Telephone Call/Contact Centers

Research in State-of-the-Art

Service Engineering

ניהול ותפעול מוקדי שירות (טלפוניים)

המי"ל

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1. Supporting Material (Downloadable)

M. "Call Centers: Research Bibliography with Abstracts." Version 5, July, 2003.

Gans (U.S.A.), Koole (Europe), and M. (Israel): "Telephone Call Centers: Tutorial, Review and Research Prospects." *MSOM, 2003.*

M., Sakov, **Zeltyn**: "Empirical Analysis of a Telephone Call Center: A Queueing-Science Perspective."

Brown, Gans, M., Sakov, Shen, **Zeltyn**, Zhao: "Statistical Analysis of a Telephone Call Center: A Queueing-Science Perspective." Submitted, 2003.

Borst, M. and Reiman: "Dimensioning Large Telephone Call Centers." *OR, 2004.*

Erlang: "On the rational determination of the number of circuits." Written in 1923, Used in **1913**,
Published in "*The life and works of A.K. Erlan*g," 1948.
Amazingly, still the most prevalent model in support of WFM.

Contents

1. Service Engineering – Research, Teaching, Practice.
2. Workforce Management (Staffing): Hierarchical View
3. Operational Regime: Quality-Driven, Efficiency-Driven

   The QED (Halfin-Whitt) Regime

Leading to (Useful) Models:

7. Impatient (Abandoning) Customers
8. Skills-Based Routing (Heterogeneous Customers & Agents)

and Tools:

9. 4CallCenters: Personal Tool for WFM (OR/IE/OM)
10. Data MOCCA = Data Model for CC Analysis (Stat., MIS)

BONUS SUPPLEMENT: E-TAILING'S FUTURE

e.biz GEN

www.businessweek.com

BusinessWeek

OCTOBER 23, 2000

A PUBLICATION OF THE McGRAW-HILL COMPANIES

Mutual Funds

How to avoid a big tax bill

Wall Street

Will tech's slide keep spreading?

Dot-coms

The search for new business models

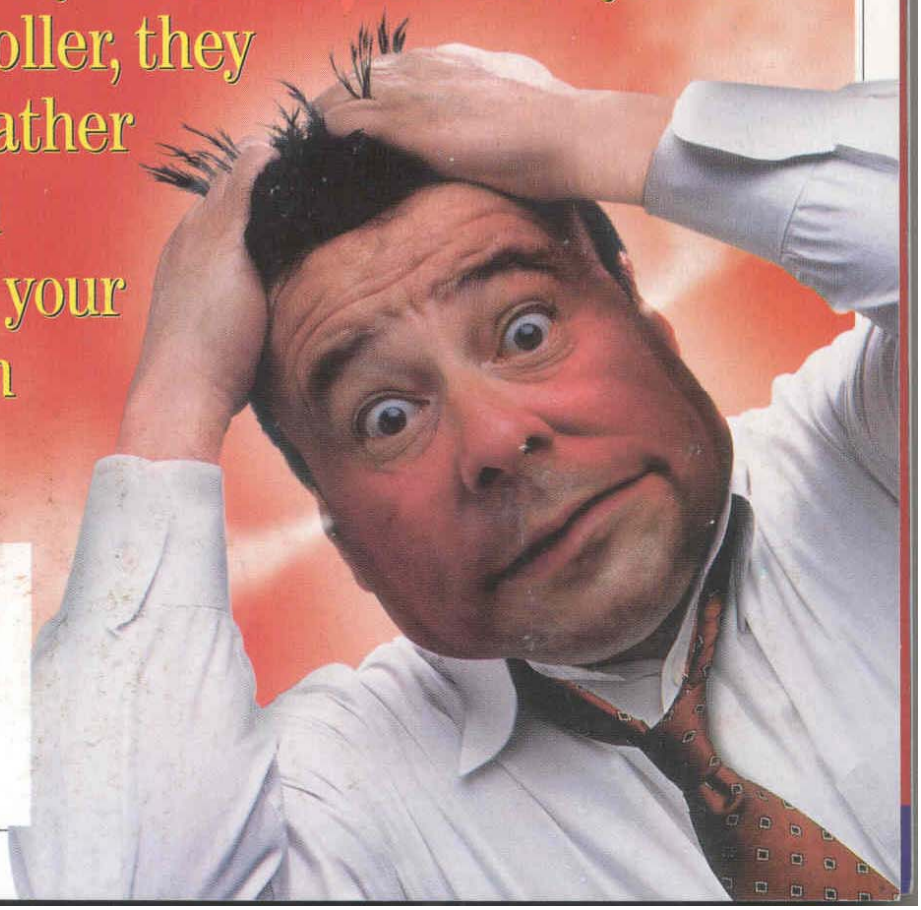
Managed Care

Employers seek a new solution

WHY SERVICE STINKS

Companies know just how good a customer you are—and unless you're a high roller, they would rather lose you than fix your problem

PAGE 118



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AOL Keyword: BW

About OR

OR Topics

Queueing for Toilets

- estimating the required number of toilets using queueing theory

Don McNickle

The New Zealand Works Consultancy Services was contracted to study of the number of sanitary facilities to be provided in buildings, in order to revise the tables in the New Zealand Building Code. A very extensive data-gathering exercise to predict occupancy times and demand for various kinds of buildings was carried out. Simple queueing models proved to be the most appropriate tools for use to estimate the waiting times that the new standards would produce. While the aim of the project was to produce consistent standards, a preliminary analysis indicated the new standards might produce savings with a NPV of about $80 million.

-oo0oo-

The New Zealand Building Code (Clause G1 Personal Hygiene) requires that 'appropriate and sufficient numbers' of 'sanitary fixtures' (that is WC's, urinals, handbasins) be provided for people in buildings. The Buildings Industry Authority publishes a document (G1/AS1) which gives tables of Acceptable Solutions (number and types of facilities) as a means of compliance with the requirement. The numbers in G1/AS1 had been copied from various pieces of legislation and other sources over the years, and were known to be often wildly inconsistent. In 1994 Works Consultancy Services (a state-owned engineering consultancy with a long tradition of excellent service, since sold to the private sector) was contracted to revise the G1/AS1 tables. They in turn approached me for help with data analysis and modelling the delays that various numbers of facilities would produce.

Most countries have some kind of standards like these, and there have been a number of attempts, usually based on queueing models, to put them on a scientific footing. We found reports from Canada, the UK, Australia, and the USA. A review of these showed that although there had been some good studies (see, for example, Davidson and Courtney (1976)), these either covered too few types of building or were not exhaustive enough to produce comprehensive standards. We also had a sneaking worry that toilet habits might vary from country to country, so it was decided to carry out a complete analysis for New Zealand.

Collecting and analysing the data

Data collection started in 1994. Works Consultancy staff collected data from thirteen types of buildings, including office buildings, schools, theatres, swimming pools and shopping plazas. 27 locations were surveyed, and

Service Engineering of Stochastic Networks

Background, with a focus on Tele-Services

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The subject of this note, and a central theme of my present research, are *Service Networks*: these include public service centers (municipal, government), telephone services (business and marketing, emergency, assistance), banks and insurance (front and back office), hospitals (emergency rooms, outpatient clinics, operating rooms), airports, supermarkets, maintenance and field-service operations, some transportation systems, and even more. (In many such systems, the network-view, as opposed to that of a one-stop service-station, is essential.) Significant motivators for my research efforts have been *tele-services*, in which customers and servers are remote from and invisible to each other. Communication in tele-services is through snail-mail, fax, electronic-mail, interactive-voice-response, telephone and increasingly the Internet. However, existing tele-services are predominantly telephone-based hence my heavy emphasis on telephony.

When lecturing on Stochastic Service Networks, I typically divide my presentation into three parts:

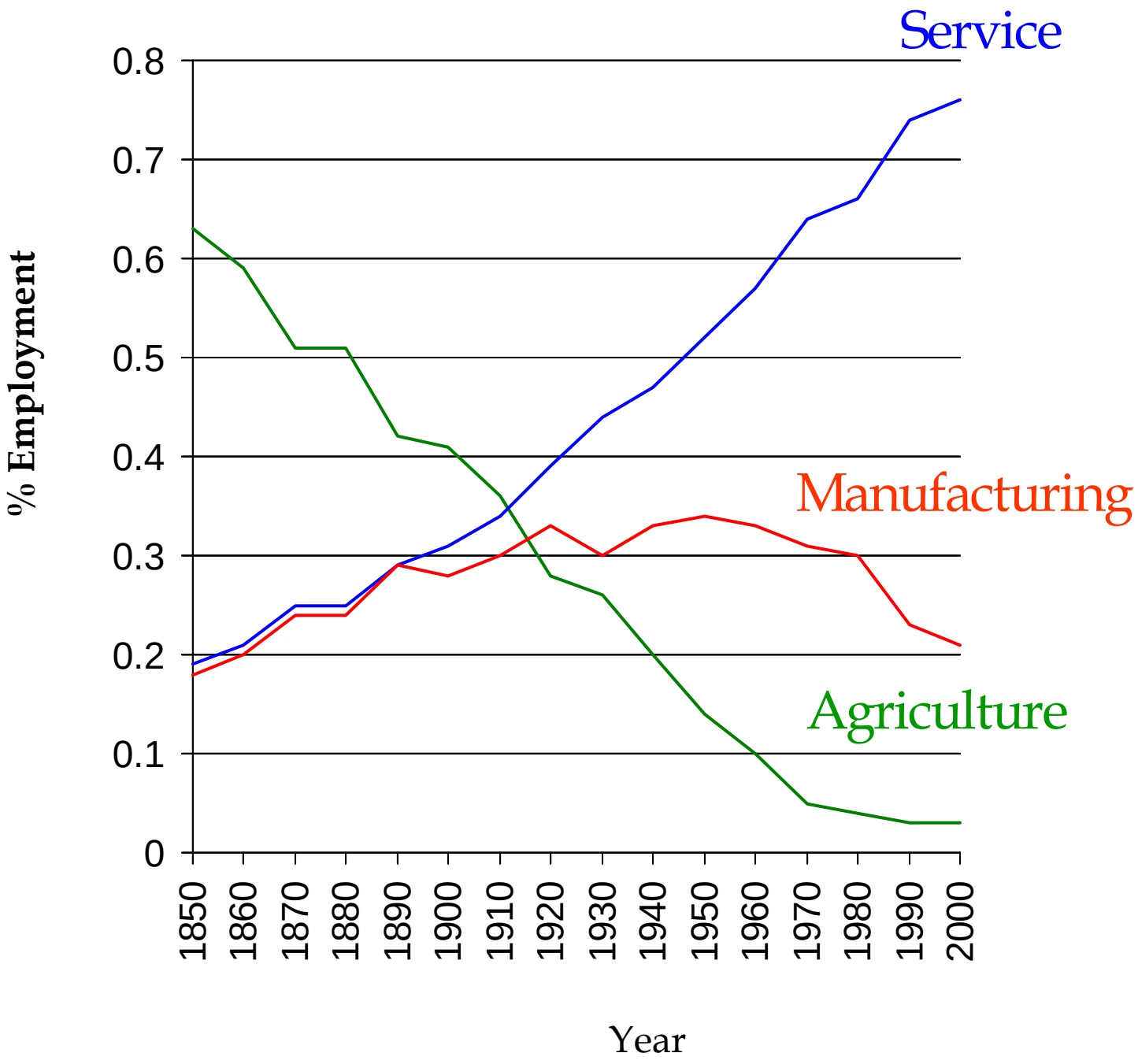
- *Introduction to Service Engineering and Management.* Ample examples are described, based on my experience in project-supervision and consulting, with an emphasis on the practical significance of basic theoretical research. The examples are mainly of congestion-prone service networks, in particular their measurements, time-varying behavior, and the controllable drivers of delay-queues (synchronization gaps, scarce resources).

- *Service-driven Theory.* Successful service analysis and management must often be multi-disciplinary, fusing ingredients from Operations Research, Statistics, Industrial Engineering, Sociology, Psychology, Game Theory, Economics, Management Information Systems, and even more. In this part, theoretical examples are surveyed that support design/engineering (for example pooling of service components), control (for example skills-based-routing to match demand with supply) and management (for example staffing scenarios.)

- *Tele-services and Call/Contact Centers.* This part deals with telephone call centers, or more broadly contact centers. Of importance is on the interface between human and operational aspects, most notably customers' impatience. For example, I have been seeking to characterize and measure human patience while waiting in phantom (invisible) queues. With the lessons learned, one could then incorporate patience into operational models and derive comprehensive performance measures.

The text in the sequel provides some background on Services and Stochastic Networks, followed by (my conception of) Service Engineering, more background on Call Centers and Tele-Nets, and finally a sample of some research projects.

Employment History: 1850 – 2000+



Services: Subjective Trends

- "Everything is Service"

Rather than buying a product, why not buy its service only?
For example, why setup and run a help-desk for technical support, with its costly fast-to-obsolete hardware, growing-sophisticated software, high-skilled peopleware and ever-expanding infoware, rather than let **outsourcing** do it all for you?

- Data; Technology and Humans; Limit Theorems

Far too little reliance on **data, the language of nature**, in formulating models for the systems of the deepest importance to human beings, namely those in which **we are actors**.
Systems with fixed rules, such as physical systems, can be relatively simple, whereas systems involving human beings expressing their microgoals … can exhibit incredible complexity; yet there is hope to devise tractable models through remarkable collective effects…
(Robert Herman, in "Reflection on Vehicular Traffic **Science**".)

- Fusion of Disciplines: POM, IT, HRM, Mkg

The highest challenge facing banks with respect to efficient and effective innovation lies in the "**New Age Industrial Engineer**" that must combine technological knowledge with process design in order to create the delivery system of the future.

(F. Frei, P. Harker, L. Hunter, in "Innovation in Retail Banking")

Service Engineering – a Subjective View

- Contrast with the traditional and prevalent

  Service Management (Business Schools; U.S.A.)

  Industrial Engineering (Engineering Schools; Europe)

- Goal: Develop scientifically-based design principles (rules-of-thumb) and tools (software) that support the balance of service quality, process efficiency and business profitability, from the (often conflicting) views of customers, servers and managers.

  - Theoretical Framework: Queueing Networks
  - Applications focus: Call (Contact) Centers

Example: Staffing - How many agents required for balancing service-quality with operational-efficiency.

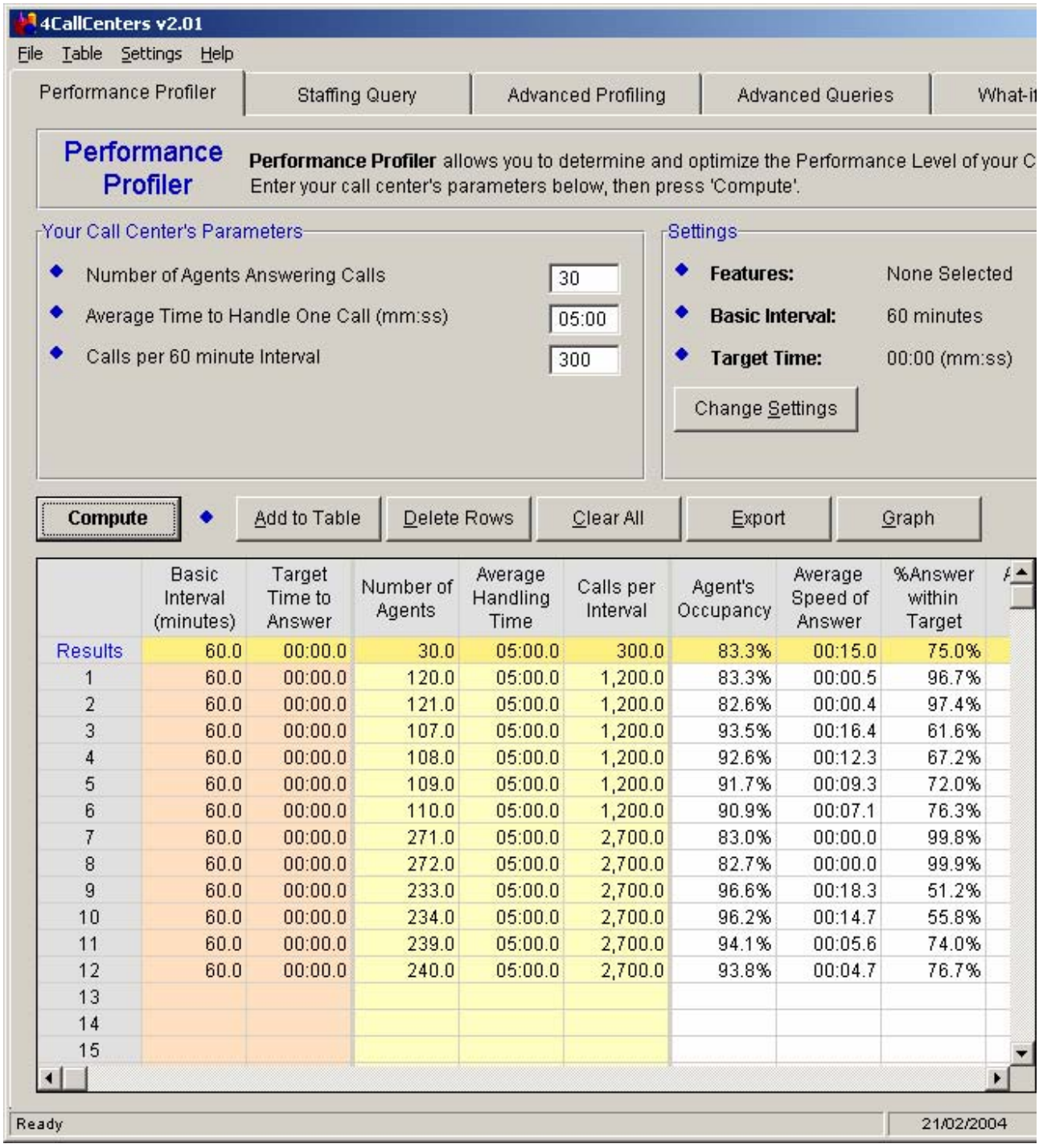
Example: Skills-Based Routing (SBR) – Platinum and Gold and Silver customers, all seeking Support or Purchase, via the Telephone or IVR or e.mail or Chat.

Example: Service Process Design + Staffing + SBR

Multi-Disciplinary: Typical (IE/OR, Marketing, CS, HRM)

4CallCenters

(Demo: Operational Regimes while Pooling)



	Basic Interval (minutes)	Target Time to Answer	Number of Agents	Average Handling Time	Calls per Interval	Agent's Occupancy	Average Speed of Answer	%Answer within Target
Results	60.0	00:00.0	30.0	05:00.0	300.0	83.3%	00:15.0	75.0%
1	60.0	00:00.0	120.0	05:00.0	1,200.0	83.3%	00:00.5	96.7%
2	60.0	00:00.0	121.0	05:00.0	1,200.0	82.6%	00:00.4	97.4%
3	60.0	00:00.0	107.0	05:00.0	1,200.0	93.5%	00:16.4	61.6%
4	60.0	00:00.0	108.0	05:00.0	1,200.0	92.6%	00:12.3	67.2%
5	60.0	00:00.0	109.0	05:00.0	1,200.0	91.7%	00:09.3	72.0%
6	60.0	00:00.0	110.0	05:00.0	1,200.0	90.9%	00:07.1	76.3%
7	60.0	00:00.0	271.0	05:00.0	2,700.0	83.0%	00:00.0	99.8%
8	60.0	00:00.0	272.0	05:00.0	2,700.0	82.7%	00:00.0	99.9%
9	60.0	00:00.0	233.0	05:00.0	2,700.0	96.6%	00:18.3	51.2%
10	60.0	00:00.0	234.0	05:00.0	2,700.0	96.2%	00:14.7	55.8%
11	60.0	00:00.0	239.0	05:00.0	2,700.0	94.1%	00:05.6	74.0%
12	60.0	00:00.0	240.0	05:00.0	2,700.0	93.8%	00:04.7	76.7%
13								
14								
15								

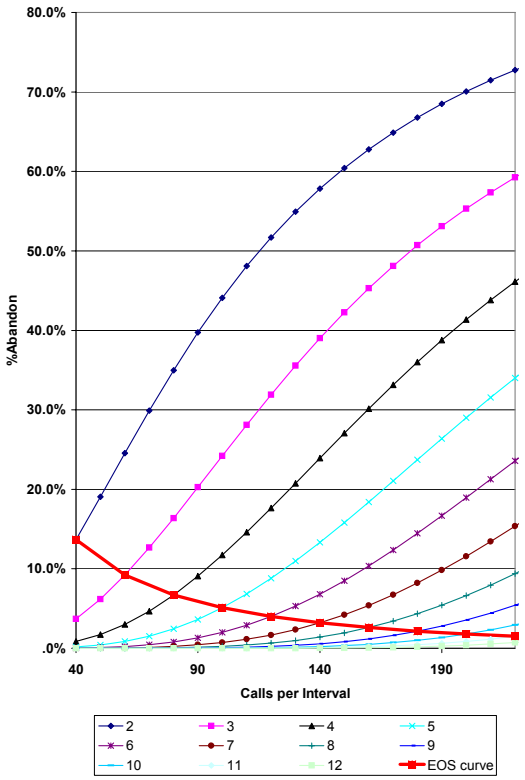
Advanced features of 4CallCenters

Advanced profiling

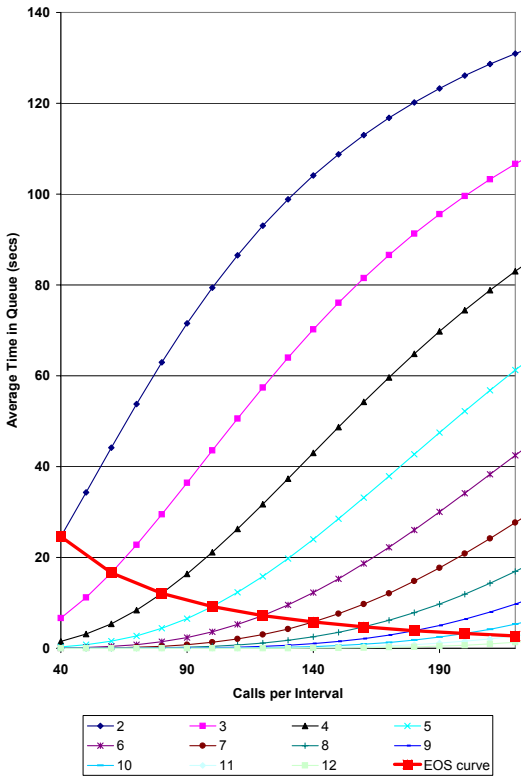
Vary input parameters of Erlang-A and display output (performance measures) in a table or graphically.

Example: $1/\mu = 2$ minutes, $1/\theta = 3$ minutes;
λ varies from 40 to 230 calls per hour, in steps of 10;
n varies from 2 to 12.

Probability to abandon



Average wait



Red curve: EOS (Economies-Of-Scale)

Tele-Nets: Call/Contact Centers

Scope	Examples	Perf. Meas.
Information (uni, bi-dir)	#411, Tele-pay, Help Desks	Avg. Delay > 0
Business	Tele-Banks, #800-Retail	Abandons, Econ % Wait > T
Emergency	Police #911	% Wait > 0
Mixed		Weighted
Info + Emerg.	Utility, City Halls	
Info + Bus.	Airlines	

Scale

- 10s to 1000s of agents in a "single" Call Center
- 3% of U.S. work force in call centers (several millions)
- 70% of total business transactions in call centers
- 20% growth rate of the call center industry
- Leading-edge technology, but 70% costs for "people"

Trends: THE interface for/with customers

- Beyond the classical quality vs. efficiency paradigm (Scale)
- Contact Centers (E-Commerce/Multimedia), outsourcing,…
- Retails outlets of 21-Century
- but also the Sweat-shops of the21-Century

(Typical) History of Call Centers at "Tele-Phone"

(http://ie.technion.ac.il/serveng/Lectures/MultiServer.pdf, on pages 28-31.)

- "Tele-Phone" "born" in the late 80's;
  Phone services by regular employees;

- First Call Center "born" in 1990, with 6 agents, via a single phone-number;

- Grew to 60 agents (10-15 per shift) in 1994, with 3 phone numbers for Service, Technical Support and Business.

- In 2003, employs well over 1000 agents, who work in about 10 interconnected call centers (few large, several small), with 300-400 agents handling calls at a peak hour.

[דוגמא: **תכן מוקד** (ראשית שנות ה-90)

* מצב קיים: 3 מספרים (טכני, חשבונות, כללי)

? מספר יחיד: השלכות

* לקוחות: עדיפות, סבלנות... **פסיכולוגיה**

פילוח **שיווק, סטטיס.**

* מוקדנים: גמיש לעומת מומחה **הנדסת תעשיה**

הכשרה, מיון, תמריצים... **משאבי אנוש**

* מערכת: איוש, משמרות, זימון... **חקר ביצועים**

ממשק לקוח-מוקדן-מערכת **מערכות מידע**

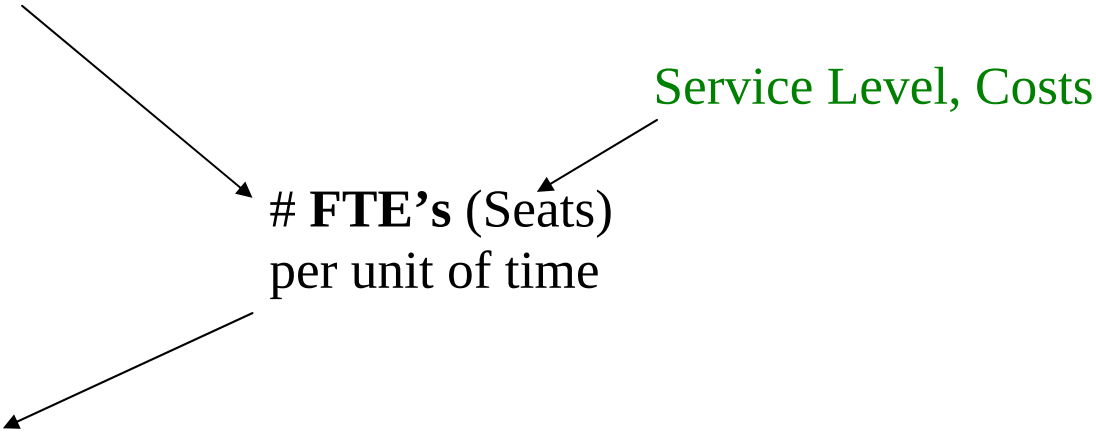
אולי חזית+עורף **רב תחומי**

מהי רמת שירות נאותה **רב תחומי**]

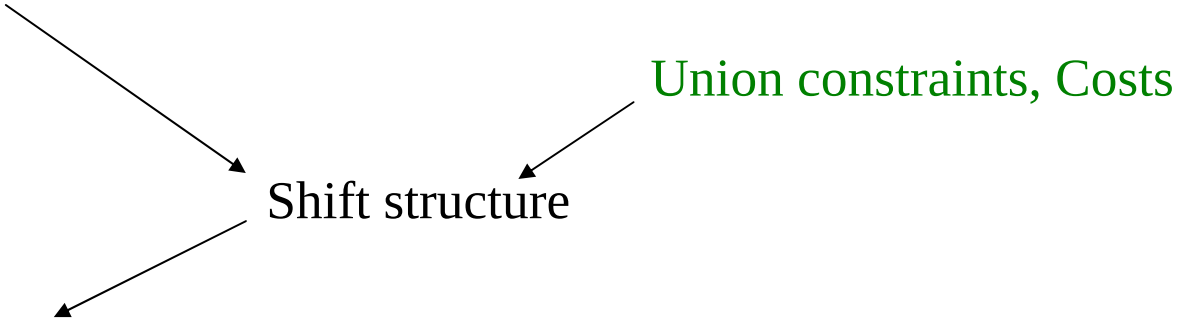
Workforce Management (WFM): Hierarchical Operational View

Forecasting Customers (Statistics), Agents (HRM)

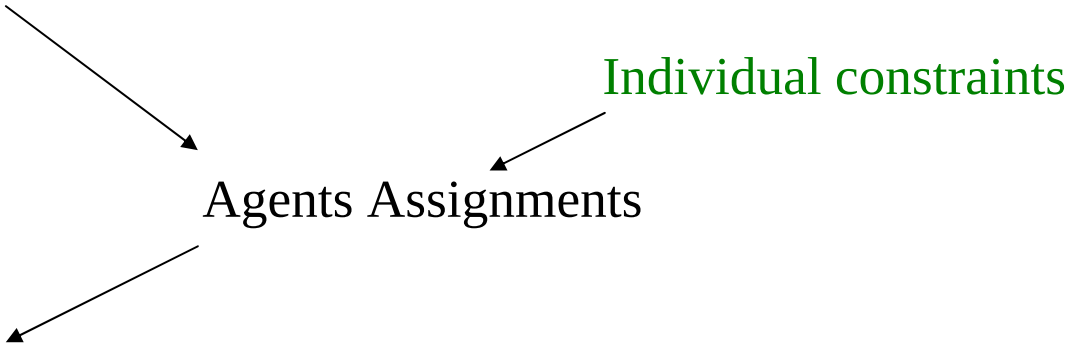
Staffing: Queueing Theory (M/M/N based)



Shifts: IP, Combinatorial Optimization; LP



Rostering: Heuristics, AI (Complex)



Skills-based Routing: Stochastic Control (of Q's)

Staffing (+SBR): How Many Agents?

- Fundamental problem in service operations / call centers:
  - People = 70% operating costs; 3% U.S. workforce.
  - HiTec Retail Outlets but also Sweat Shops of 21-Century

Reality

- Workforce Management (WFM) is Erlang-based (1913!)
- Reality is complex and becoming even more so
- Solutions are urgently needed
- Technology enables smart systems
- Theory lags significantly behind needs

$\Rightarrow$ Ad-hoc methods: heuristics, simulation-based

Research Progress is based on

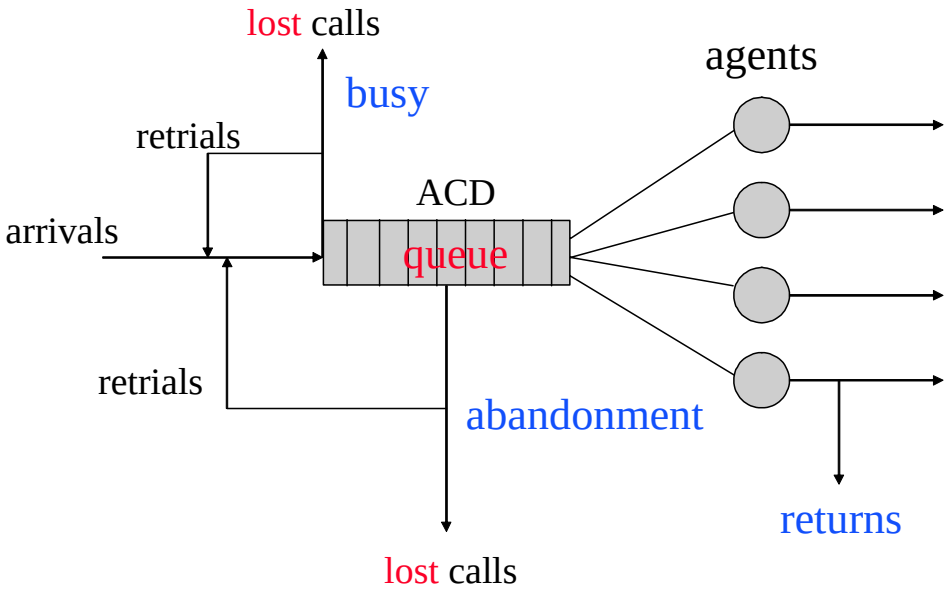
- Small yet significant models for theoretical insight

the analysis of which gives rise to

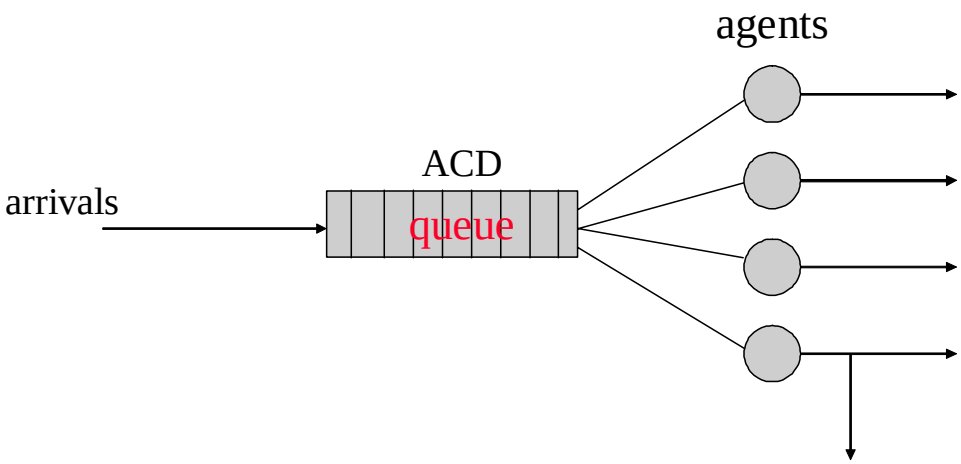
- Principles, Guidelines, Tools: Service Engineering

S

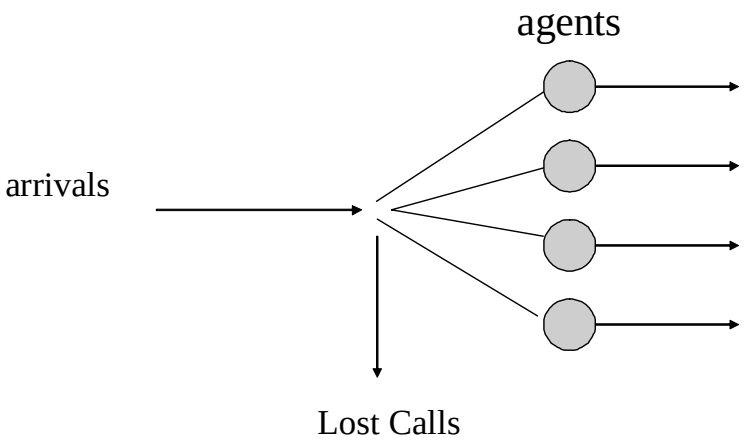
The Basic Call Center



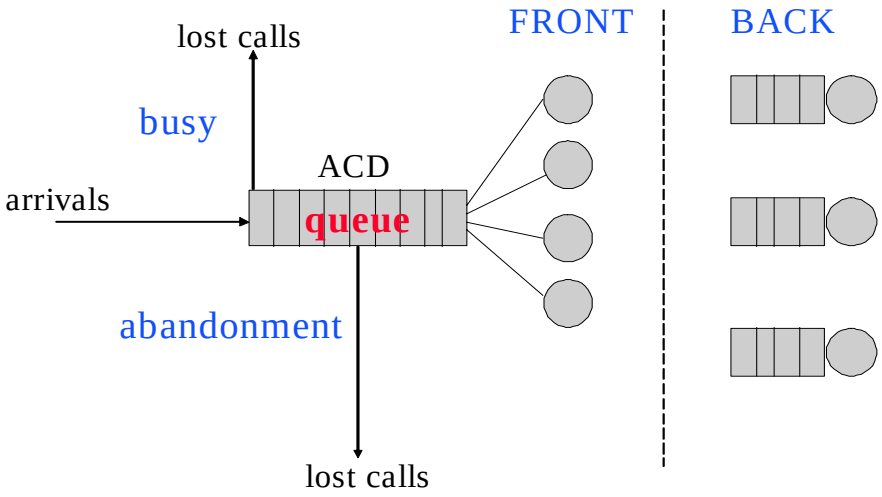
Erlang-C = M/M/N



Erlang-B



Erlang-A <4CallCenters>



Bottleneck Analysis: Short – Run Approximations
Time – State Dependent Q-Net

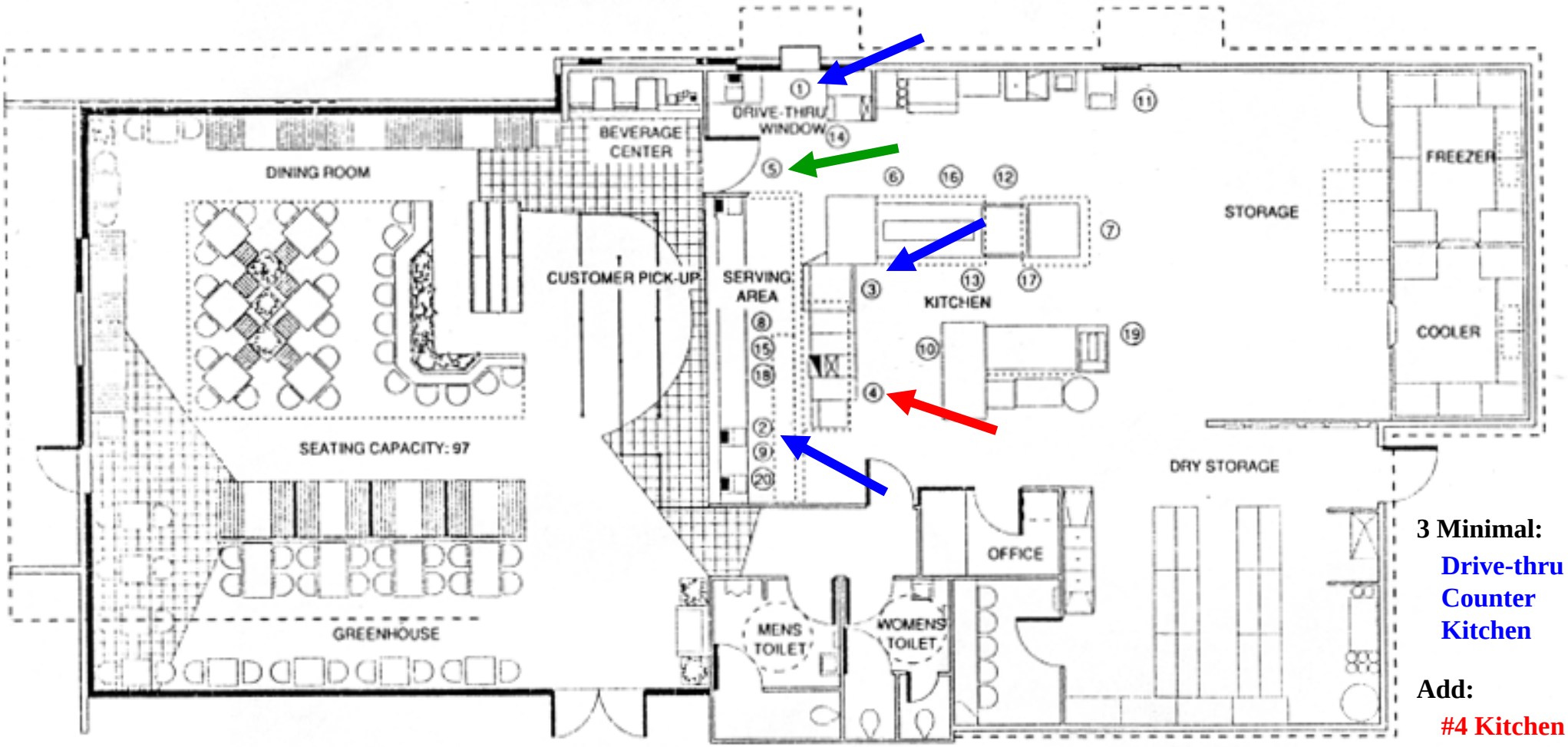


FIGURE F1 Layout of the Noblesville Burger King. The circled numbers indicate the sequence of additions of workers to the kitchen as demand increases.

3 Minimal:

- Drive-thru
- Counter
- Kitchen

Add:

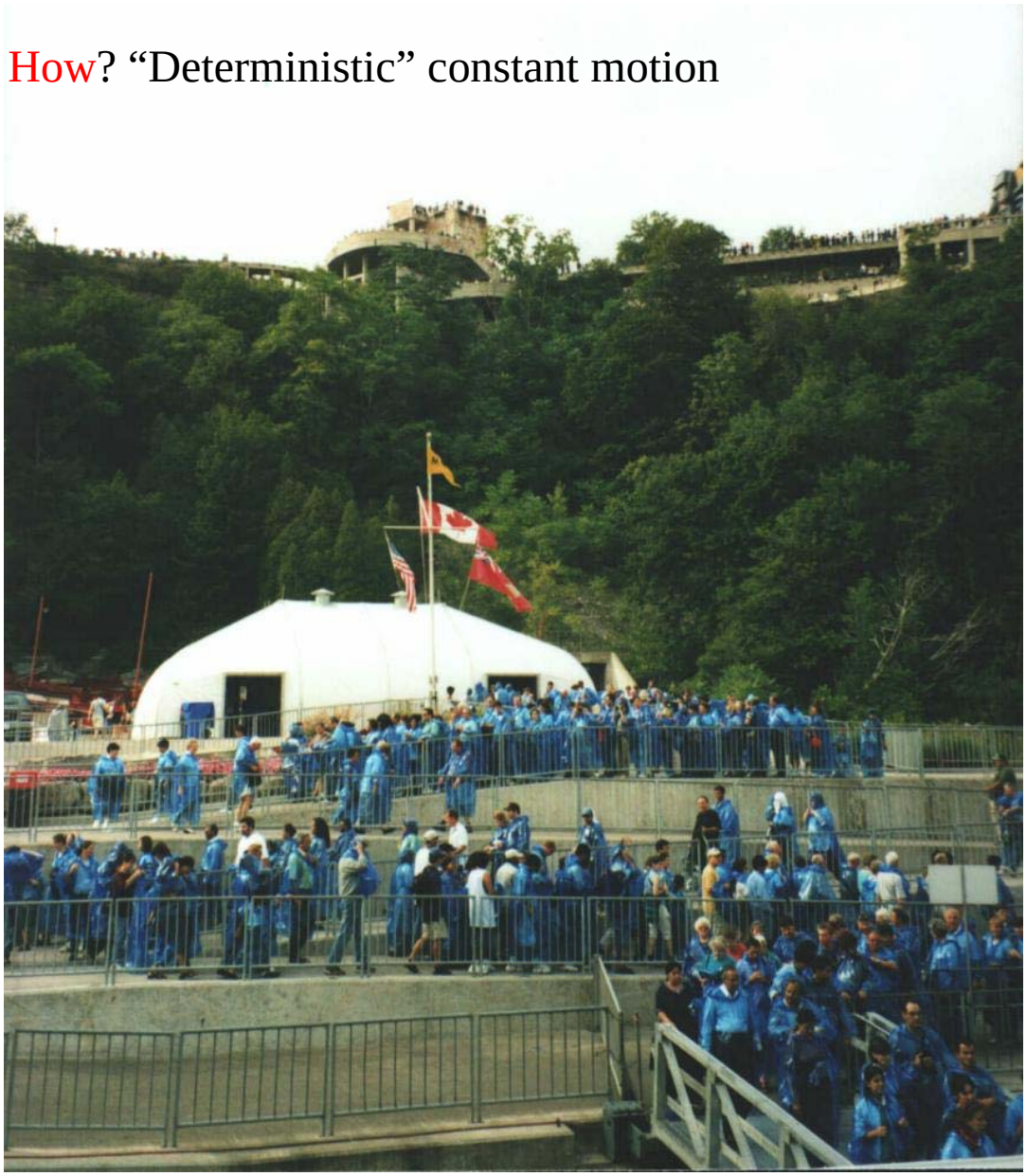
- #4 Kitchen
- #5 Help
  - Drive -thru

Labor-Day Queueing in Niagara Falls

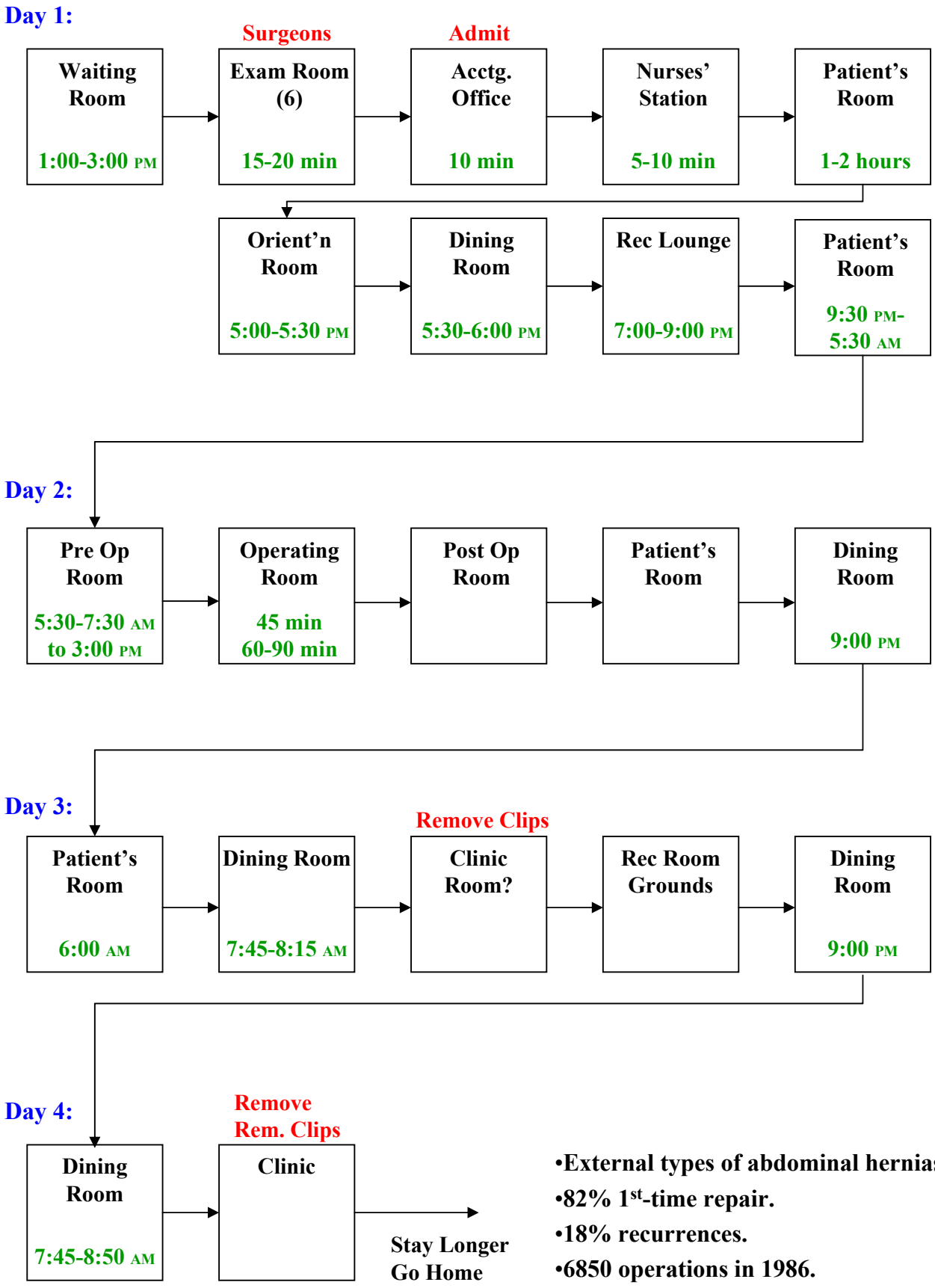
Three-station Tandem Network:
Elevators, Coats, Boats

Total wait of 15 minutes
from upper-right corner to boat

How? “Deterministic” constant motion



Shouldice Hospital: Flow Chart of Patients' Experience



- External types of abdominal hernias.
- 82% 1st-time repair.
- 18% recurrences.
- 6850 operations in 1986.
- **Recurrence rate: 0.8% vs. 10% Industry Standard.**

Customer Service and Support

A Passion to Delight

Our Guiding Principles: *Commitment, Passion, Learning, Integrity, Respect, Balance, Family, Fun and Service Excellence*

About Us

Customer Service and Support is an integral part of Bank of America, employing more than 9,500 highly skilled associates in contact centers located in twenty cities across the United States. These associates provide service and financial solutions to more than 130 million phone customers and 1.74 million e-mail customers each year, making our contact centers among the busiest in the country.

Customer Service and Support is working to build a world-class customer service organization. The nine guiding principles listed above and the Bank of America Spirit provide the foundation for our daily work routine. Our associates are brand ambassadors whose hard work and determination will be the driving force behind our goal to make Bank of America the most admired company in the world.

Customer Service and Support is focused on building better, stronger and deeper relationships with our customers. Our associates have a passion for reaching a Higher Standard, achieving results and winning for our customers. It is important to all of us that we strive to provide the highest level of service to ensure that all of our customers are "delighted" with their Bank of America experience.

Functional Scope Areas

Customer Service and Support

National Consumer Service Centers
- Consumer and Consumer Card
- Dealer Financial Services
- IBCC
- NDS
- Plus
- Prime

Associate Experience and Communications

Client Service and Support
- Associate Banking
- Commercial
- Merchant and Commercial Card Services
- Premier
- Small Business

Multicultural Services

Customer Service Process and Operations
- Resolution Services and Support

Risk Management

Customer Delight

Strategy and Marketing

Customer Contact Management

Factoids:

Annualized

Customer Calls Received by VRU in 2002 ……..……508,500,000

Customer Calls Handled by VRU in 2002 ……503,500,000

Customer Calls Offered to Associates in 2002 ……..147,000,000

Customer Calls Handled by Associates in 2002 ……...130,000,000

Avg. Speed to Answer……...96.54 secs

E-mails Received in 2002……..1,750,000

E-mails Processed in 2002……1,740,000

2002 Customer Delight……..54.3%

Certified Green Belts through 3/03……203

Certified Black Belts through 3/03……...2

Associate Satisfaction in 2002 ..…….. 72%

Associate Retention in 2002……..…….. 78%

2003 Performance Plan

Bank of America Vision:
Be recognized as the world's most admired company

Customer Service and Support Vision:
A Passion to Delight

To reach our goal of being the world's most admired company, we must do the following:

- Execute on our Hoshin Plan
- Live the Bank of America Spirit
- Communicate accurately and consistently
- Execute reliable, repeatable, consistent processes
- Focus on delivering world-class service for our customers

The focus for 2003 is: 65 / 75 / 64

- **65%** Customer Delight
- **75%** Associate Delight
- **$64** million in productivity benefits (Shareholder Delight)

Command Center Intraday Report

Date
06/13 - Tue

Updated Through: All Day

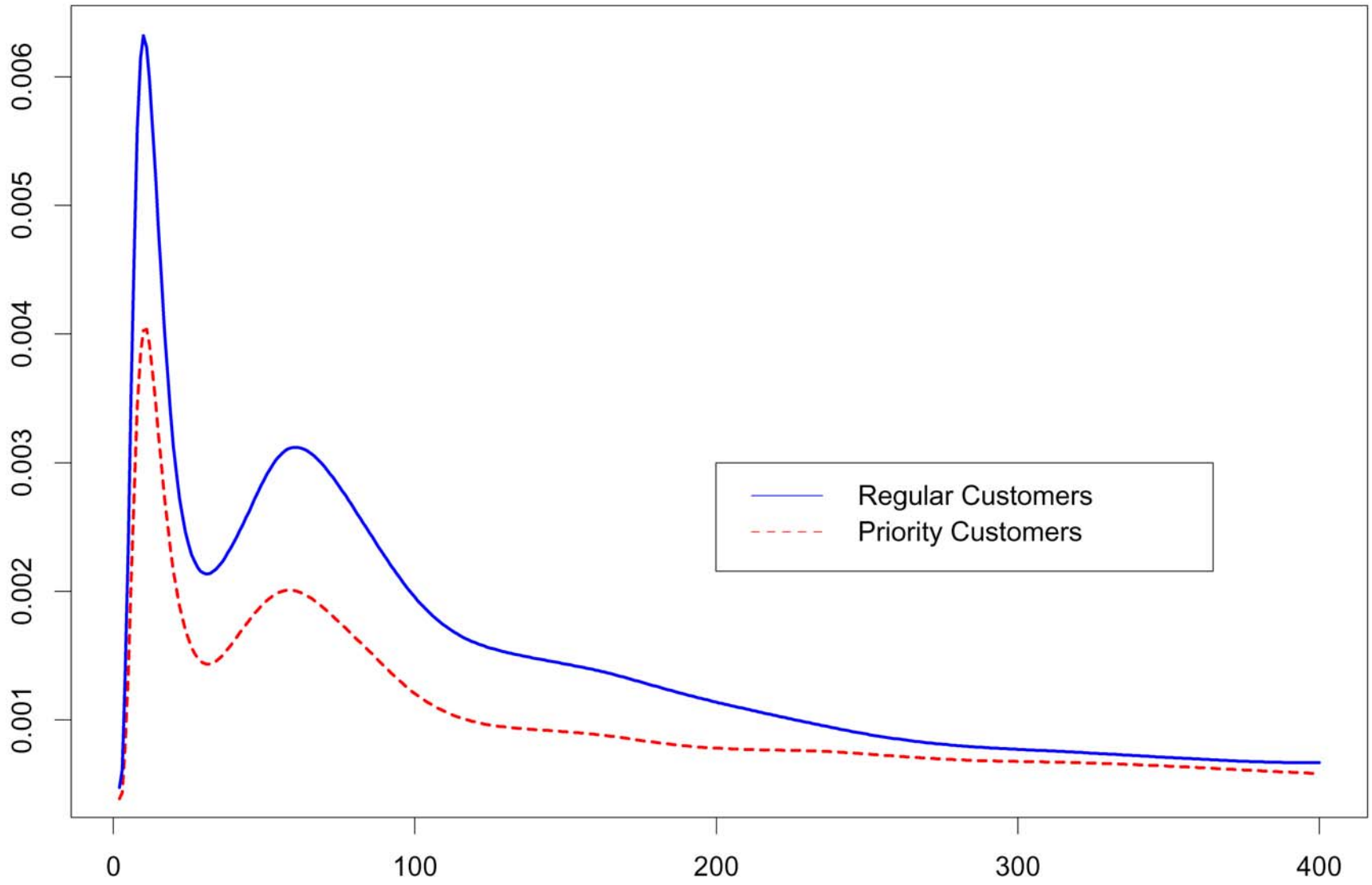
		Recvd	Answ	Abn %	ASA	AHT	Occ %	On Prod%	On Prod FTE	Sch Open FTE	Sch Avail %
	Total:	**129,960**	**126,321**	**2.8%**	**31**	**318**	**90.9%**	**88.4%**	**1531.7**	**1585.0**	**96.6%**
INQ	Charlotte	20,577	19,860	3.5%	30	307	95.1%	85.4%	222.7	234.6	95.0%
INQ	Columbus MCSC	7,973	7,773	2.5%	36	314	94.9%	89.8%	89.2	94.5	94.4%
INQ	Phoenix	17,102	16,757	2.0%	31	298	92.7%	91.8%	187.3	194.8	96.2%
INQ	Scranton	1,257	1,254	0.2%	6	515	78.6%	28.9%	28.5	35.1	81.2%
INQ	Tampa	9,174	8,859	3.4%	42	366	91.5%	93.6%	123.1	125.9	97.8%
CEN	Bourbonnais	6,070	5,937	2.2%	33	362	86.7%	90.2%	86.0	88.4	97.3%
CEN	Bristol	10,667	10,505	1.5%	25	355	95.1%	93.1%	136.3	139.6	97.6%
CEN	Columbus Claims	5,258	5,153	2.0%	27	293	86.7%	89.8%	60.5	62.2	97.3%
STH	Atlanta	7,514	7,338	2.3%	40	318	82.1%	89.5%	98.6	99.8	98.8%
STH	Sherman	19,669	18,833	4.3%	46	252	93.8%	90.6%	175.5	174.9	100.4%
STH	Wilmington	10,422	9,888	5.1%	21	285	89.9%	92.1%	108.7	114.6	94.8%
WST	Visalia	14,277	14,164	0.8%	10	382	87.2%	85.0%	215.2	220.6	97.6%

12 cc's

6/13/00 - Tue

[redacted] - Center

Time	Recvd	Answ	Abn %	ASA	AHT	Occ %	On Prod%	On Prod FTE	Sch Open FTE	Sch Avail %
0	**20,577**	**19,860**	**3.5%**	**30**	**307**	**95.1%**	**85.4%**	**222.7**	**234.6**	**95.0%**
8:00	332	308	7.2%	27	302	87.1%	79.5%	59.3	66.9	88.5%
8:30	653	615	5.8%	58	293	96.1%	81.1%	104.1	111.7	93.2%
9:00	866	796	8.1%	63	308	97.1%	84.7%	140.4	145.3	96.6%
9:30	1,152	1,138	1.2%	28	303	90.8%	81.6%	211.1	221.3	95.4%
10:00	1,330	1,286	3.3%	22	307	98.4%	84.3%	223.1	229.0	97.4%
10:30	1,364	1,338	1.9%	33	296	99.0%	84.1%	222.5	227.9	97.6%
11:00	1,380	1,280	7.2%	34	306	98.2%	84.0%	222.0	223.9	99.2%
11:30	1,272	1,247	2.0%	44	298	94.6%	82.8%	218.0	233.2	93.5%
12:00	1,179	1,177	0.2%	1	306	91.6%	88.6%	218.3	222.5	98.1%
12:30	1,174	1,160	1.2%	10	302	95.5%	93.6%	203.8	209.8	97.1%
13:00	1,018	999	1.9%	9	314	95.4%	91.2%	182.9	187.0	97.8%
13:30	1,061	961	9.4%	67	306	100.0%	88.9%	163.4	182.5	89.5%
14:00	1,173	1,082	7.8%	78	313	99.5%	85.7%	188.9	213.0	88.7%
14:30	1,212	1,179	2.7%	23	304	96.6%	86.0%	206.1	220.9	93.3%
15:00	1,137	1,122	1.3%	15	320	96.9%	83.5%	205.8	222.1	92.7%
15:30	1,169	1,137	2.7%	17	311	97.1%	84.6%	202.2	207.0	97.7%
16:00	1,107	1,059	4.3%	46	315	99.2%	79.4%	187.1	192.9	97.0%
16:30	914	892	2.4%	22	307	95.2%	81.8%	160.0	172.3	92.8%
17:00	615	615	0.0%	2	328	83.0%	93.6%	135.0	146.2	92.3%
17:30	420	420	0.0%	0	328	73.8%	95.4%	103.5	116.1	89.2%
18:00	49	49	0.0%	14	180	84.2%	89.1%	5.8	1.4	416.2%


Hazard Rate: Empirical (Im)Patience
0.001
0.002
0.003
0.004
0.005
0.006
0
100
200
300
400
Regular Customers
Priority Customers

TYCO: NOBODY BUYS AND BUILDS LIKE DENNIS KOZLOWSKI

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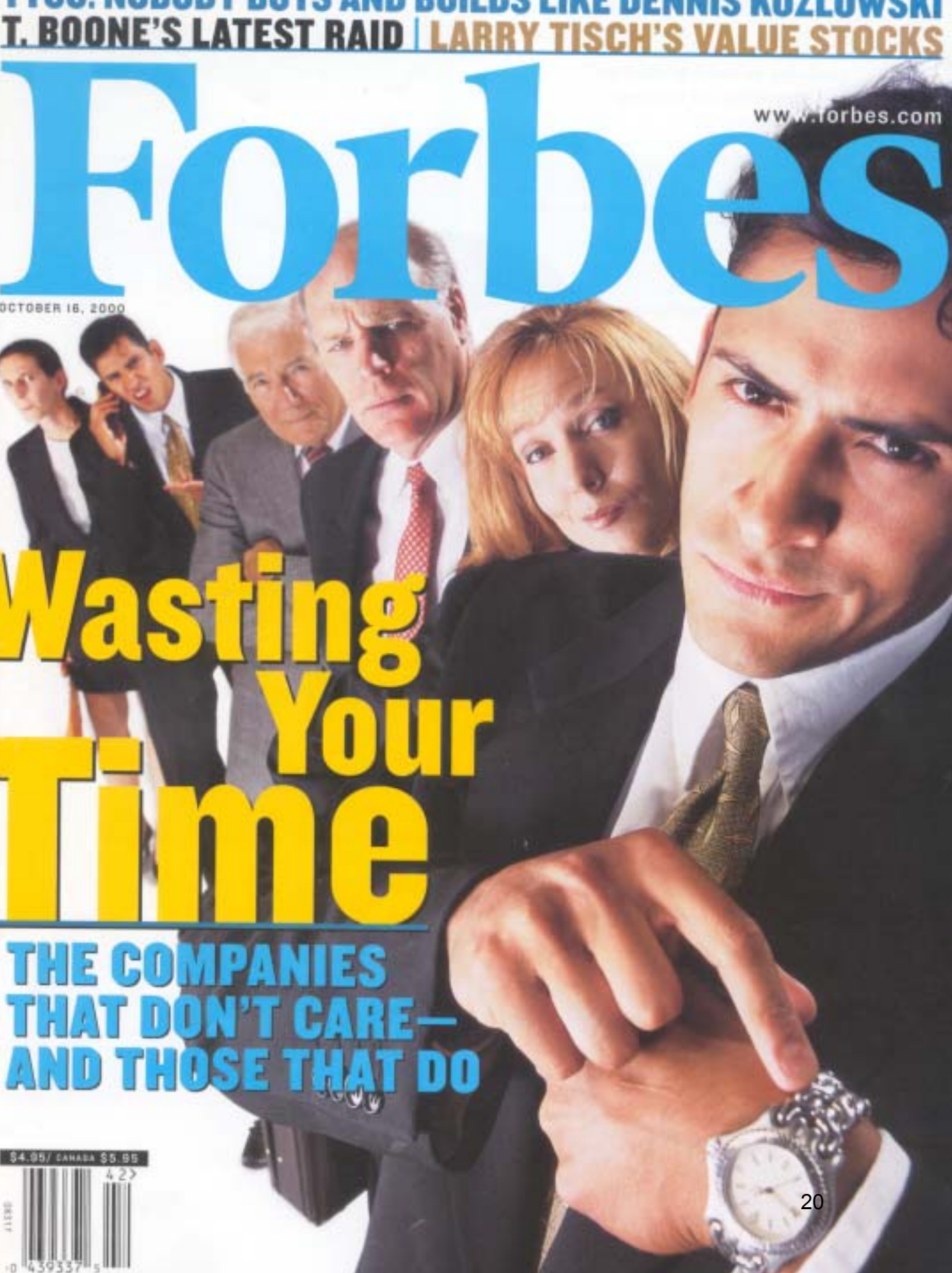


Wasting Your Time

THE COMPANIES THAT DON'T CARE— AND THOSE THAT DO

$4.95/ CANADA $5.95

42>

Service Networks = Queueing Networks

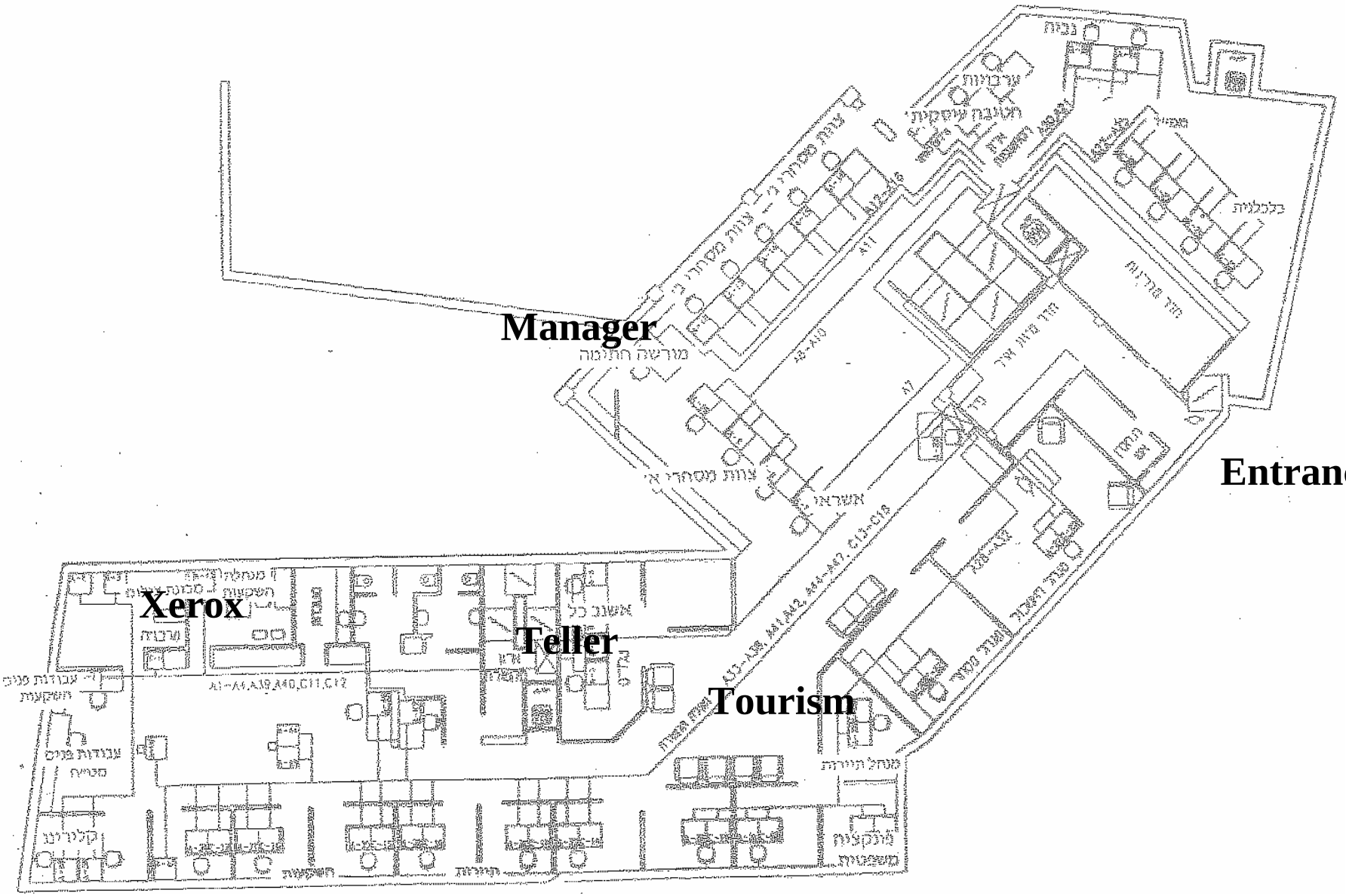
- People, waiting for service: teller, repairman, ATM
- Telephone-calls, to be answered: busy, music, info.
- Forms, to be sent, processed, printed; for a partner
- Projects, to be developed, approved, implemented
- Justice, to be made: pre-trial, hearing, retrial
- Ships, for a pilot, berth, unloading crew
- Patients, for an ambulance, emergency room, operation
- Cars, in rush hour, for parking
- Checks, waiting to be processed, cashed

- Queues Scarce Resources, Synchronization Gaps

  Costly, but here to stay

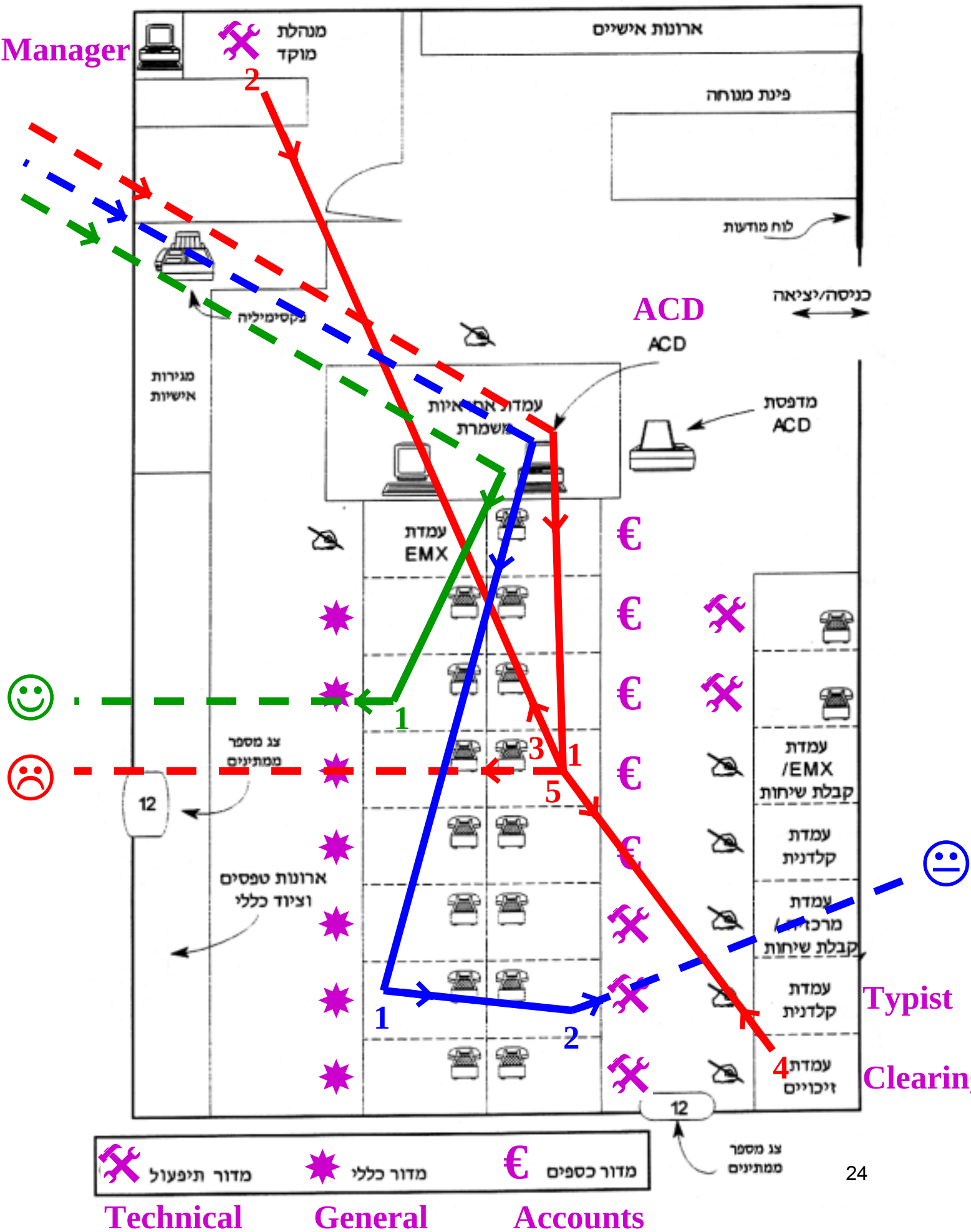
  - Face-to-face Nets (Chat) (min.)
  - Tele-to-tele Nets (Telephone) (sec.)
  - Administrative Nets (Letter-to-Letter) (days)
  - Fax, e.mail (hours)
  - Face-to-ATM, Tele-to-IVR
  - Mixed Networks (Contact Centers)

Bank – 2nd Floor Measurements

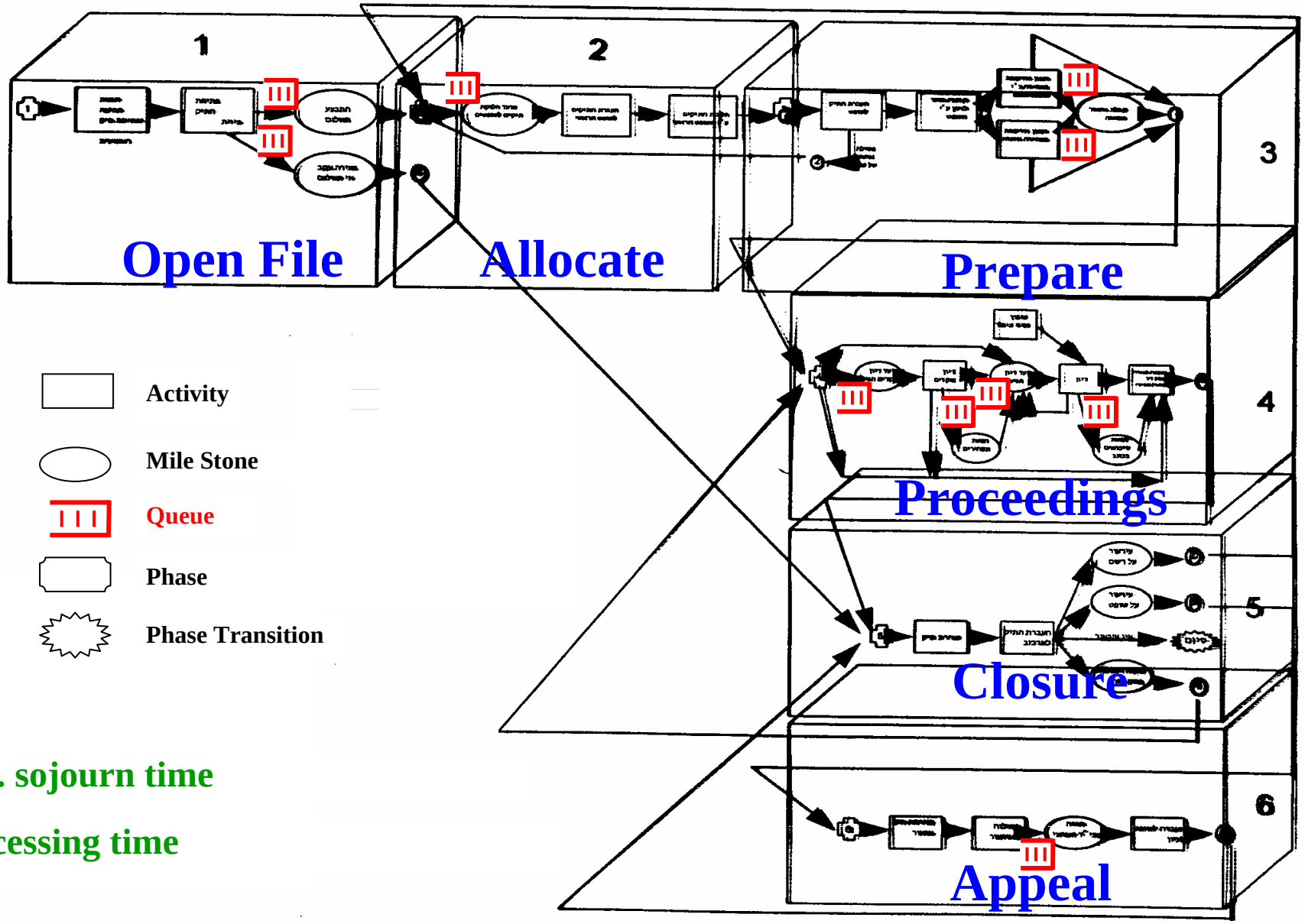


O1	O2	O3	O4	Clear

Schematic Chart – Pelephone Call-Center 1994
= Tele Net = Queueing Network



“Production” Of Justice

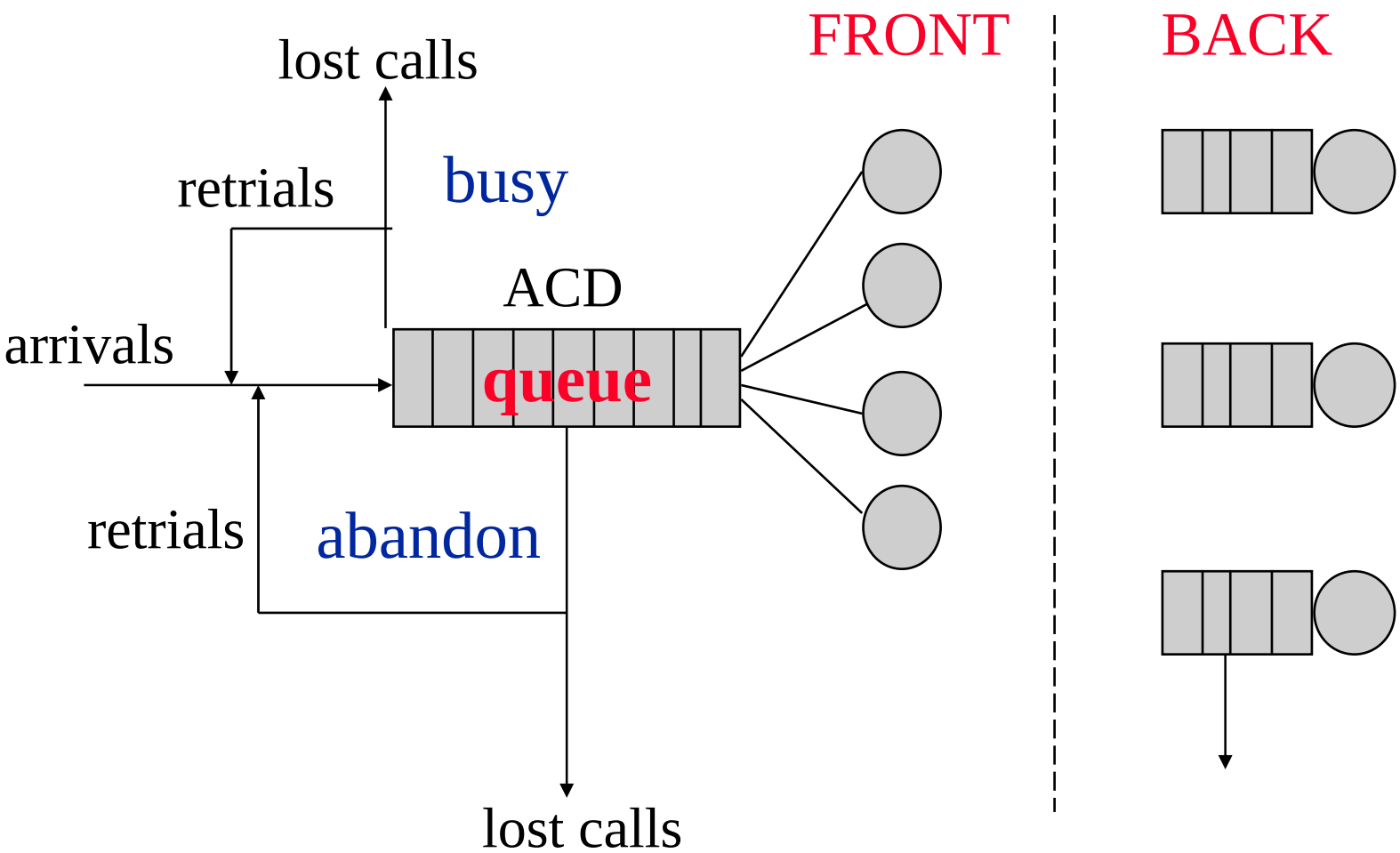


Avg. sojourn time

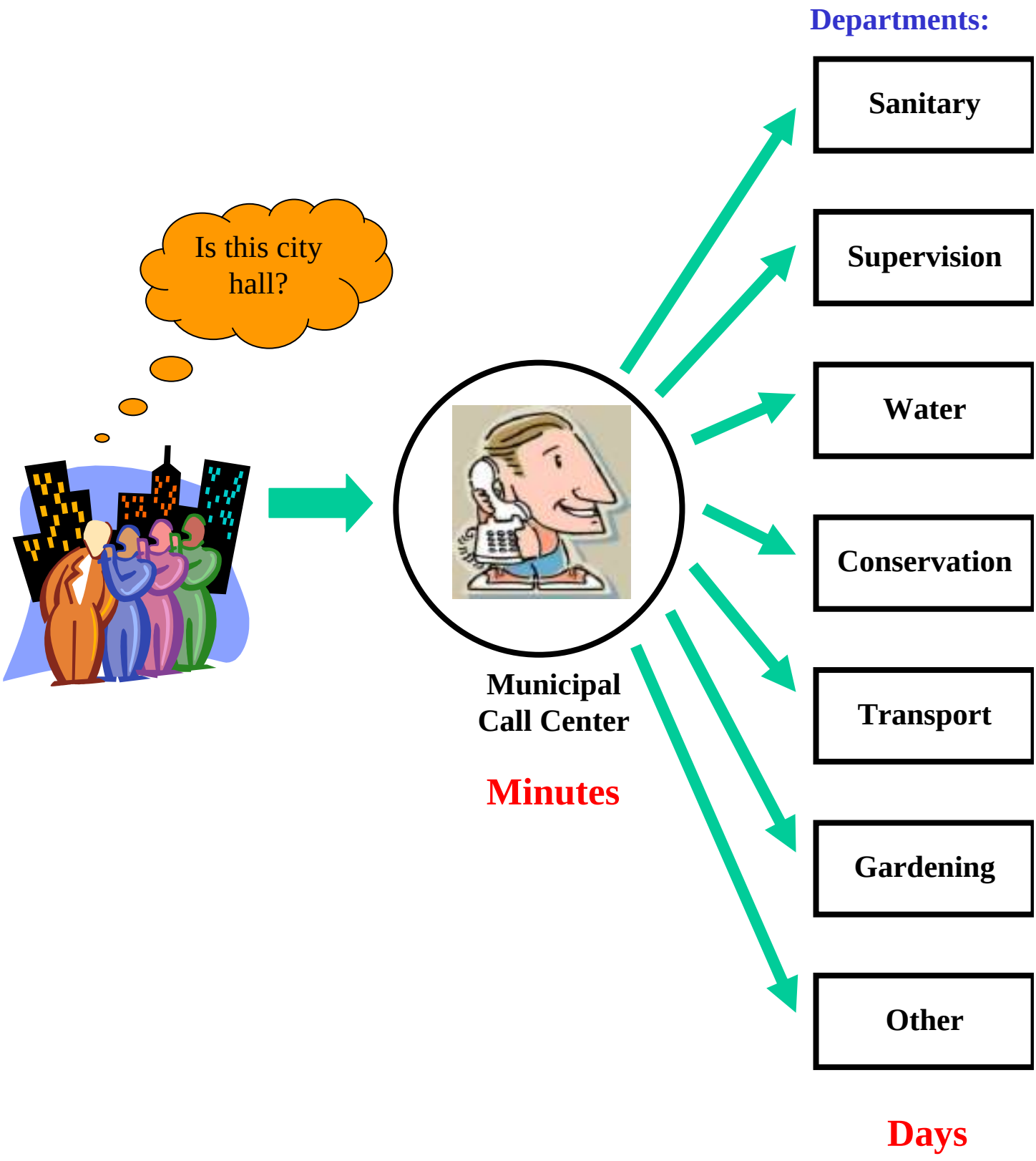
Processing time

O1 Clear

Telephone Network



Municipal Call Center
Emergency Handling



Challenge: Mixture of Emergency + Information

BONUS SUPPLEMENT: E-TAILING'S FUTURE

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OCTOBER 23, 2000

A PUBLICATION OF THE McGRAW-HILL COMPANIES

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The search for new business models

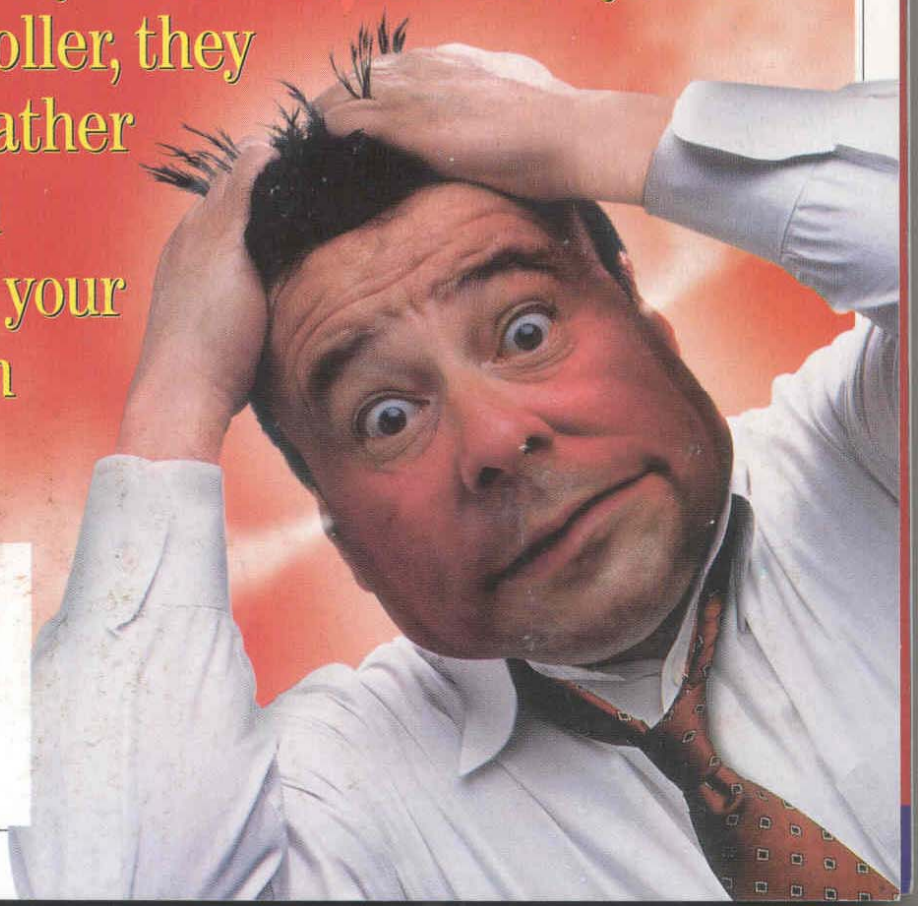
Managed Care

Employers seek a new solution

WHY SERVICE STINKS

Companies know just how good a customer you are—and unless you're a high roller, they would rather lose you than fix your problem

PAGE 118



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AOL Keyword: BW

Service Engineering
May 2000; Under Revision

An Introduction to Skills-Based Routing and its Operational Complexities

By Ofer Garnett and Avishai Mandelbaum

Technion, ISRAEL

(**Full** Version)

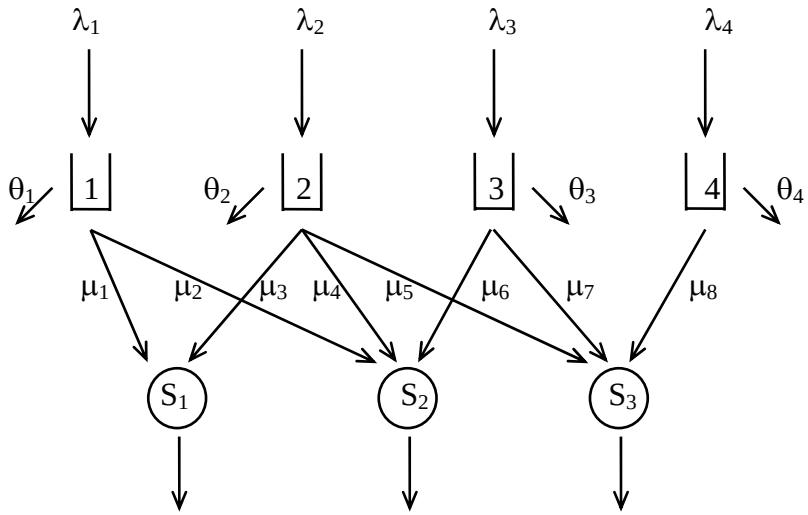
Contents:

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**

Acknowledgement: 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:

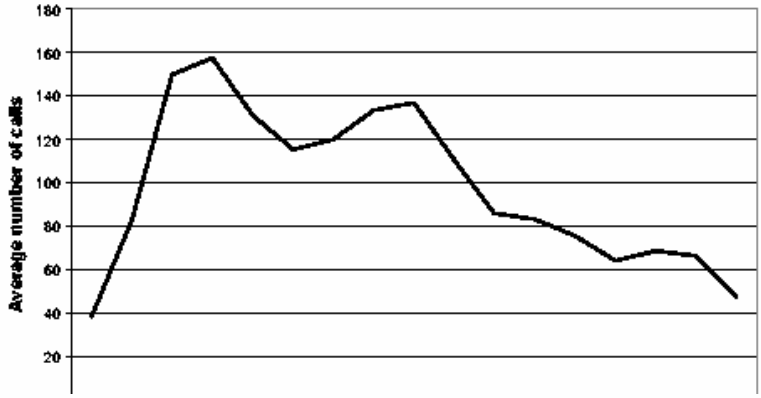
- **Queue**: "customer-type" requiring a specific type of service;
- **Server-Pool**: "skills" defining the service-types it can perform;
- **Arrow**: leading into a server-pool define its skills / constituency.

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

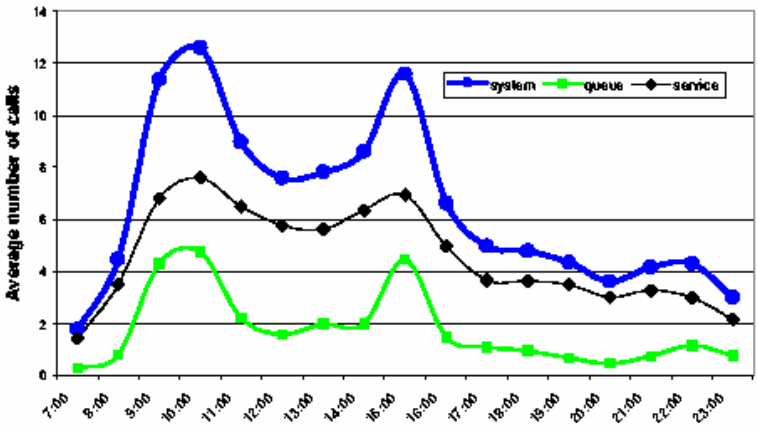
Customers of type 3 arrive randomly at rate λ_3 customers/hour, equipped with an impatience rate of θ_3.

Predictable Variability

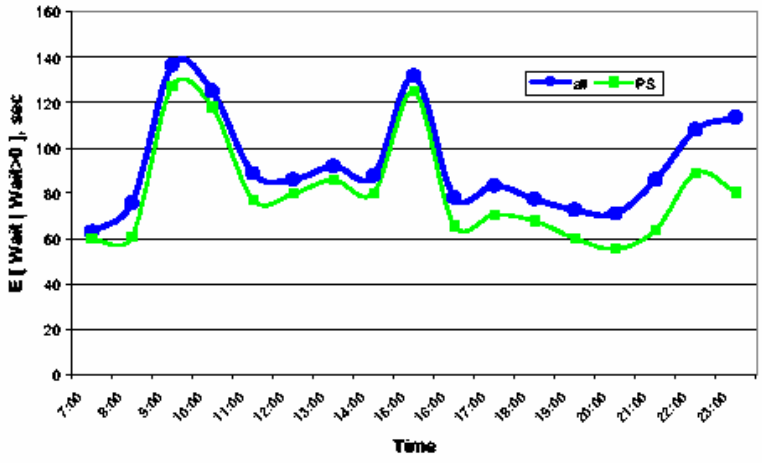
Arrivals



Queues



Waiting



Q-Science

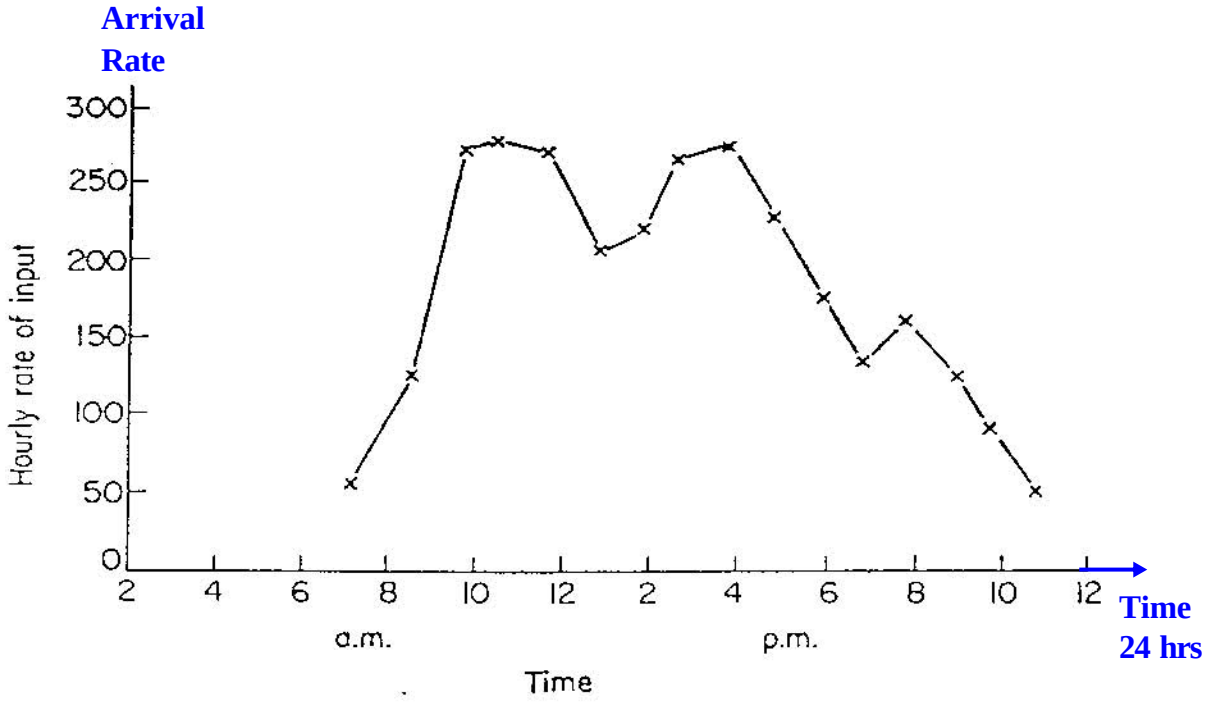
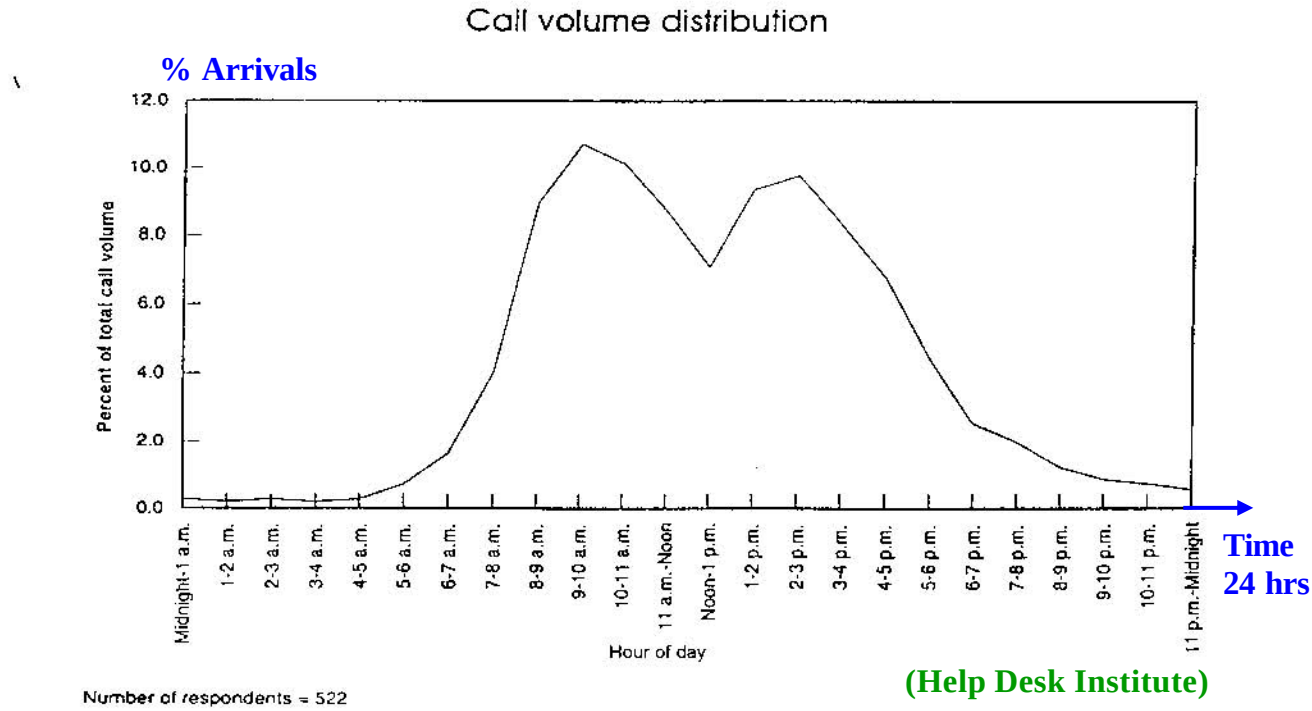


Fig. 15.1 The variation in the hourly input rates of reservations calls during a typical day (in May 1959)

(Lee A.M., Applied Q-Th)

1995 Help Desk and Customer Support Practices Report



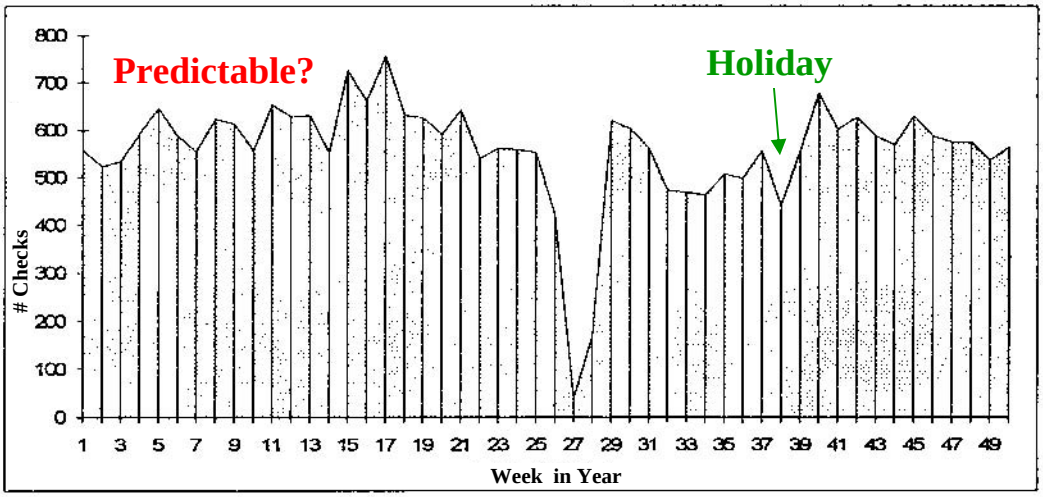
Number of respondents = 522

(Help Desk Institute)

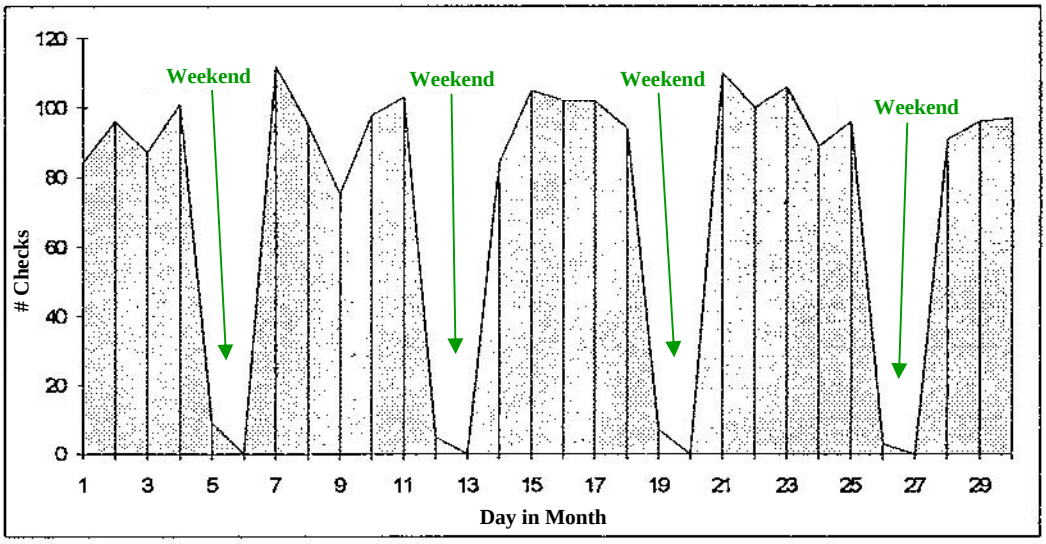
O1 Clear

Custom Inspections at an Airport

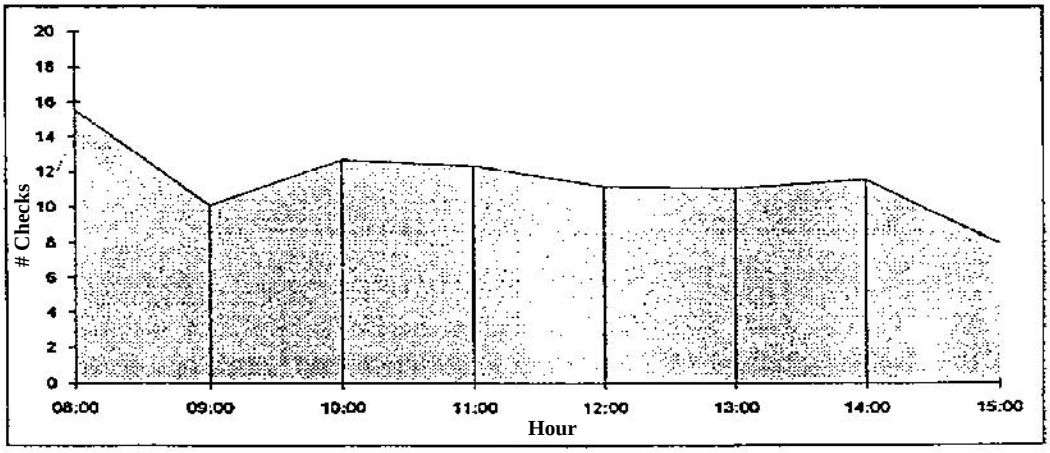
Number of Inspections Made During 1993:



Number of Inspections Made in November 1993:



Average Number of Inspections During the Day:



Source: Ben-Gurion Airport Custom Inspectors Division

O1 Clear

Why Only Now?

- History
  - Telephone - 1910 (Erlang, Palm)
  - Computers - 1960 (Moore, Kleinrock)
  - Transportation - 1960 (Newell)
  - Manufacturing - 1970 (Jackson, Solberg)
  - Communications - 1980,...

- Services
  - Research: academic, anecdotal
  - Public sector: monopoly, no resources
  - Management: vision, intuition
  - Attitude: customer neglect, we're experts
  - Technology: Telephone, ... ,Multimedia,...
  - Measurements
    - Why bother?
    - Time statistics scarce