wedge N_1)) \wedge (N_2 - Q_2(t))^+) -$$
$$\theta_2 Q_2(t) - \beta_2 Q_2(t) - \mu_2 \cdot (Q_2(t) \wedge N_2)$$
$$\dot{Q}_3(t) = (p_{13}(t)\mu_1 \cdot (Q_1(t) \wedge N_1)) \wedge (N_3 - Q_3(t))^+) -$$
$$\theta_3 Q_3(t) - \beta_3 Q_3(t) - \mu_3 \cdot (Q_3(t) \wedge N_3)$$
$$\dot{Q}_4(t) = (p_{14}(t)\mu_1 \cdot (Q_1(t) \wedge N_1)) \wedge (N_4 - Q_4(t))^+) -$$
$$\theta_4 Q_4(t) - \beta_4 Q_4(t) - \mu_4 \cdot (Q_4(t) \wedge N_4).$$

Asymptotic Landscape: 9 Operational Regimes, and then some

Erlang-A, w/ I. Gurvich & J. Huang

Erlang-A μ & θ fixed	Conventional scaling			Many-Server scaling			NDS scaling		
	Sub	Critical	Over	QD	QED	ED	Sub	Critical	Over
Offered load per server	$\frac{1}{1+\delta}$	$1-\frac{\beta}{\sqrt{n}}$	$\frac{1}{1-\gamma}$	$\frac{1}{1+\delta}$	$1-\frac{\beta}{\sqrt{n}}$	$\frac{1}{1-\gamma}$	$\frac{1}{1+\delta}$	$1-\frac{\beta}{n}$	$\frac{1}{1-\gamma}$
Arrival rate λ	$\frac{\mu}{1+\delta}$	$\mu-\frac{\beta}{\sqrt{n}}\mu$	$\frac{\mu}{1-\gamma}$	$\frac{n\mu}{1+\delta}$	$n\mu-\beta\mu\sqrt{n}$	$\frac{n\mu}{1-\gamma}$	$\frac{n\mu}{1+\delta}$	$n\mu-\beta\mu$	$\frac{n\mu}{1-\gamma}$
# servers	1			n			n		
Time-scale	n			1			n		
Impatience rate	θ/n			θ			θ/n		
Staffing level	$\frac{\lambda}{\mu}(1+\delta)$	$\frac{\lambda}{\mu}(1+\frac{\beta}{\sqrt{n}})$	$\frac{\lambda}{\mu}(1-\gamma)$	$\frac{\lambda}{\mu}(1+\delta)$	$\frac{\lambda}{\mu}+\beta\sqrt{\frac{\lambda}{\mu}}$	$\frac{\lambda}{\mu}(1-\gamma)$	$\frac{\lambda}{\mu}(1+\delta)$	$\frac{\lambda}{\mu}+\beta$	$\frac{\lambda}{\mu}(1-\gamma)$
Utilization	$\frac{1}{1+\delta}$	$1-\sqrt{\frac{\theta}{\mu}}\frac{h(\hat{\beta})}{\sqrt{n}}$	1	$\frac{1}{1+\delta}$	$1-\sqrt{\frac{\theta}{\mu}}\frac{\hat{h}(\hat{\beta})}{\sqrt{n}}$	1	$\frac{1}{1+\delta}$	$1-\sqrt{\frac{\theta}{\mu}}\frac{h(\hat{\beta})}{n}$	1
$\mathbb{E}(Q)$	$\frac{1}{\delta(1+\delta)}$	$\sqrt{n}g(\hat{\beta})$	$\frac{n\mu\gamma}{\theta(1-\gamma)}$	$\frac{1}{\delta}\varrho_n$	$\sqrt{n}g(\hat{\beta})\alpha$	$\frac{n\mu\gamma}{\theta(1-\gamma)}$	$o(1)$	$ng(\hat{\beta})$	$\frac{n^2\mu\gamma}{\theta(1-\gamma)}$
$\mathbb{P}(Ab)$	$\frac{1}{n}\frac{1}{\delta}\frac{\theta}{\mu}$	$\frac{\theta}{\sqrt{n}\mu}g(\hat{\beta})$	γ	$\frac{1}{n}\frac{(1+\delta)}{\delta}\frac{\theta}{\mu}\varrho_n$	$\frac{\theta}{\sqrt{n}\mu}g(\hat{\beta})\alpha$	γ	$o(\frac{1}{n^2})$	$\frac{\theta}{n\mu}g(\hat{\beta})$	γ
$\mathbb{P}(W_q>0)$	$\frac{1}{1+\delta}$	≈ 1		ϱ_n	$\alpha\in(0,1)$	≈ 1	≈ 0	≈ 1	
$\mathbb{P}(W_q>T)$	$\frac{1}{1+\delta}e^{-\frac{\delta}{1+\delta}\mu T}$	$1+O(\frac{1}{\sqrt{n}})$	$1+O(\frac{1}{n})$	≈ 0		$f(T)$	≈ 0	$\frac{\bar{\Phi}(\hat{\beta}+\sqrt{\theta\mu}T)}{\bar{\Phi}(\hat{\beta})}$	$1+O(\frac{1}{n})$
Congestion $\frac{\mathbb{E}W_q}{\mathbb{E}S}$	$\frac{1}{\delta}$	$\sqrt{n}g(\hat{\beta})$	$n\mu\gamma/\theta$	$\frac{1}{n}\frac{(1+\delta)}{\delta}\varrho_n$	$\frac{\alpha}{\sqrt{n}}g(\hat{\beta})$	$\frac{\mu\gamma}{\theta}$	$o(\frac{1}{n})$	$g(\hat{\beta})$	$n\mu\gamma/\theta$

Story 3: What's Next - Diagnosis

- Many fast changes, mainly due to technological advances but no less so because of **data** availability through these technologies: unprecedented quantity, granularity and quality
- Strong market demand for "data-professionals" (vaguely defined)
- IE&M has always had a "**Data Culture**" (Climate): in research and teaching, collected in the real-world or research labs (controlled experiments)
- Technion & IE&M, being **research**-driven institutions, advance the boundary of knowledge, and disseminate the knowledge created through teaching and alumni
- IE&M has been a great **success-story**: 13 programs in Israel is clear testimony to our success, but it also calls for perhaps **Reinvention** or at least **Invigoration** of the profession (within Technion) – and we are in the process of doing both

What's Next: Prognosis

- Reinvention: Created the profession **Data Science & Engineering** - B.Sc. in DS&E, who will extract useful information from vast amounts of data via computerized technologies

- Invigoration: DS&E requires additional faculty members, new courses and improved infrastructure, which will be used to invigorate the existing IE&M (e.g. Increase fraction of electives, consolidate concentrations)

Data Handling (Education)

	Gathering	Managing	Analyzing	Visualizing
Tasks	• Web and social media crawling • Stream processing • Information elicitation	• Data integration • Big graph partitioning • Probabilistic data management	• (Sponsored) Search • Sentiment analysis • Decision making • Time series • Process analysis • Ad exchange • Differential pricing • Prediction	• Interaction • Animation
Areas/Tools	• Mechanism design (crowd sourcing) • Event processing and sensors (hospitals, transportation)	• Search engines • Databases (SQL, noSQL, newSQL, probabilistic DB) • Cloud computing	• Economics & computation • Information retrieval & natural language processing • Operations research (optimization, simulation) • Statistics & machine learning	• User experience • Cognitive science

Data Science and Engineering

Technion
Israel Institute of Technology

Gaining Experience with Data:

- Data collection and management laboratory
- Data analysis and presentation laboratory
- Industry project (summer internship)

Data Types:

- Applied econometrics (economic)
- Information retrieval (textual)
- Natural language processing (textual)
- Service system engineering (operational)
- Periodic series (time-based)
- Event processing (sensory)
- Environmental data
- Epidemiological data

Data collection and management:

- Database management systems
- Managing distributed data
- Distributed information systems

Information analysis and presentation:

- Statistical theory
- Data mining
- Computational learning and online optimization
- Visual information presentation and cognition

Scientific and Engineering Fundamentals:

- Introduction to data science
- Deterministic models in operations research
- Stochastic models in operations research
- Introduction to statistics
- Fundamentals of artificial intelligence
- Models of electronic commerce
- Industrial psychology
- Human factor engineering
- Numerical simulation

Mathematics:

- Two calculus courses
- Algebra
- Discrete mathematics
- Numerical analysis
- Probability
- Rational agents

Computer Science:

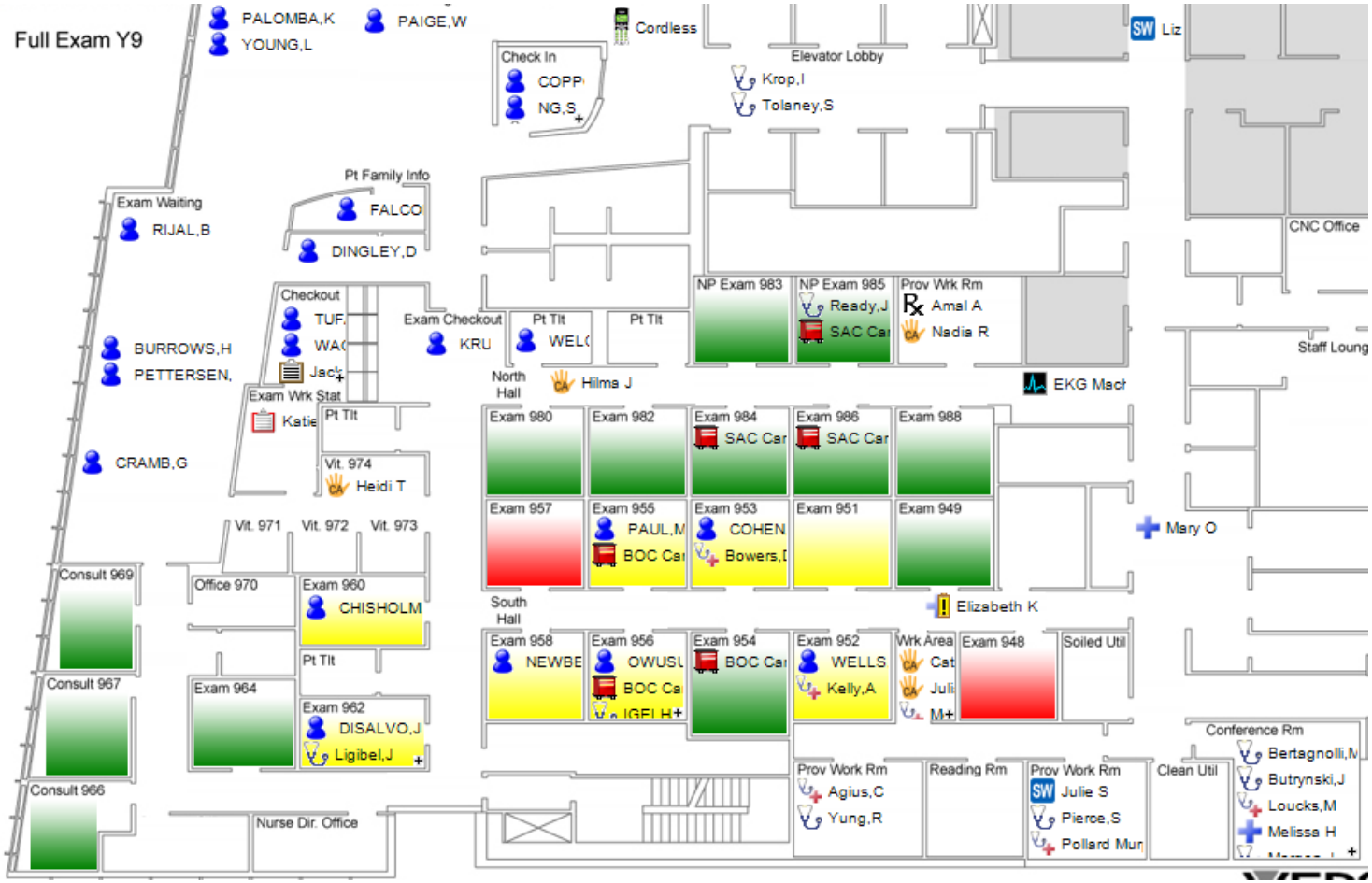
- Introduction to computer science
- Data structures and algorithms
- Introduction to computation and logic modeling

General:

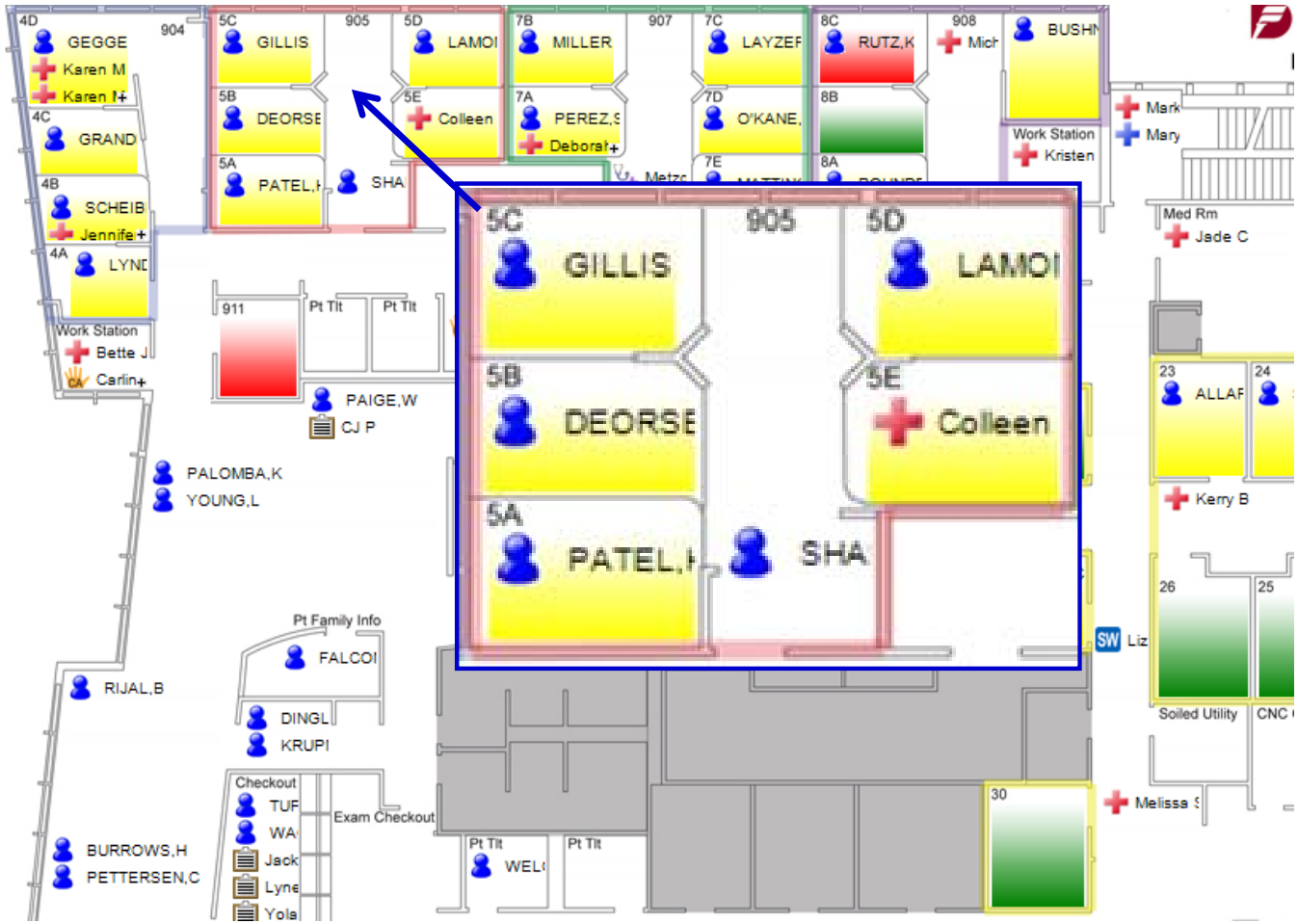
- Physics 1
- Two scientific courses
- Physical education
- English

Closing the Data-Gap: Call-Centers & Hospitals

- **Large call center**:
  - Thousands of agents
  - Hundreds of thousands of calls per day
  - Automatically, individual customers & agents (event log)
    - Operational
    - Financial, ...
- **Large hospital**:
  - 1000+ Beds
  - Thousands of nurses, hundreds of doctors
  - Incomplete data (at best) ...


Full Exam Y9
PALOMBA,K
YOUNG,L
PAIGE,W
Cordless
Check In
COPP
NG,S
Elevator Lobby
Krop,I
Tolaney,S
SW Liz
CNC Office
Staff Loung
Pt Family Info
FALCO
DINGLEY,D
Exam Waiting
RIJAL,B
BURROWS,H
PETTERSEN,
CRAMB,G
Checkout
TUF
WA
Jack
Exam Wrk Stat
Katie
Exam Checkout
KRU
Pt Tlt
WELC
Pt Tlt
NP Exam 983
NP Exam 985
Ready,J
SAC Car
Prov Wrk Rm
Amal A
Nadia R
EKG Mach
North Hall
Hilma J
Pt Tlt
Vit. 974
Heidi T
Exam 980
Exam 982
Exam 984
SAC Car
Exam 986
SAC Car
Exam 988
Exam 957
Exam 955
PAUL,M
BOC Car
Exam 953
COHEN
Bowers,D
Exam 951
Exam 949
Mary O
Vit. 971
Vit. 972
Vit. 973
Consult 969
Office 970
Exam 960
CHISHOLM
South Hall
Elizabeth K
Exam 958
NEWBE
Exam 956
OWUSU
BOC Ca
IGELH
Exam 954
BOC Car
Exam 952
WELLS
Kelly,A
Wrk Area
Cat
Juli
M
Exam 948
Soiled Util
Pt Tlt
Consult 967
Exam 964
Exam 962
DISALVO,J
Ligibel,J
Conference Rm
Bertagnolli,M
Butrynski,J
Loucks,M
Melissa H
Consult 966
Nurse Dir. Office
Prov Work Rm
Agius,C
Yung,R
Reading Rm
Prov Work Rm
SW Julie S
Pierce,S
Pollard Mur
Clean Util


4D
GEGGE
Karen M
Karen M
904
4C
GRAND
4B
SCHEIB
Jennife
4A
LYNE
Work Station
Bette J
Carlin
5C
GILLIS
905
5D
LAMOI
5B
DEORSE
5E
Colleen
5A
PATEL,
SHA
7B
MILLER
907
7C
LAYZEF
7A
PEREZ,S
Deborah
Metzg
7D
O'KANE,
7E
MATTIN
8C
RUTZ,K
908
Mich
BUSHN
8B
8A
POUNDE
Work Station
Kristen
Mark
Mary
Med Rm
Jade C
Gloria
Laurie H
911
Pt Tlt
Pt Tlt
Vitals
Bri
915
PAIGE,W
CJ P
Pt Tlt
Pt Tlt
918
KIMBRO
Pharmacy
22
Main Elevator Lobby
23
ALLAF
24
Kerry B
Pt Staff Arriv.
Cordles
Check In
COPP
NG,S
Brenc
HENNESSEY
Krop,I
Tolaney,S
PALOMBA,K
YOUNG,L
27
LEBLANC
SW
Liz
26
25
Soiled Utility
CNC
Pt Family Info
FALCOI
DINGL
KRUPI
RIJAL,B
Checkout
TUF
WA
Jack
Lyne
Yola
Exam Checkout
30
Melissa
BURROWS,H
PETTERSEN,C
Pt Tlt
WEL
Pt Tlt


4D
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Deborat
7D
O'KANE,
7E
8C
RUTZ,K
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Mich
8B
8A
BUSHN
Work Station
Kristen
Mark
Mary
Med Rm
Jade C
911
Pt Tlt
Pt Tlt
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CJ P
PALOMBA,K
YOUNG,L
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ALLAF
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Soiled Utility
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FALCOI
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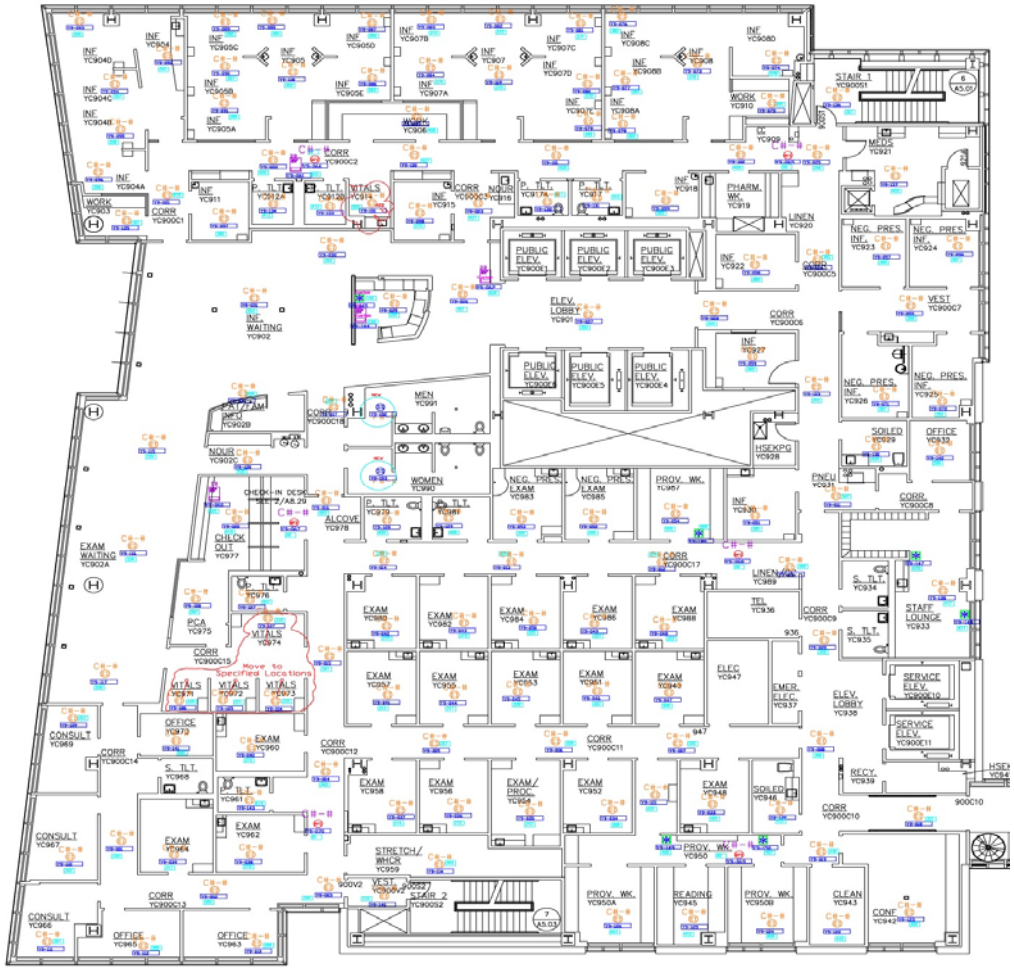
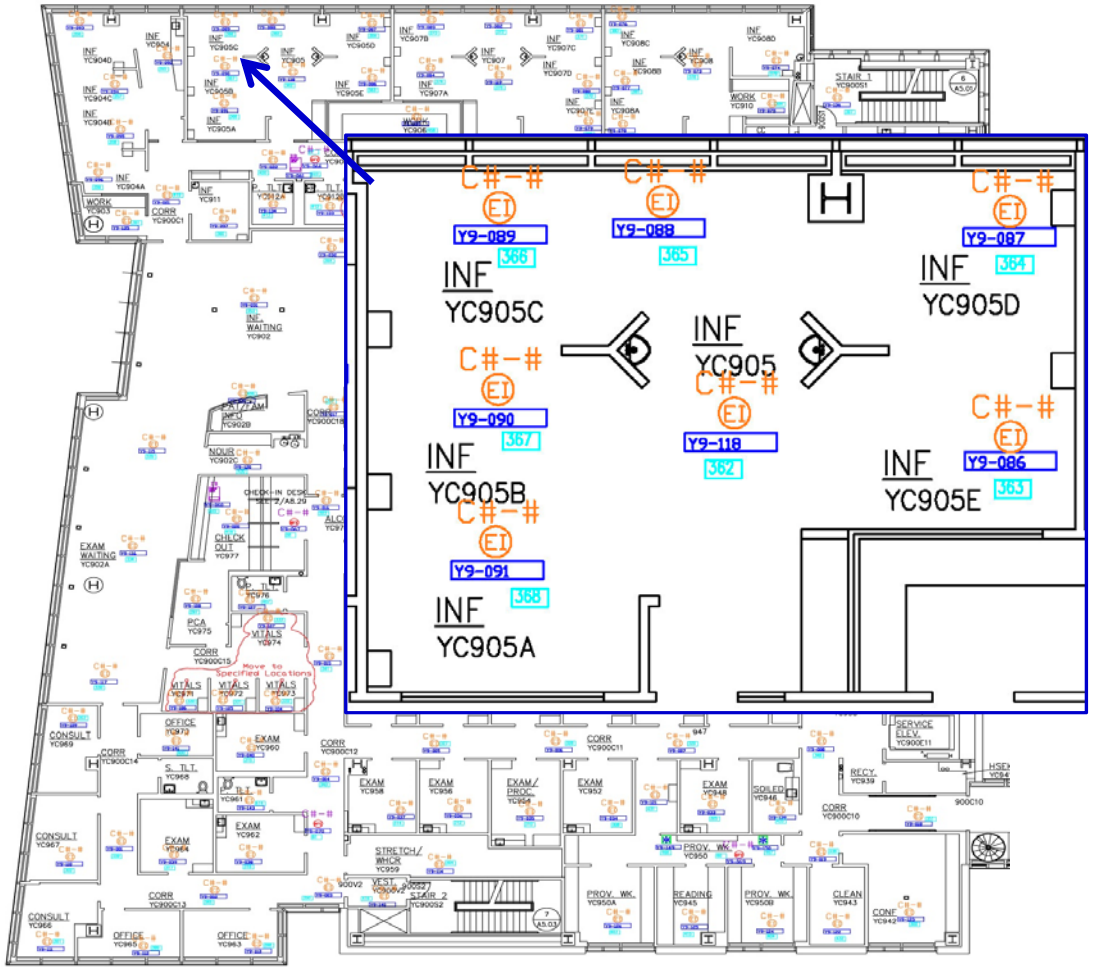
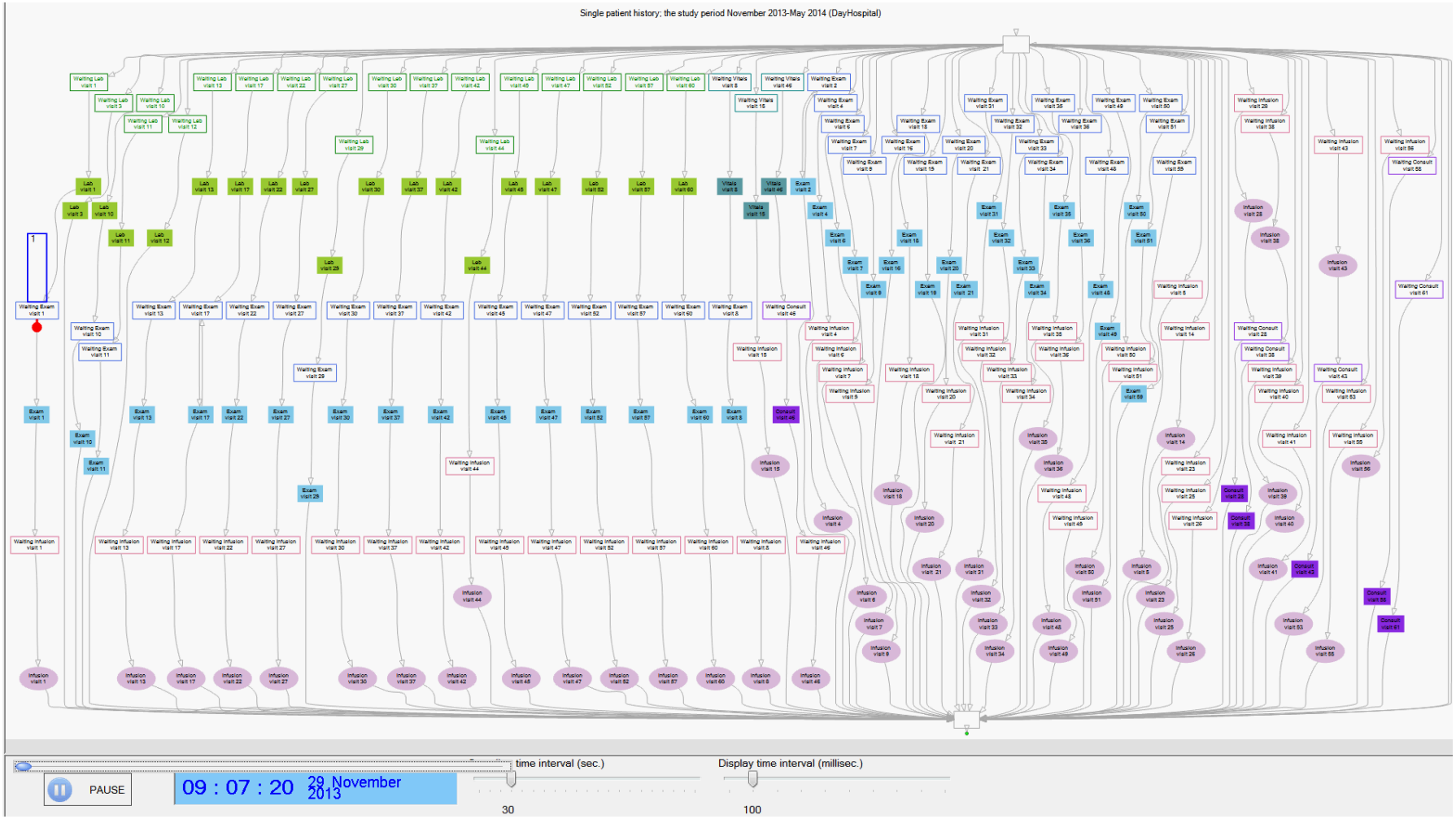
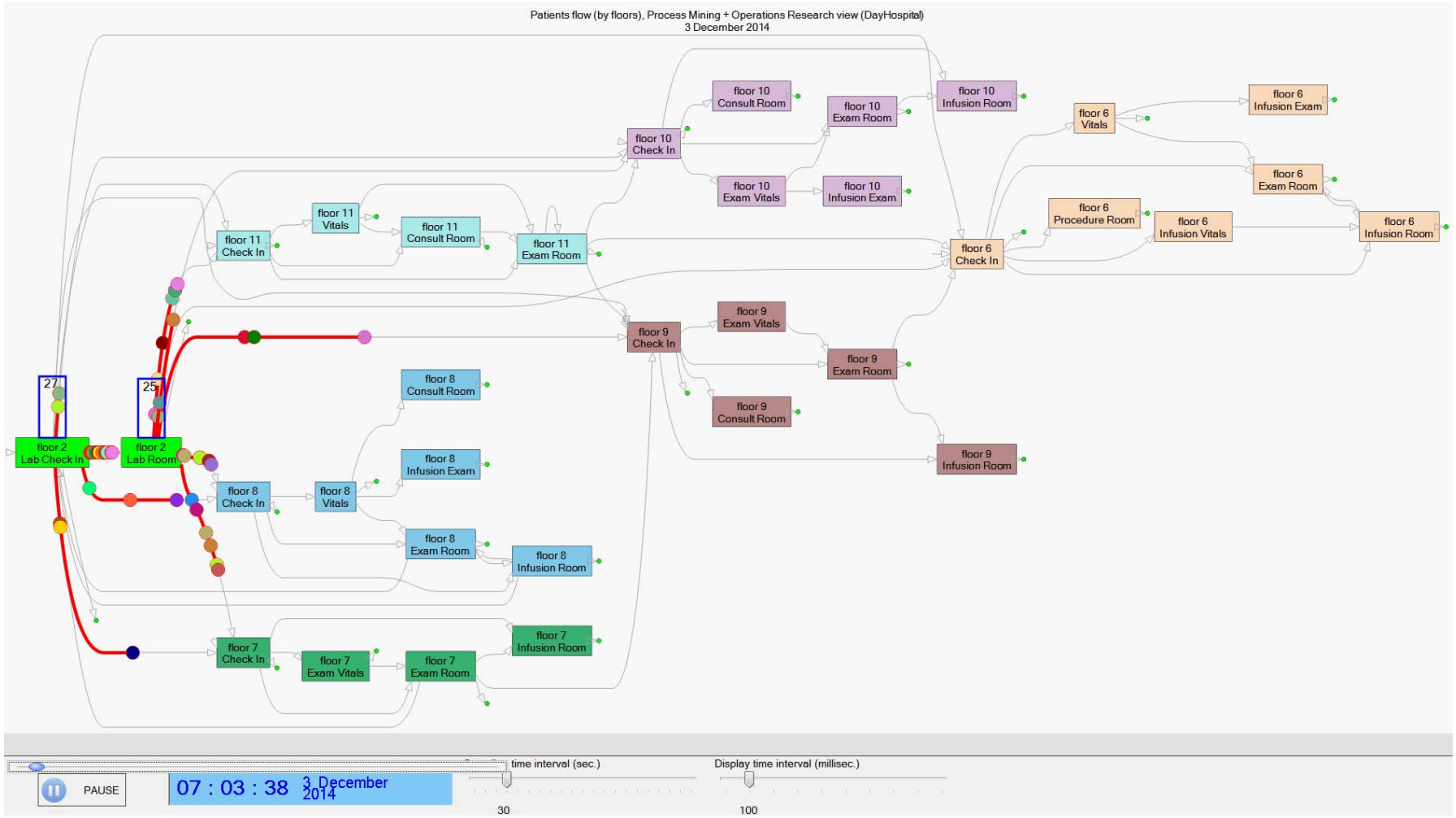
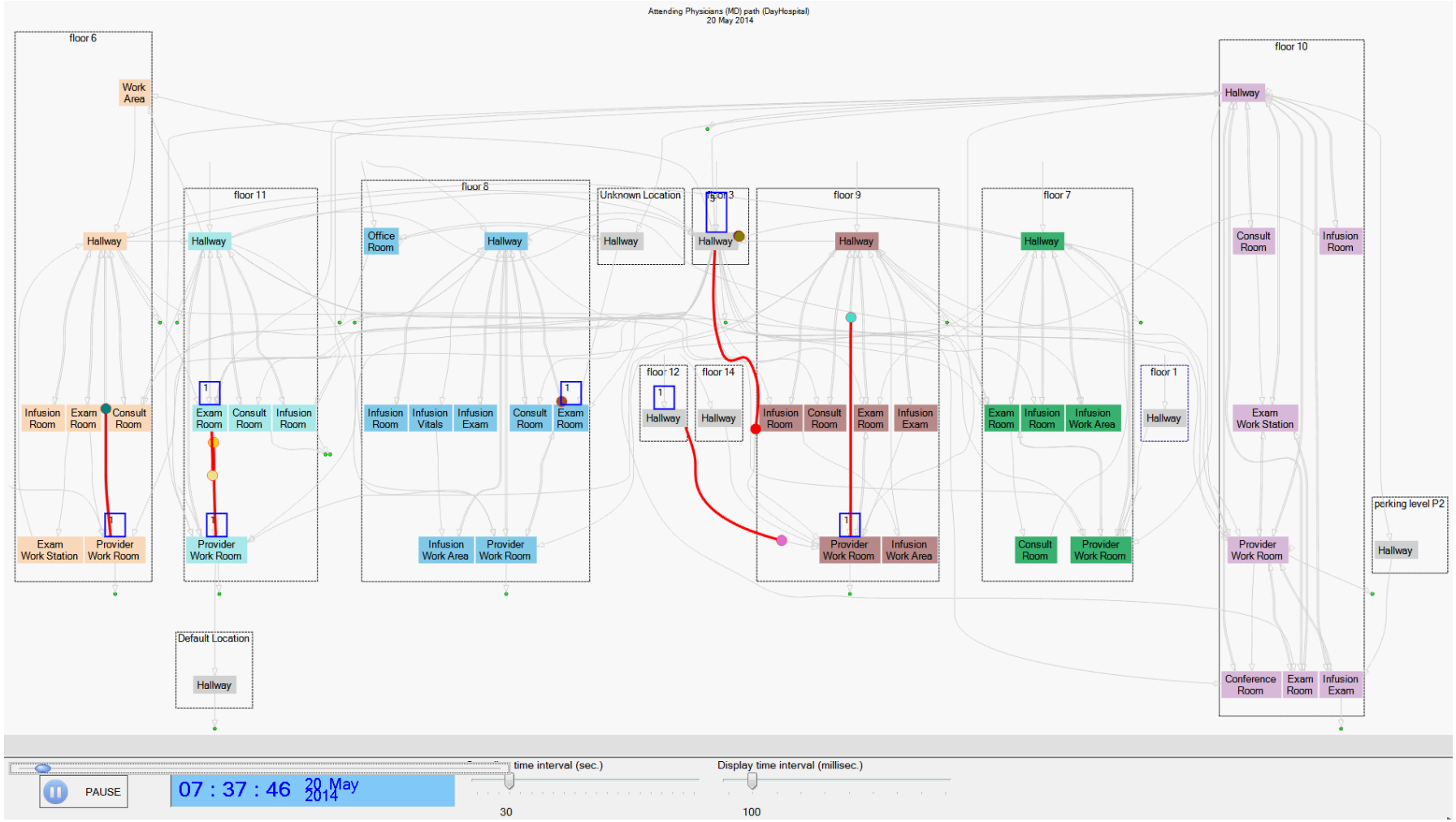
KRUPI
RIJAL,B
Checkout
TUF
WA
Jack
Lyne
Yola
Exam Checkout
BURROWS,H
PETTERSEN,C
Pt Tlt
WEL
Pt Tlt
30
Melissa

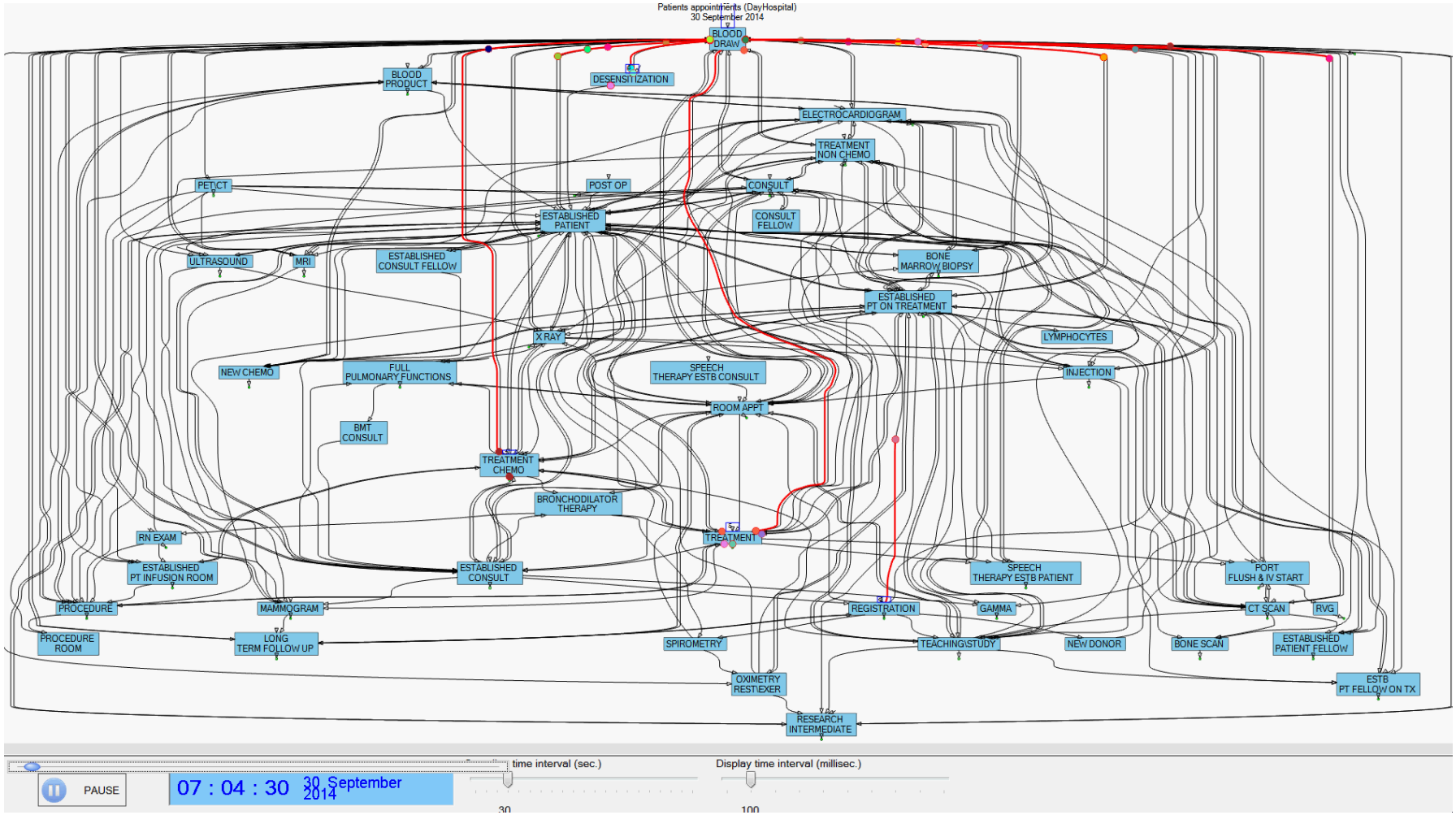

Move to Specified Locations

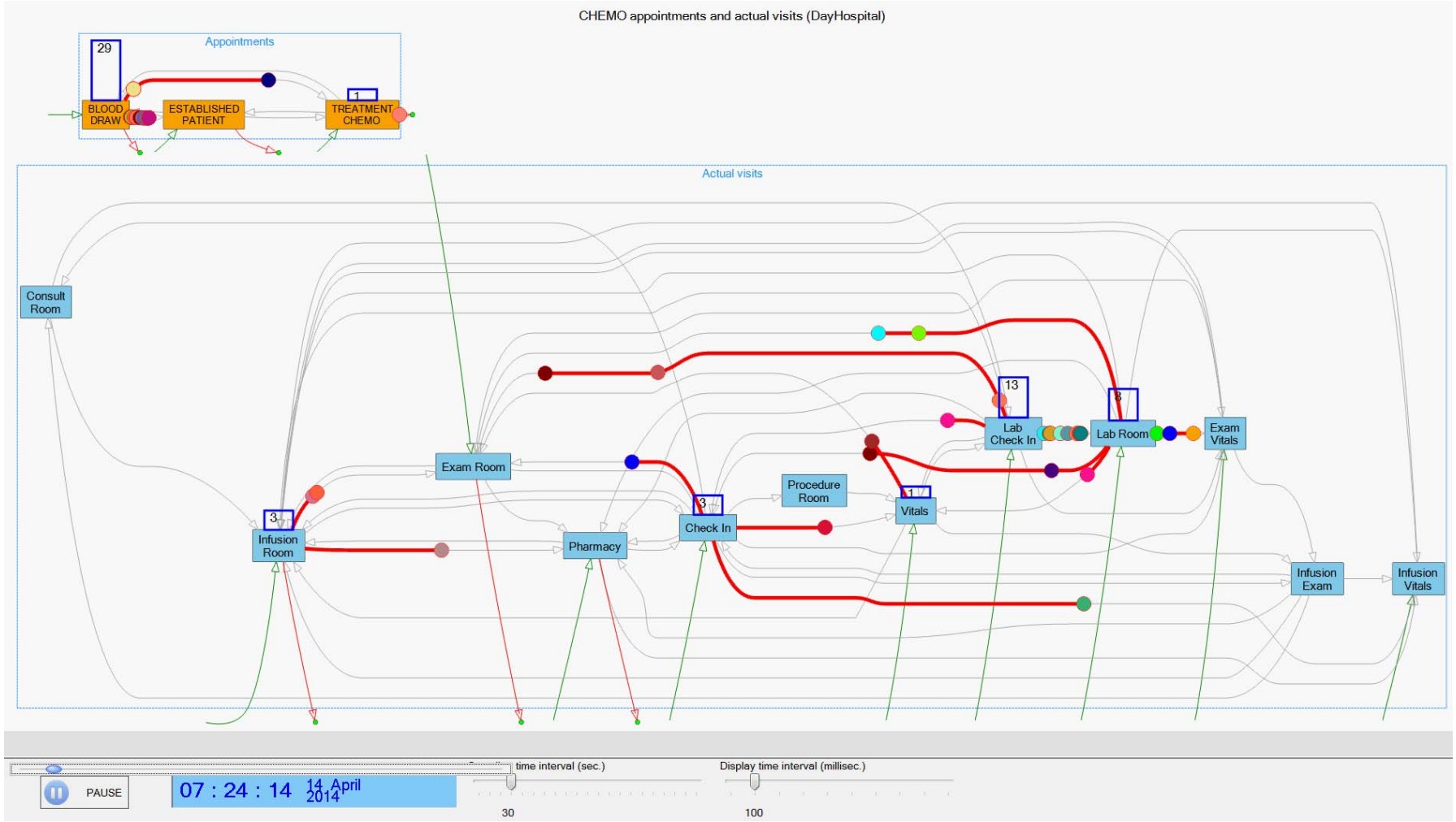

C#-#
EI
Y9-089
366
INF
YC905C
C#-#
EI
Y9-088
365
H
C#-#
EI
Y9-087
364
INF
YC905D
INF
YC905
C#-#
EI
Y9-090
367
INF
YC905B
C#-#
EI
Y9-118
362
C#-#
EI
Y9-086
363
INF
YC905E
C#-#
EI
Y9-091
368
INF
YC905A


Single patient history; the study period November 2013-May 2014 (DayHospital)
PAUSE
09 : 07 : 20
29 November 2013
time interval (sec.)
30
Display time interval (millisec.)
100


Patients flow (by floors), Process Mining + Operations Research view (DayHospital)
3 December 2014
floor 10 Consult Room
floor 10 Exam Room
floor 10 Infusion Room
floor 10 Check In
floor 10 Exam Vitals
floor 10 Infusion Exam
floor 6 Vitals
floor 6 Infusion Exam
floor 6 Exam Room
floor 6 Procedure Room
floor 6 Infusion Vitals
floor 6 Infusion Room
floor 6 Check In
floor 11 Vitals
floor 11 Consult Room
floor 11 Check In
floor 11 Exam Room
floor 9 Exam Vitals
floor 9 Check In
floor 9 Exam Room
floor 9 Consult Room
floor 9 Infusion Room
27
25
floor 2 Lab Check In
floor 2 Lab Room
floor 8 Consult Room
floor 8 Infusion Exam
floor 8 Check In
floor 8 Vitals
floor 8 Exam Room
floor 8 Infusion Room
floor 7 Infusion Room
floor 7 Check In
floor 7 Exam Vitals
floor 7 Exam Room
PAUSE
07 : 03 : 38
3 December 2014
time interval (sec.)
30
Display time interval (millisec.)
100

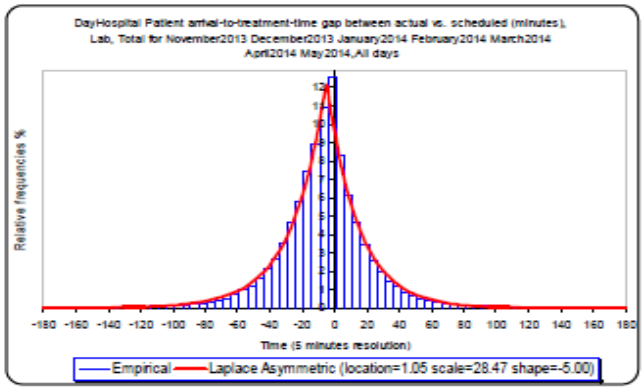

Attending Physicians (MD) path (DayHospital)
20 May 2014
floor 6
Work Area
Hallway
Infusion Room
Exam Room
Consult Room
Exam Work Station
Provider Work Room
floor 11
Hallway
Exam Room
Consult Room
Infusion Room
Provider Work Room
Default Location
Hallway
floor 8
Office Room
Hallway
Infusion Room
Infusion Vitals
Infusion Exam
Consult Room
Exam Room
Infusion Work Area
Provider Work Room
Unknown Location
Hallway
floor 3
Hallway
floor 12
Hallway
floor 14
Hallway
floor 9
Hallway
Infusion Room
Consult Room
Exam Room
Infusion Exam
Provider Work Room
Infusion Work Area
floor 7
Hallway
Exam Room
Infusion Room
Infusion Work Area
Consult Room
Provider Work Room
floor 1
Hallway
floor 10
Hallway
Consult Room
Infusion Room
Exam Work Station
Provider Work Room
Conference Room
Exam Room
Infusion Exam
perking level P2
Hallway
PAUSE
07 : 37 : 46
20 May 2014
time interval (sec.)
30
Display time interval (millisec.)
100


Patients appointments (DayHospital)
30 September 2014
BLOOD DRAW
BLOOD PRODUCT
DESENSITIZATION
ELECTROCARDIOGRAM
TREATMENT NON CHEMO
PET\CT
POST OP
CONSULT
ESTABLISHED PATIENT
CONSULT FELLOW
ULTRASOUND
MRI
ESTABLISHED CONSULT FELLOW
BONE MARROW BIOPSY
ESTABLISHED PT ON TREATMENT
X RAY
LYMPHOCYTES
NEW CHEMO
FULL PULMONARY FUNCTIONS
SPEECH THERAPY ESTB CONSULT
INJECTION
ROOM APPT
BMT CONSULT
TREATMENT CHEMO
BRONCHODILATOR THERAPY
RN EXAM
TREATMENT
ESTABLISHED PT INFUSION ROOM
ESTABLISHED CONSULT
SPEECH THERAPY ESTB PATIENT
PORT FLUSH & IV START
PROCEDURE
MAMMOGRAM
REGISTRATION
GAMMA
CT SCAN
RVG
PROCEDURE ROOM
LONG TERM FOLLOW UP
SPIROMETRY
TEACHING\STUDY
NEW DONOR
BONE SCAN
ESTABLISHED PATIENT FELLOW
OXIMETRY REST\EXER
ESTB PT FELLOW ON TX
RESEARCH INTERMEDIATE
PAUSE
07 : 04 : 30
30 September 2014
time interval (sec.)
30
Display time interval (millisec.)
100

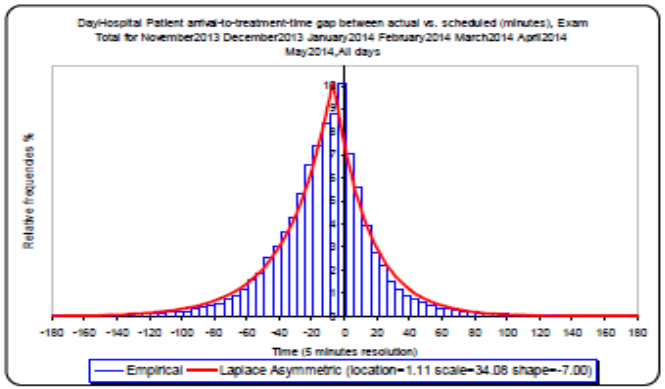

CHEMO appointments and actual visits (DayHospital)
Appointments
29
BLOOD DRAW
ESTABLISHED PATIENT
1
TREATMENT CHEMO
Actual visits
Consult Room
Exam Room
3
Infusion Room
Pharmacy
3
Check In
Procedure Room
1
Vitals
13
Lab Check In
8
Lab Room
Exam Vitals
Infusion Exam
Infusion Vitals
PAUSE
07 : 24 : 14 14 April 2014
time interval (sec.)
30
Display time interval (millisec.)
100

Statistical-Deviation of Planned vs. Actual

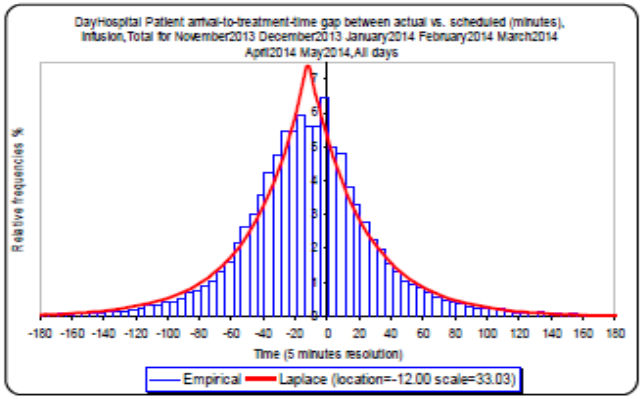
Lab (mean = -7 min)



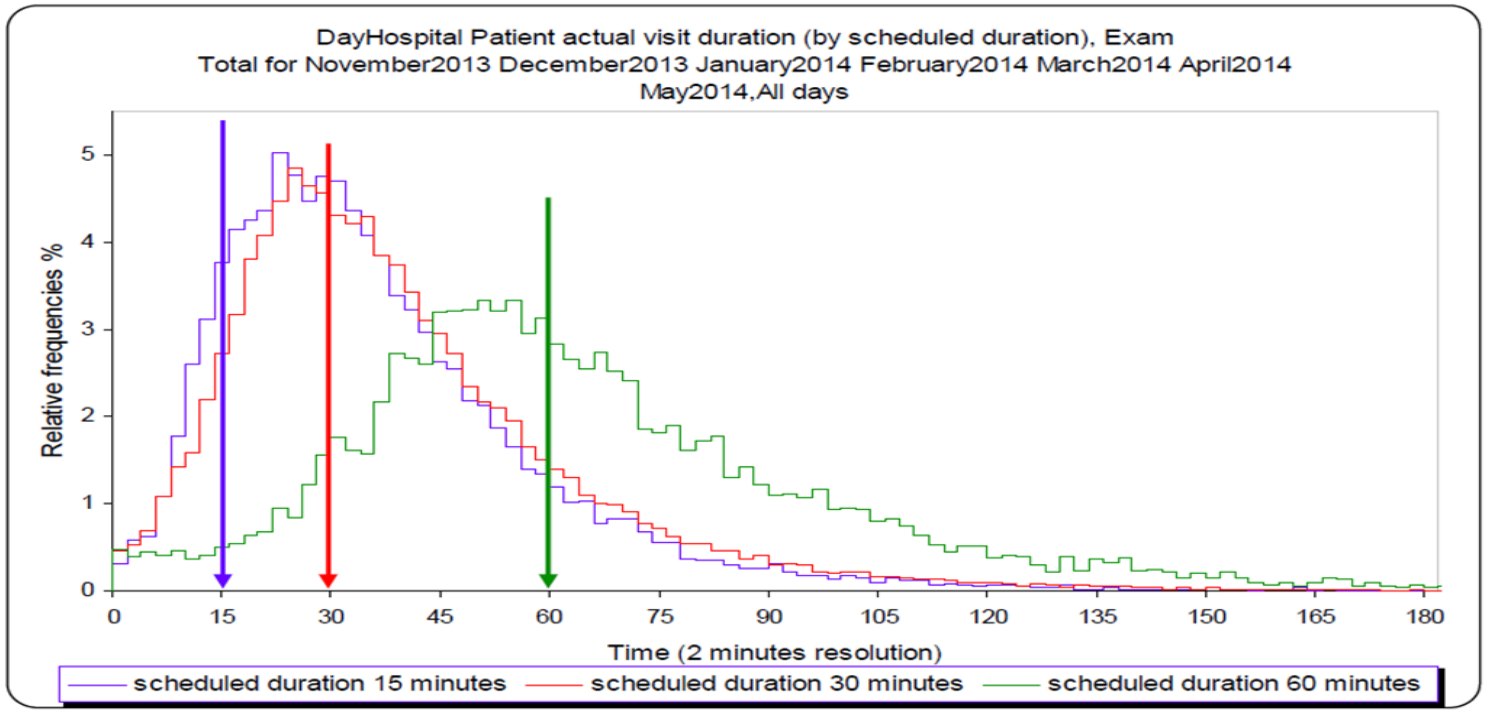
Exam (mean = -12 min)



Infusion (mean = -12 min)



Exam: actual duration for 15, 30 and 60 min scheduled-duration



DayHospital Patient actual visit duration (by scheduled duration), Exam, Total for November2013 December2013 January2014 February2014 March2014 April2014 May2014,All days			
	scheduled duration 15 minutes	*scheduled duration 30 minutes*	*scheduled duration 60 minutes*
N	17637	50898	9615
N(average per day)	145.76	420.64	79.46
Mean	35.98	39.2	65.49
Standard Deviation	23.39	25.03	34.64
Median	31	34	59
Minimum	1	1	1
Maximum	598	539	420

Applications in DFCI

Control: rooms status, physicians location, long wait times

Planning: number infusion chairs, load-balancing among floors

Management: evidence-based

Design vs. Performance: exam durations (no 15-minutes)

Motivating improvement: room for physician vs. room for patient

SEELab: Converging to the Vision

e.g. Specific Emergency-Department, with ample reliable data

- Real-time: data-based **control of** patient-flow (bottlenecks)
- Short-term: on Monday, set Tuesday's **staffing** levels (or next week's)
- Long-term: calculate real **cost** of care for individual patient (as opposed to insurance costs)
- Above, by online creation of data-based ED **model(s)** (empirical, simulation, mathematical)


1
2
3
4
5
Elaine
Next: CT Scan At: 15:30
Geting there
Time left: about 5 hours
CT Scan
Blood test
Exam 1
Study
Blood test
Exam 2
X-Ray
Blood test
X-Ray
Go to: Clinical center 10
Back to full schedule
Next: Blood test At: 16:15
Go to: Clinical center 6
Change screen on button click
Time left: about 4 hours
Waiting for blood test results
More info
Idle state:
Seeing the planned schedule before anything started
The next activity highlighted up front
Next activity screen
Next activity screen:
Switch to it is automatic after previous activity was completed.
Idle state:
Seeing the planned schedule after one activity was completed.
The next activity highlighted up front
Idle state:
Seeing the planned schedule after two activities were completed.
The next activity highlighted up front but
6
7
8
Idle state:
Seeing the planned schedule after two activities were done
The next activity highlighted up front but time unknown.
Selecting a later activity to get more details
Later: Exam Planned at: 17:00
Location at: Clinical center 9a
Later activity screen
Blood test results back
Next: Exam 1 At: 16:30
Getting there
Idle state:
Seeing the planned schedule after two activities were completed.
Status of recent activity updated.
The next activity highlighted up front with time and location.


Technion
S.E.E
Center
Service Enterprise Engineering