Class 3

Measurements – The First Prerequisite

- Transaction-based (Event-based) measurement: Bank Tellers, Telephone, Internet, Transportation, Administrative.
- Towards Queueing Science.
- Summary statistics and simple tools: Pareto charts, Histograms, Fishbone diagrams, Scatterplots, ...
- The System's (Network) View.
- Some subtleties in Measurements: Patience; What is Service-Time (Duration) - Part I?
- Sample Size; Scales, Resolution, Aggregation.
- Hall – Measurements and MOP's (Chapter 2).

Modelling

- Flanders: important to recognize the existence of skeptics, useful to recruit influential opponents, and unethical to deny limitations.
- Larson: first example of a Dynamic Stochastic **Processing Network**: the AToA process; Further Examples: Research and Development, Software Development, Product Development (which has lead to DS-PERT/CPM and Multi-Project Management), QC (Quality Control) Labs in the Pharmaceutical and Biotechnology Industries.

Reading Assignments, on Measurements and Models, for next class:

The following two readings provide the basis for parts of **next** class's discussion. The subject is "The Two Prerequisites for our Course: Measurements and Models." Read the two articles. Then discuss, within your study group, the questions that follow.

- **Read** "Modelling court delay", by S. Flanders, *Law and Policy Quarterly*, 2, 305–320, 1980.
- Discuss within your study group answers to the following questions:
  F1. In the "Production process of Justice", who are the customers? Who are the servers?
  F2. What are the costs of delay? (It is often said that "Justice delayed is justice denied".) Who is paying?
  F3. Why is the justice process challenging (perhaps impossible) to model?
  F4. What are Flanders' alternatives to model-based analysis? Should they be alternatives or perhaps supplements?
  F5. On the last line of page 316, Flanders describes the "Profit and loss statement" of a judge. How can it be used to infer "processing times" of files? (See also Note 5.) Contemplate on the use of models to fill in data that is either missing or expensive to collect.
  F6. In any service system, performance record-holders are important to identify. Why? What is peak performance for judges? What constitutes an expert judge?
  F7. Understand the problems in dividing files into types. How can they be overcome, or at least simplified?
  F8. Why "Design and Scope of models must achieve a delicate balance"? (pg. 306).

0.1

- **Read** (carefully enough to be able to answer the questions that follow)
  "Improving the N.Y. City Arrest-to-Arraignment System", by R. Larson, *Interfaces*, 23, 76–96, 1993.

- Discuss within your study group answers to the following questions:
  L1. Understand the AtoA process, especially Figure 1. How does it differ from traditional PERT/CPM ? (Hint: stochastic, dynamic)
  L2. What are here the costs of delay? Supplement F2. above, if relevant.
  L3. Prove that, for any random variables $X_1, X_2, \ldots, X_i, \ldots$, we have:
  $E[Max_i X_i] >= Max_i E[X_i]$.
  When is an equality possible?
  Verify that the inequality applies to Figure 1 of Larson's article. (See also page 84 of "Improving the N.Y. City Arrest-to-Arraignment System", by R. Larson, *Interfaces*, 23, 76–96, 1993, which can be downloaded from the Related Material to Lecture 2 on the course site.)
  L4. What were the reasons for choosing Simulation? Spreadsheet?
  L5. Identify decisions at the strategic, tactical and operational level, in managing the AtoA process.

Recitation 3: Empirical Models.

HW 3:, "Empirical Models".

Reading Packets: *Measurements and Performance Measures*

- Larson, R., "Improving the N.Y. City Arrest-to-Arraignment System", *Interfaces*, 23, 76–96, 1993.

- Flanders, S., "Modeling court delay", *Law and Policy Quarterly*, 2, 305–320, 1980.

- Hall, Chapter 2, "Observations and Measurements", mainly Section 2.7 on Measurement Techniques.

- Kotha, S.K, Barnum, M.P. and Bowen, D.A., "KeyCorp Service Excellence Management System", *Interfaces*, 26, 54-74, 1966.

- "Empirical analysis of a call center", Mandelbaum, A., Sakov, A., Zeltyn, S., October 2000, in
  http://iew3.technion.ac.il/serveng/References/ccdata.pdf

- "Customer view of Internet service performance: measurement methodology and metrics", Cross-Industry Working Team, Sep. 1998, in **www.xiwt.org**:
  http://www.xiwt.org/documents/IPERF-paper.pdf

- F&F, Chapter 9, "The service encounter", mainly pages 258–265.
  A useful supplement on Work Measurements, mainly for non-I.E. students.

0,2

Service Engineering
http://ie.technion.ac.il/serveng200·

Measurements and MOP (Measures Of Performance)

Why Now? Why Measure?
Measurements - Some Empirical Axioms

Transaction-based (Event-based) Data; Time statistics

- Face-to-Face: The **T, C, S, I, F, O** methods.
- Telephone: ACD, CTI/CRM, Surveys.
- Internet: Log files.
- Transportation: The Hertzel-Balfur intersection.
- Administration: Project Management, Emergency Services, Government.
- Healthcare: Emergency Departments,...

Averages do NOT tell the whole story

The Systems/Network View

- Niagra Falls, A Bank, A Call Center.
- Networks: Decentralized Call Centers, Haifa City Hall, Shouldice Hospital.

Simple Tools: Pareto, Fishbone Diagrams, Histrograms. Sometimes enough, but often lead to the use of models and, moreover:

Subtleties: What is Service Time, Customers Patience (later)

Sample Size Matters

Scales; Frequencies of use; Model-based Database (eg. DATA MOCCA = Data Models for Call Center Analysis; Extansions to Healthcare, Internert,...)

The Fluid View: Introduction

Lord Kelvin said (roughly) the following: "We can not understand (do science with, manage) that which we can not measure (quantify)." Galileo Galilei adds: "Measure what can be measured, and make measurable what can not be measured." (Does this really apply when "measuring people"?) And Leonard Cohen sings in "The Future": Won't be nothing = Nothing you can measure anymore.

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

לענות בתוך שניות במוקד 166

אנו מתחייבים לענות ל-90% מהפניות תוך 10 שניות, כי גם אנחנו בבזק לא אוהבים להמתין בטלפון...

אנא המתן ותיענה

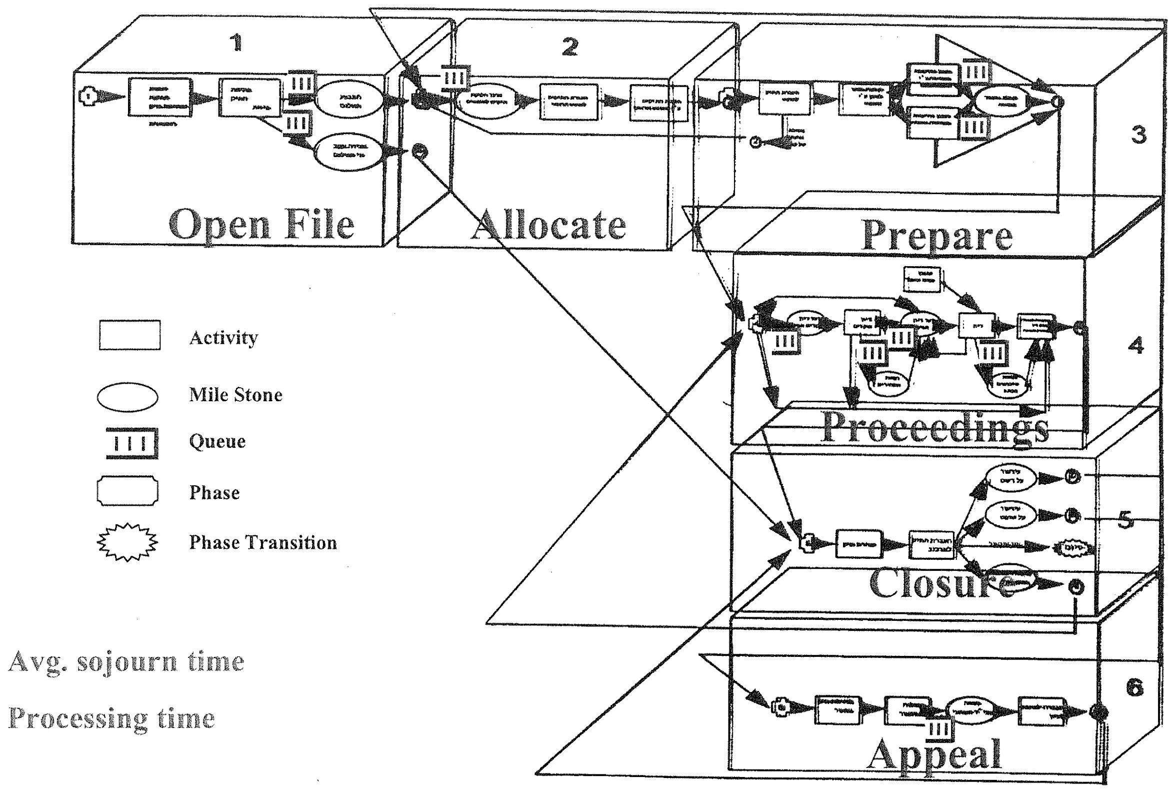
כמה זמן לוקח למשטרה, למד"א, לחברת החשמל, לעירייה, למשרד הפנים ולגופים אחרים שאנחנו זקוקים להם לענות לפניות הטלפוניות שלנו? ■ ואיך הם עונים? באדיבות, ברצון, עם מידע מדוייק, או באגרסיביות חסרת נימוס שנותנת לפונה תחושה שנותן השרות שונא אותו? ■ "שופינג" הקדיש כמה ימים ל... ה בן לטלפון

המימסד אינו עונה

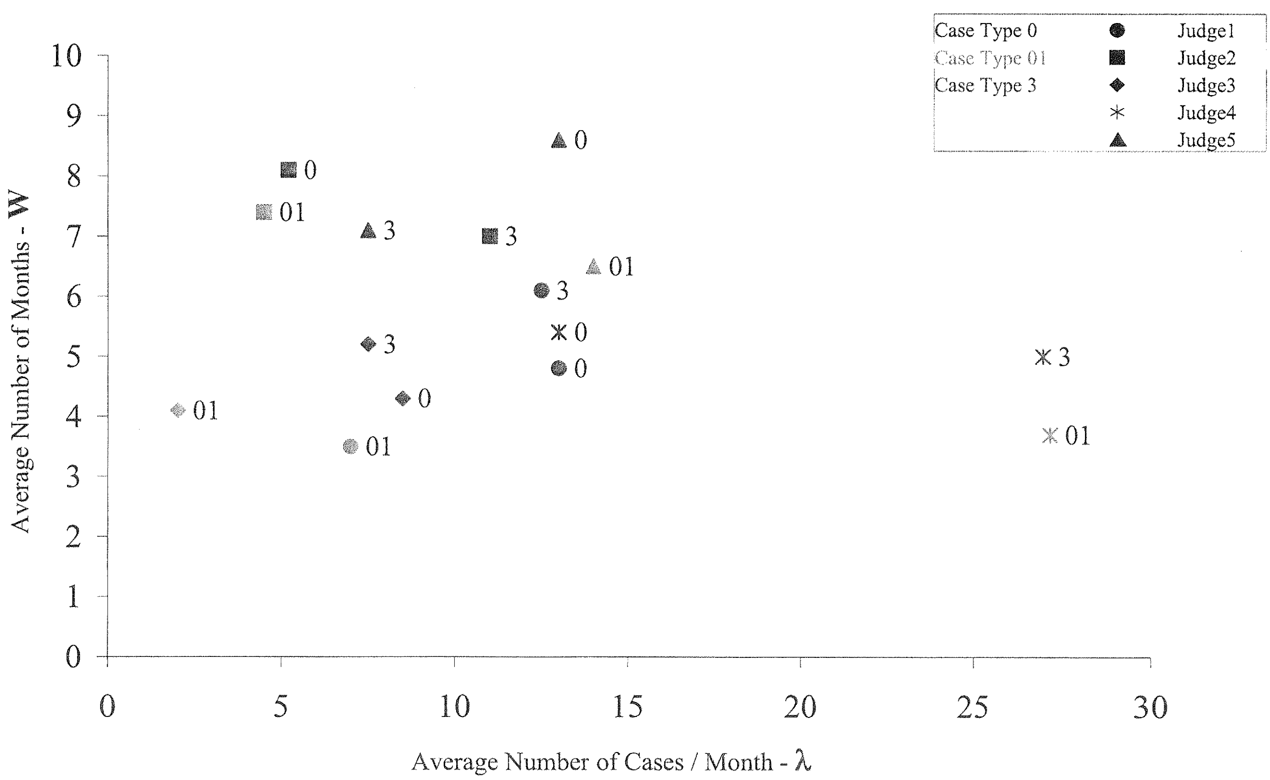
הנה רשימת מוסדות שלפני נסיונו, אין לך סיכוי לקבל בהם מענה. הטלפון מצלצל ומצלצל, או שזה תפוס לנצח.

נציב תלונות הציבור
משרד התקשורת, לשכת משרד השר בת"א
המשרד לקליטה ועליה מחוז ת"א
משרד הפנים מחוז ת"א
משרד התחבורה בת"א
משרד הרישוי בצפון ת"א
בתי הדין הרבניים
משרד השיכון והבינוי, ת"א
אחיות סיעודיות במשרד הבריאות
עובדות סוציאליות במשרד הבריאות

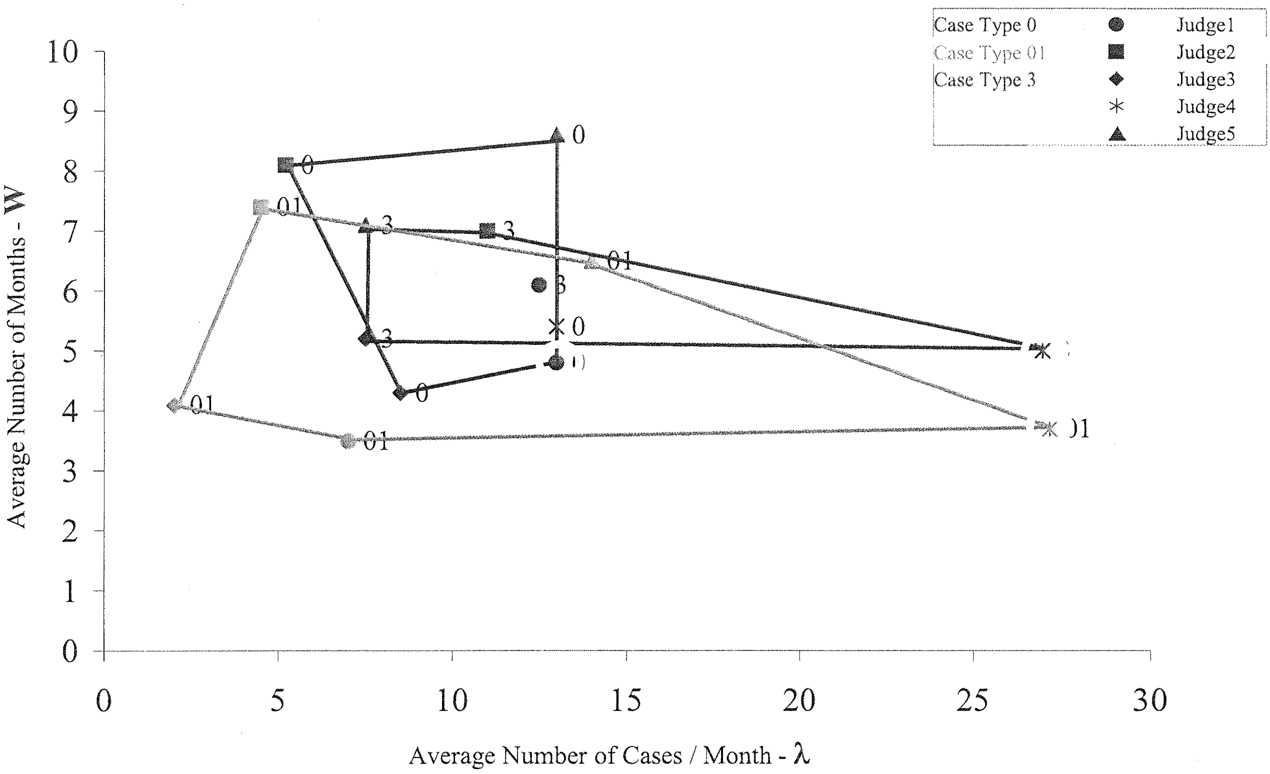
"Production" Of Justice



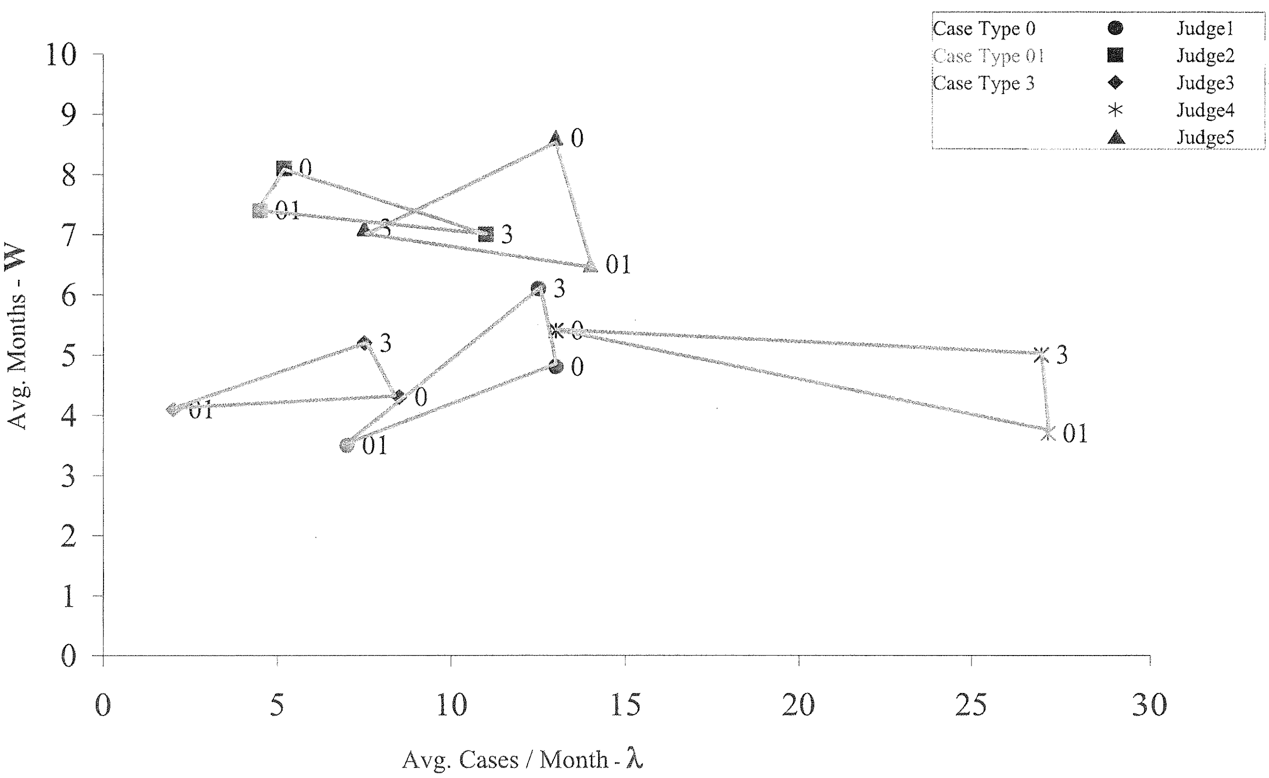
Judges: Operational Performance – Base Case



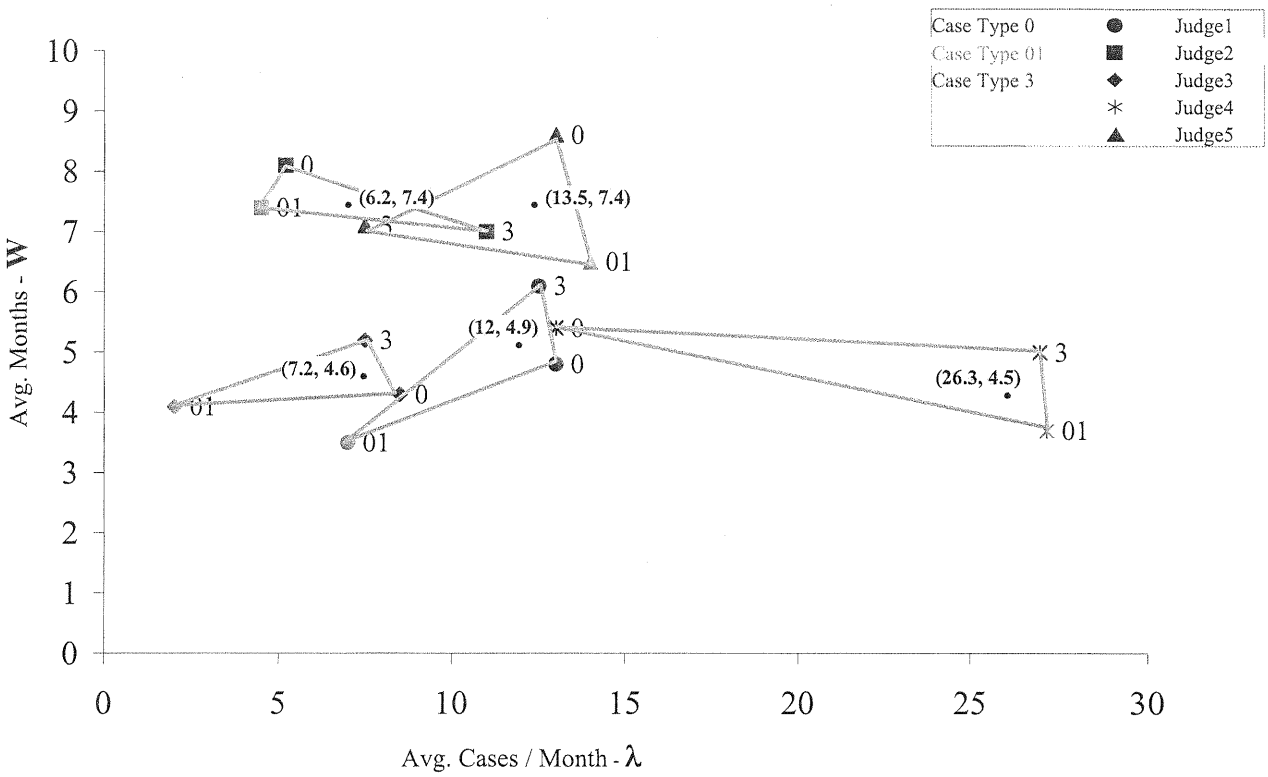
Judges: Performance by Case-Type



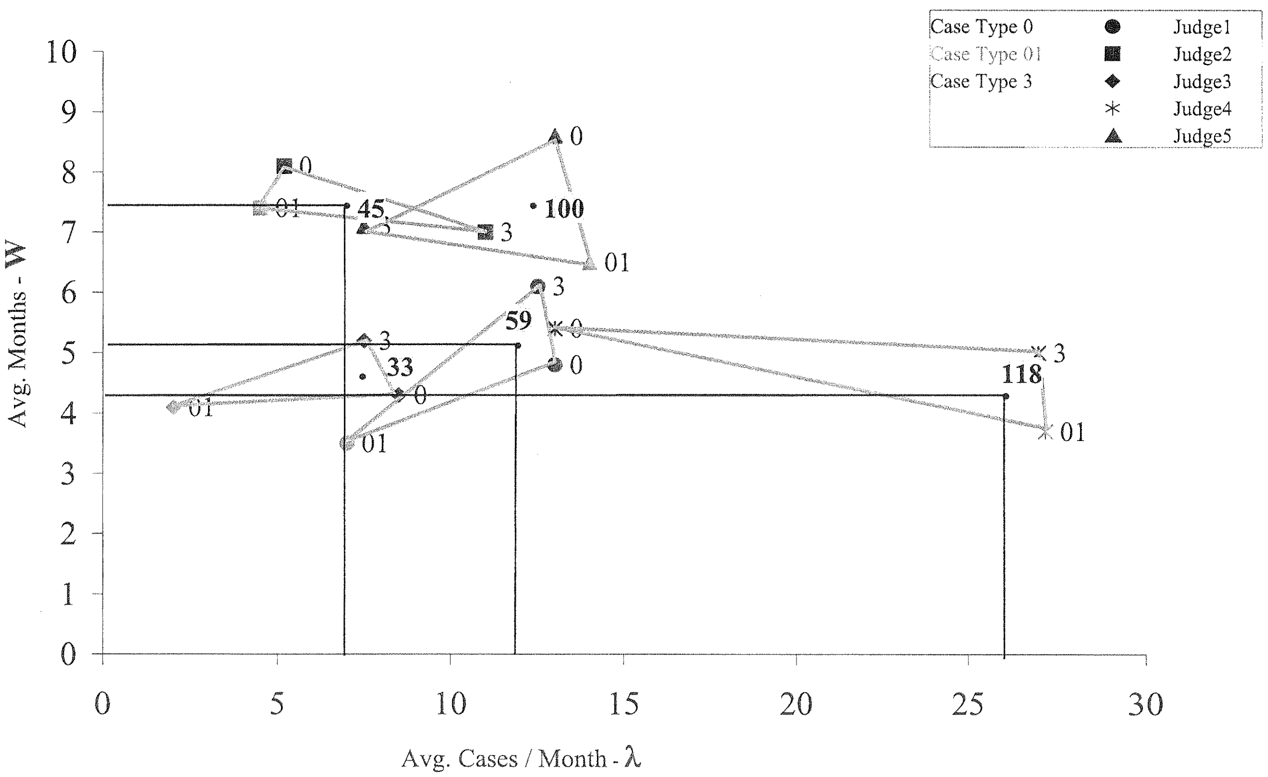
Judges: Performance Analysis



Judges: Performance Analysis



Judges: Performance Analysis



Service Engineering
http://ie.technion.ac.il/serveng200·

Call Center Measurements, Data Models and Data Analysis

Adapted from: **Telephone Call Centers: Tutorial, Review, and Research Prospects**

By Noah Gans (Wharton), Ger Koole (Vrije Universiteit) and Avishai Mandelbaum (Technion).
Published in Manufacturing and Service Operations Management (M&SOM), 5 (2), 2003;
downloadable from http://ie.technion.ac.il/serveng/References/CCReview.pdf

Abstract: Telephone call centers are an integral part of many businesses, and their economic role is significant and growing. They are also fascinating socio-technical systems in which the behavior of customers and employees is closely intertwined with physical performance measures. In these environments traditional operational models are of great value – and at the same time fundamentally limited – in their ability to characterize system performance.

We review the state of research on telephone call centers. We begin with a tutorial on how call centers function and proceed to survey academic research devoted to the management of their operations. We then outline important problems that have not been addressed and identify promising directions for future research.

1 Data Generation and Reporting

As it operates, a large call center generates vast amounts of data. Its IVR(s) and ACD are special-purpose computers that use data to mediate the flow of calls. (Acronyms are explained in the Appendix at the end.) Each time one of these switches takes an action, it records the call's identification number, the action taken, the elapsed time since the previous action, as well as other pieces of information. As a call winds its way through a call center, a large number of these records may be generated.

From these records, a detailed history of each call that enters the system can, in theory, be reconstructed: when it arrived; who was the caller; what actions the caller took in the IVR and how long each action took; whether and how long the caller waited in queue; whether and for how long a CSR served the call; who was the CSR. If the call center uses CTI, then additional data from the company's information systems may be included in the record: what the call was about; the types of actions taken by a CSR; related account information.

In practice, call centers have not typically stored or analyzed records of individual calls, however. This may be due, in part, to the historically high cost of maintaining adequately large databases – a large call center generates many gigabytes of call-by-call data each month – but clearly these quantities of data are no longer prohibitively expensive to store. It is also likely due to the fact that the software used to manage call centers – itself developed at a time when data storage was expensive – often uses only simple models which require limited, summary statistics. Finally, we believe that it is due to lack of understanding of how and why more detailed analyses should be carried out.

Instead, call centers most often summarize call-by-call data from the ACD (and related systems) as averages that are calculated over short time intervals, most often 30 minutes in length. These ACD data are used both for planning purposes and to measure system performance. They are carefully and continuously watched by call-center managers. Hence we shall describe them in class, and you will using then in assignments.

While the specifics of ACD reports may vary from one site to the next, the reports almost always (as far as we have seen) contain statistics on four categories:

- numbers of arrivals and abandonment
- average service times
- CSR utilization, and
- the distribution of delay in queue.

This is hardly surprising – it simply reflects the fact that call centers can be viewed, naturally and usefully, as queueing systems.

2 Data Analysis and Forecasting

The modelling and control of call centers must necessarily start with careful data analysis. For example, when used to model performance at time-period t, the simple Erlang C queueing model requires the estimation of a calling rate (λ_t) and a mean service time (μ_i^{-t}). Moreover, the performance of call centers in peak hours can be extremely sensitive to changes in these underlying parameters.

It follows that accurate estimation and forecasting of parameters are prerequisites for a consistent service level and an efficient operation. Furthermore, given the computer-mediated, data-intensive environment of modern call centers, one might imagine that highly developed estimation and forecasting methods would exist.

But in fact, though there is a vast literature on statistical inference and forecasting, surprisingly little has been devoted to stochastic processes, and much less to queueing models in general and call centers in particular. Indeed, the practice of statistics and time series analysis is still in its infancy in the world of call centers, and serious research efforts are required to bring it up to par with prevalent needs.

3 Types of Call Center Data

Call centers generate a great deal of data, which we divide into four categories: operational, marketing, human resources, and psychological.

Operational data reflect the physical process by which calls are handled. These data are typically collected by pieces of the telephone infrastructure such as IVRs and ACDs. They can be usefully organized in two, complementary fashions.

Operational *customer* data provide listings of every call handled by a site or network of call centers. Each record includes time-stamps for when the call arrived, when it entered service or abandoned, when it ended service, as well as other identifiers, such as who was the CSR and at which location the call was served.

Operational *agent* data provide a moment-by-moment history of the time each logged-in agent spent in various system states: available to take calls, handling a call, performing wrap-up work, and assorted unavailable states. These data allow one to deduce the numbers of agents working at any time. Often these records include identifiers of the calls being served and (with difficulty) can be matched to the operational customer data described above, for joint analysis.

Marketing or *business* data are gathered by a company's corporate information system. They may include records of the transactions that took place over the customer's entire history with the company, through call centers as well as through other channels. They may also capture information concerning the customer's current status at the business.

In theory, operational and marketing data can be seamlessly integrated via CTI software, which connects the telephone infrastructure with a company's customer databases. That is, given the existence of CTI, one might expect companies to record and analyze a full view of what happens to each call as it enters the system: marketing data concerning what happened during the service, together with operational data concerning how and when the service happened. In practice, however, the use of CTI appears, thus far, to be limited to facilitating the service process through "screen pops" which save CSRs time, not to the joint reporting of call data. Incompatibility between data storage schemes of (older) ACD and (newer) CTI systems may be the problem that prevents this integration from taking place.

Human resources data record the history and profile of agents. Typical data include information concerning employees' tenure at the company, what training they have received and when, and what types of call they are capable of handling. With one frequent exception, these data generally reside within the records of a company's human resources department. The exception is that of "skills" data, which define the types of calls that agents can handle. This information is needed, by the ACD (or those that manage it), to support skills-based routing.

Finally, *psychological* data are collected from surveys of customers, agents or managers. They record subjective perceptions of the service level and working environment.

Two additional sources of data are important to acknowledge. First, some companies record individual calls for legal needs (e.g., brokerage and insurance businesses) or training reasons. While potentially useful, we are not aware of any simple machinery that can extract these data for analysis (say, into a spreadsheet). A second source is subjective surveys in which call center managers report statistics that summarize their operations. These surveys can include both operational and marketing data, such as arrival and utilization rates, average handle times, and the average dollar value of a transaction. While they may facilitate rough benchmarking, these data should be handled with care. By their nature, they are biased and should *not* serve as a substitute, or even a proxy, for the operational and marketing data discussed above.

4 Types of Data Models

As in any statistical work, the analysis of call-center data can take a number of forms. We briefly make three sets of distinctions.

Descriptive, Explanatory and Theoretical Analysis: We first distinguish among descriptive, explanatory, and theoretical analysis. Each mode is important, and we briefly describe the three in turn.

Descriptive models organize and summarize the data being analyzed. The simplest of these are tables or histograms of parameters and performance. An example is a histogram of service duration by service type, or of customers' patience by customer type, or of waiting times for those ultimately served.

These can be contrasted with *theoretical models* that seek to test whether or not the phenomenon being observed conforms to various mathematical or statistical theories. Examples include the identification of an arrival process as a Poisson process or of service durations as being exponentially distributed.

In between descriptive and theoretical models fall *explanatory models.* These are often created in the context of regression and time series analysis. Explanatory models go beyond, say, histograms by identifying and capturing relationships in terms of explanatory variables. For example, average service times of calls may be systematically higher from 11am to 3pm and lower at other periods. At the same time, these models fall short of theoretical models in that there is no attempt to develop or test a formal, mathematical theory to explain the relationships.

Queueing models constitute theoretical models which mathematically define relationships among building blocks, for example arrivals and services, which we refer to here as *primitives.* Queueing analysis of a given model starts with assumptions concerning its primitives and culminates in properties of performance measures, such as the distribution of delay in queue or the abandonment rate. Validation of the model then amounts to a comparison of its primitives and performance measures – typically theoretical – against their analogs in a given call center – mostly empirical.

For example, as will be discussed in class, theoretical analysis of the $G/G/N$ queue gives rise to Kingman's law of congestion: in conventional heavy traffic, the waiting time of delayed customers is close to being exponentially distributed, with a calculable parameter. Empirical analysis of call centers operating in heavy traffic can then validate or refute Kingman's law. Refuting it would trigger theoretical research in order to identify alternative theoretical models, possibly in non-conventional heavy-traffic regime of Halfin-Whitt (the QED regime).

Estimation versus Prediction: We also distinguish between two closely related, but different, statistical tasks: estimation and prediction. *Estimation* concerns the use of existing (historical) data to make inferences about the parameter values of a statistical model. *Prediction* concerns the use of the estimated parameters to forecast the behavior of a sample outside of the original data set (used to make the estimate). Predictions are "noisier" than estimates, because, in addition to uncertainty concerning the estimated parameters, they contain additional sources of potential errors.

As an example, consider a simple model in which the arrival rate to a call center (each day from 9:00am–9:30am) is a linear function of the number of customers receiving a promotional mailing.

That is

$$\lambda_i = \alpha + \beta x_i + \varepsilon_i \,, \tag{1}$$

where λ_i is the arrival rate, x_i is the number of mailings, α and β are unknown constants, and the ε_i are *i.i.d.* normally-distributed noise terms with mean zero. Given n sample points (x_i, λ_i), one may use regression techniques (such as least squares) to produce parameter estimates $\hat{\alpha}$ and $\hat{\beta}$. There is uncertainty, however, regarding how closely these estimates match the true α and β. That is $\hat{\alpha}$ and $\hat{\beta}$ are random variables that are functions of the n *i.i.d.* samples, and given our estimated function

$$\hat{\lambda}_i = \hat{\alpha} + \hat{\beta} x_i \,, \tag{2}$$

the associated estimation error is distributed as

$$\lambda_i - \hat{\lambda}_i \;=\; (\alpha - \hat{\alpha}) + (\beta - \hat{\beta}) x_i \,.$$

Now suppose we are told the number of mailings that customers will receive on day $n+1$, and we are asked to predict what λ_{n+1} will be. Then we use $\hat{\lambda}_{n+1}$ to predict the $(n+1)$st arrival rate, and from (1)–(2) we see that the prediction error is distributed as

$$\lambda_{n+1} - \hat{\lambda}_{n+1} \;=\; (\alpha - \hat{\alpha}) + (\beta - \hat{\beta}) x_{n+1} + \varepsilon_{n+1} \,.$$

In particular, the ε_{n+1} term makes the prediction error larger than the estimation error that arises from the use of $\hat{\alpha}$ and $\hat{\beta}$.

5 Models for Operational Parameters

In the original article, here we review work devoted to primitives: arrivals, service times, abandonment (patience) and retrials. These, in turn, will be discussed and analyzed in class and assignments.

6 Future Work in Data Analysis and Forecasting

There has been recent progress in the analysis of call-center data. Call-by-call data from a small number of sites have been obtained and analyzed, and these limited results have proven to be fascinating. In some cases, such as the characterization of the arrival process and of the delay of arriving calls to the system, conventional assumptions and models of system performance have been upheld. In others, such as the characterization of the service-time distribution and of customer patience, the data have revealed fundamental, new views of the nature of the service process. Of course, these limited studies are only the beginning, and the effort to collect and analyze call-center data can and should be expanded in every dimension.

Perhaps the most pressing practical need is for improvements in the forecasting of arrival rates. For highly utilized call centers, more accurate, distributional forecasts are essential. While there exists some research that develops methods for estimating and predicting arrival rates, there is surely room for additional improvement to be made. However, further development of models for estimation and prediction will depend, in part, on access to richer data sets. We believe that much of the randomness of Poisson arrival *rates* may be explained by covariates that are not captured in currently available data.

Procedures for predicting waiting-times are also worth pursuing. Field-based studies that characterize the performance of different statistics and methods would also be of value. More broadly, there is need for the development of a wider range of descriptive models. While a characterization of arrival rates, abandonment from queue, and service times are essential for the management of call centers, they constitute only a part of the complete picture of what goes on. For example, there exist (self) service times and abandonment (commonly called "opt-out") behavior that arise from customer use of IVRs. Neither of these phenomena is likely to be the same as its CSR analogue. Similarly, sojourn times and abandonment from web-based services have not been examined in multi-media centers.

Parallel, descriptive studies are also needed to validate or refute the robustness of initial findings. For example, lognormal service times have been reported in two call centers, both of which are part of retail financial services companies. Perhaps the service-time distribution of catalogue retailers or help-desk operations have different characteristics. Similarly, one would like to test some finding that the waiting-time messages customers hear while tele-queueing promote, rather than discourage, abandonment.

It would also be interesting to put work on abandonment (Palm, Roberts, Kort, Mandelbaum with Sakov and Zeltyn) in perspective. These studies provide empirical and exploratory models for (im)patience on the phone in Sweden in the 40's, France in the late 70's, the U.S. in the early 80's, and Israel in the late 90's. A systematic comparison of patience across countries, for current phone services, should be a worthy, interesting undertaking.

There is the opportunity to further develop and extend the scope of explanatory models. Indeed, given the high levels of system utilization in the QED regime, a small percentage error in the forecast of the offered load can lead to significant, unanticipated changes in system performance. In particular, the state of the art in forecasting call volumes is still rudimentary. Similarly, the fact that service times are lognormally distributed enables the use of standard parametric techniques to understand the effect of covariates on the (normally distributed) natural log of service times.

In well-run QED call centers, only a small fraction of the customers abandon (around 1-3%), hence about 97% of the (millions of) observations are censored. Based on such figures, one can hardly expect any reasonable estimate of the whole patience distribution, non-parametrically at least. Fortunately, however, theoretical analysis suggests that only the behavior of impatience near the origin is of relevance, and this is observable and analyzable.

Indeed, call-center data are challenging the state-of-the-art of statistics, and new statistical techniques seem to be needed to support their analysis. Two examples are the accurate non-parametric estimation of hazard rates, with corresponding confidence intervals, and the survival analysis of tens of thousands, or even millions, of observations, possibly correlated and highly censored.

Last but certainly not least, a broader goal should be, in fact, the analysis of *integrated* operational, marketing, human resources, and psychological data. That is, the analysis of these integrated data is essential if one is to understand and quantify the role of operational service quality as a driver for business success.

7 A Vision: Central Repository for Call-Center Data and Expertise

A prerequisite for understanding the financial effects of operational decisions is the ability to analyze an integrated data set that includes both operational (ACD) and marketing / business (customer information systems) data. With this information, one can attempt to tease out the longer-term, financial effects of operational policies.

Our experience has been that both types of data are very difficult to access, however. One reason for this is technical. Only recently have the manufacturers of telephone equipment given customers something of an "off the shelf" ability to capture, store, and retrieve detailed, call-by-call data. Similarly, the integration of these operational data with the business data captured in customer information systems is only now becoming widely available. Another reason stems from confidentiality concerns; companies are rightly wary of releasing customer information. Once managers recognize the great untapped value of these data, we believe they will employ mechanisms for preserving confidentiality in order to reap the benefit.

Ultimately, we envision a data-repository that is continuously fed by many call centers of varying types. The collected data would be continuously and automatically analyzed, from both operations and marketing perspectives. Then the data would be both archived and fed back to the originating call centers, who would use it (through visualization tools) to support ongoing operations, as well as tactical and strategic goals.

Little imagination is required for appreciating the value of such a data-base. As a start, its developer could become a benchmark that sets industry standards, as far as customer-service quality and call-center efficiency are concerned. As already mentioned, such a data-base would enable the identification of success-drivers of call-center business transaction.

A Glossary of Call-Center Acronyms

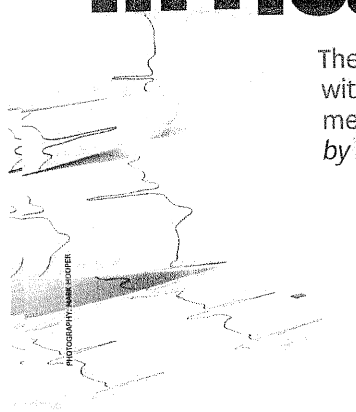
Acronym	Description	Definition
ACD	automatic call distributor	p. ??
ANI	automatic number identification	p. ??
ASA	average speed of answer	p. ??
CRM	customer relationship management	p. ??
CSR	customer service representative	p. ??
CTI	computer-telephony integration	p. ??
DNIS	dialed number identification service	p. ??
IVR	interactive voice response unit (also called VRU)	p. ??
PABX	private automatic branch exchange (also called PBX)	p. ??
PBX	private automatic branch exchange (also called PABX)	p. ??
PSTN	public switched telephone network	p. ??
QED	Quality and Efficiency Driven (operational regime)	p. ??
TSF	telephone service factor (also called the 'service level')	p. ??
VRU	interactive voice response unit (also called IVR)	p. ??
WFM	workforce management	p. ??

Robert S. Kaplan is a Baker Foundation Professor at Harvard Business School.

Michael E. Porter is the Bishop William Lawrence University Professor at Harvard. He is based at Harvard Business School.

How to Solve The Cost Crisis In Health Care

The biggest problem with health care isn't with insurance or politics. It's that we're measuring the wrong things the wrong way.
by Robert S. Kaplan and Michael E. Porter



PHOTOGRAPHY: MARK HOOPER

Idea in Brief

Much of the rapid escalation in health care costs can be attributed to the fact that providers have an almost complete lack of understanding of how much it costs to deliver patient care. Thus they lack the knowledge necessary to improve resource utilization, reduce delays, and eliminate activities that don't improve outcomes.

Pilot projects under way at hospital systems in the U.S. and Europe demonstrate the transformative effect of a new approach that accurately measures costs—at the level of the individual patient with a given medical condition over a full cycle of care—and compares those costs to outcomes.

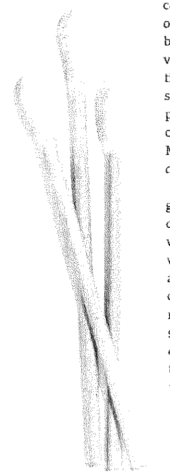
As providers and payors better understand costs, they will be positioned to achieve a true "bending of the cost curve" from within the system, not based on top-down mandates.

The sheer size of the opportunity to reduce health care costs—with no sacrifice in outcomes—is astounding.

value problem: how to deliver improved outcomes at a lower total cost.

Fortunately, we can change this state of affairs. And the remedy does not require medical science breakthroughs or top-down governmental regulation. It simply requires a new way to accurately measure costs and compare them with outcomes. Our approach makes patients and their conditions—not departmental units, procedures, or services—the fundamental unit of analysis for measuring costs and outcomes. The experiences of several major institutions currently implementing the new approach—the Head and Neck Center at MD Anderson Cancer Center in Houston, the Cleft Lip and Palate Program at Children's Hospital in Boston, and units performing knee replacements at Schön Klinik in Germany and Brigham & Women's Hospital in Boston—confirm our belief that bringing accurate cost and value measurement practices into health care delivery can have a transformative impact.

The remedy to the cost crisis does not require medical science breakthroughs or new governmental regulation. It simply requires a new way to accurately measure costs and compare them with outcomes.



Understanding the Value of Health Care

The proper goal for any health care delivery system is to improve the value delivered to patients. Value in health care is measured in terms of the patient outcomes achieved per dollar expended. It is not the number of different services provided or the volume of services delivered that matters but the value. More care and more expensive care is not necessarily better care.

To properly manage value, both outcomes and cost must be measured at the patient level. Measured outcomes and cost must encompass the entire cycle of care for the patient's particular medical condition, which often involves a team with multiple specialties performing multiple interventions from diagnosis to treatment to ongoing management. A medical condition is an interrelated set of patient circumstances that are best addressed in a coordinated way and should be broadly defined to include common complications and comorbidities. The cost of treating a patient with diabetes, for example, must include not only the costs associated with endocrinological care but also the costs of managing and treating associated conditions such as vascular disease, retinal disease, and renal disease. For primary and preventive care, the unit of value measurement is a particular patient population—that is, a group with similar primary care needs, such as healthy children or the frail and elderly with multiple chronic conditions.

Let's explore the first component of the health care value equation: health outcomes. Outcomes for any medical condition or patient population should be measured along multiple dimensions, including survival, ability to function, duration of care, discomfort and complications, and the sustainability of recovery. Better measurement of outcomes will, by itself, lead to significant improvements in the value of health care delivered, as providers' incentives shift away from performing highly reimbursed services and toward improving the health status of patients. Approaches for measuring health care outcomes have been described previously, notably in Michael Porter's 2010 *New England Journal of Medicine* article, "What Is Value in Health Care?"

While measuring medical outcomes has received growing attention, measuring the costs required to deliver those outcomes, the second component of the value equation, has received far less attention. In the value framework, the relevant cost is the total cost of all resources—clinical and administrative personnel, drugs and other supplies, devices, space, and equipment—used during a patient's full cycle of care for a specific medical condition, including the treatment of associated complications and common comorbidities. We increase the value of health care delivered to patients by improving outcomes at similar costs or

CREATING A COST MEASUREMENT SYSTEM

1 Select the medical condition and/or patient population to be examined

2 Define the care delivery value chain

3 Develop process maps of each activity in patient care delivery; identify the resources involved and any supplies used for the patient at each process

4 Obtain time estimates for each process step

5 Estimate the cost of supplying each patient care resource

6 Estimate the practical capacity of each resource provider, and calculate the capacity cost rate

7 Compute the total costs over each patient's cycle of care

(The exhibit "The Care Delivery Value Chain" shows the CDVC developed with the Brigham & Women's pilot site for patients with severe knee osteoarthritis.) This overall view of the patient care cycle helps to identify the relevant dimensions along which to measure outcomes and is also the starting point for mapping the processes that make up each activity.

3. Develop process maps of each activity in patient care delivery. Next we prepare detailed process maps for each activity in the care delivery value chain. Process maps encompass the paths patients may follow as they move through their care cycle. They include all the capacity-supplying resources (personnel, facilities, and equipment) involved at each process along the path, both those directly used by the patient and those required to make the primary resources available. (The exhibit "New-Patient Process Map" shows a process map for one segment of the patient care cycle at the MD Anderson Head and Neck Center.) In addition to identifying the capacity-supplying resources used in each process, we identify the consumable supplies (such as medications, syringes, catheters, and bandages) used directly in the process. These do not have to be shown on the process maps.

Our pilot sites used several approaches for creating process maps. Some project teams interviewed clinicians individually to learn about patient flow, while others organized "power meetings" in which people from multiple disciplines and levels of management discussed the process together. Even at this early stage in the project, the sessions occasionally identified immediate opportunities for process and cost improvement.

4. Obtain time estimates for each process. We also estimate how much time each provider or other resource spends with a patient at each step in the process. When a process requires multiple resources, we estimate the time required by each one.

For short-duration, inexpensive processes that vary little across patients, we recommend using standard times (rather than investing resources to record actual ones). Actual duration should be calculated for time-consuming, less predictable processes, especially those that involve multiple physicians and nurses performing complex care activities such as major surgery or examination of patients with complicated medical circumstances.

TDABC is also well suited to capture the effect of process variation on cost. For example, a patient who needs a laryngoscopy as part of her clinical visit requires an additional process step. The time estimate and associated incremental resources required can be easily added to the overall time equation for that patient. (See again the process map exhibit.)

To estimate standard times and time equations, our pilot sites have found it useful to bring together all the people involved in a set of processes for focused discussion. **In the future, we expect providers will use electronic handheld, bar-code, and RFID devices to capture actual times, especially if TDABC becomes the generally accepted standard for measuring the cost of patient care.**

5. Estimate the cost of supplying patient care resources. In this step, we estimate the direct costs of each resource involved in caring for patients. The direct costs include compensation for employees, depreciation or leasing of equipment, supplies, or other operating expenses. These data, gathered from the general ledger, the budgeting system, and other IT systems, become the numerator for calculating each resource's capacity cost rate.

We must also account for the time that many physicians, particularly in academic medical centers, spend teaching and doing research in addition to their clinical responsibilities. We recommend estimating the percentage of time that a physician spends on clinical activities and then multiplying the physician's compensation by this percentage to obtain the amount of pay accounted for by the physician's clinical work. The remaining compensation should be assigned to teaching and research activities.

Next, we identify the support resources necessary to supply the primary resources providing patient care. For personnel resources, as illustrated in the Patient Jones example, these include supervising employees, space and furnishings (office and patient treatment areas), and corporate functions that support patient-facing employees. When calculating the cost of supplies, we include the cost of the resources used to acquire them and make them available for patient use during the treatment process (for instance, purchasing, receiving, storage, sterilization, and delivery).

Finally, we need to allocate the costs of departments and activities that support the patient-facing work. We map those processes as we did in step 3 and then calculate and assign costs to patient-facing resources on the basis of their demands for the services of these departments, using the process that will be described in step 6.

CASE STUDY: THE CARE DELIVERY VALUE CHAIN
Severe Knee Osteoarthritis Requiring Replacement

The care delivery value chain is both a descriptive and prescriptive tool. By **systematically mapping the full set of activities delivered over the cycle of care** for a medical condition, spanning multiple providers and nonclinical care settings, the CDVC enables analysis of how the set of activities *together* generates patient value and offers providers a systematic approach to analyze, improve, and integrate the configuration of care delivery.

TYPICAL PATH OF PATIENT CARE	MONITORING/ PREVENTING	DIAGNOSING	PREPARING	INTERVENING	RECOVERING/ REHABBING	MONITORING/ MANAGING
INFORMING AND ENGAGING What do patients need to be educated about?	• Importance of exercise, weight reduction, proper nutrition	• Meaning of diagnosis • Prognosis (short- and long-term outcomes) • Drawbacks and benefits of surgery	• Setting expectations • Importance of nutrition, weight loss, vaccinations • Home preparation	• Expectations for recovery • Importance of rehab • Post-surgery risk factors	• Importance of rehab adherence • Longitudinal care plan	• Importance of exercise, maintaining healthy weight
MEASURING What measures need to be collected?	• Joint-specific symptoms and function (e.g., WOMAC scale) • Overall health (e.g., SF-12 scale)	• Loss of cartilage • Change in subchondral bone • Joint-specific symptoms and function • Overall health	• Baseline health status • Fitness for surgery (e.g., ASA score)	• Blood loss • Operative time • Complications	• Infections • Joint-specific symptoms and function • Inpatient length of stay • Ability to return to normal activities	• Joint-specific symptoms and function • Weight gain or loss • Missed work • Overall health
ACCESSING Where do patient care activities take place?	• PCP office • Health club • Physical therapy clinic	• Specialty office • Imaging facility	• Specialty office • Pre-op evaluation center	• Operating room • Recovery room • Orthopedic floor at hospital or specialty surgery center	• Nursing facility • Rehab facility • Physical therapy clinic • Home	• Specialty office • Primary care office • Health club
CARE DELIVERY What activities are performed at each stage? ORTHOPEDIC SURGEON	**MONITOR** • Conduct PCP exam • Refer to specialists, if necessary **PREVENT** • Prescribe anti-inflammatory medicines • Recommend exercise regimen • Set weight loss targets	**IMAGING** • Perform and evaluate MRI and x-ray –Assess cartilage loss –Assess bone alterations **CLINICAL EVALUATION** • Review history and imaging • Perform physical exam • Recommend treatment plan (surgery or other options)	**Overall prep** • Conduct home assessment • Monitor weight loss **SURGICAL PREP** • Perform cardiology, pulmonary evaluations • Run blood labs • Conduct pre-op physical exam	**ANESTHESIA** • Administer anesthesia (general, epidural, or regional) **SURGICAL PROCEDURE** • Determine approach (e.g., minimally invasive) • Insert device • Cement joint **PAIN MANAGEMENT** • Prescribe preemptive multimodal pain meds	**SURGICAL** • Immediate return to OR for manipulation, if necessary **MEDICAL** • Monitor coagulation **LIVING** • Provide daily living support (showering, dressing) • Track risk indicators (fever, swelling, other) **PHYSICAL THERAPY** • Daily or twice daily PT sessions	**MONITOR** • Consult regularly with patient **MANAGE** • Prescribe prophylactic antibiotics when needed • Set long-term exercise plan • Revise joint, if necessary

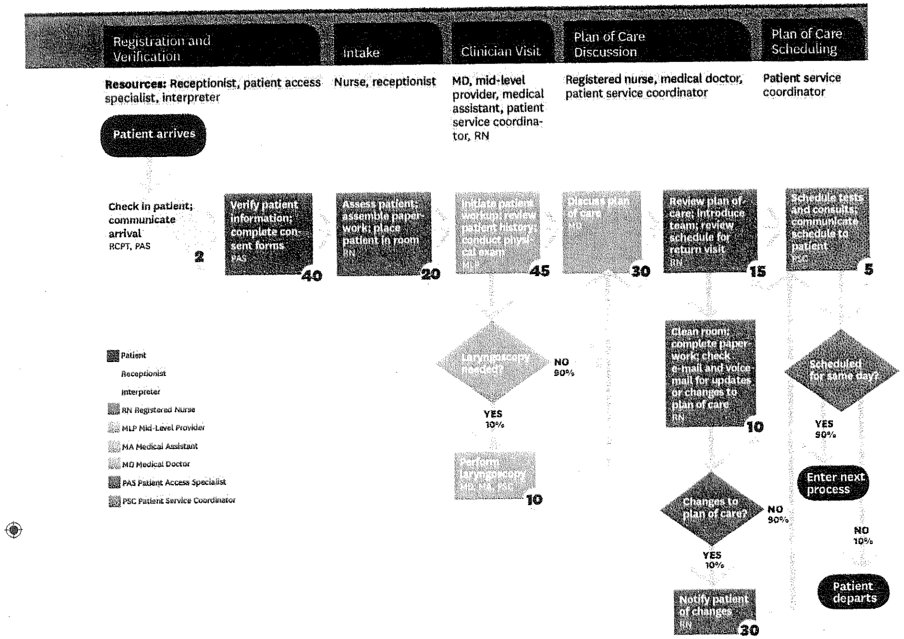
For more on the CDVC, see *Redefining Health Care: Creating Value-Based Competition on Results*, by M.E. Porter and E.O. Teisberg (Harvard Business Review Press, 2006).

This approach to allocating support costs represents a major shift from current practice. To illustrate, let's compare the allocation of the resources required in a centralized department to sterilize two kinds of surgical tool kits, those used for total knee replacement and those used for cardiac bypass. Existing cost systems tend to allocate higher sterilization costs to cardiac bypass cases than to knee replacement cases because the charges (or direct costs) are higher for a cardiac bypass than for a knee replacement. Under TDABC, however, we have learned that more time and expense are required to sterilize the typically more complex knee surgery tools, so relatively higher sterilization costs should be assigned to knee replacements.

When costing support departments, a good guideline is the "rule of 1." Support functions that have only one employee can be treated as a fixed cost; they can be either not allocated at all or allocated using a simplistic method, as is currently done. But departments that have more than one person or more than one unit of any resource represent variable costs. The workload of these departments has expanded because of increased demand for the services and outputs they provide. Their costs should and can be assigned on the basis of the patient processes that create demand for their services.

Project teams tasked with estimating the cost to supply resources—the numerator of the capacity cost rate—should have expertise in finance, human

14



the United States, the higher cost in U.S. facilities is mainly due to lower resource productivity.

Improve resource capacity utilization. The TDABC approach identifies how much of each resource's capacity is actually used to perform processes and treat patients versus how much is unused and idle. Managers can clearly see the quantity and cost of unused resource capacity at the level of individual physicians, nurses, technicians, pieces of equipment, administrators, or organizational units. Resource utilization data also reveal where increasing the supply of certain resources to ease bottlenecked processes would enable more timely care and serve more patients with only modestly higher expenditures.

When managers have greater visibility into areas where substantial and expensive unused capacity exists, they can identify the root causes. For example, some underutilization of expensive space, equipment, and personnel is caused by poor coordination and delays when a patient is handed off from one specialty or service to the next. Another cause of low resource utilization is having specialized equipment available just in case the need arises. Some facilities that serve patients with unpredictable and rare medical needs make a deliberate decision to carry extra capacity. In such cases, an understanding of the actual cost of excess capacity should trigger a discussion on how best to consolidate the treatment of such patients. Much excess resource capacity, however, is due not to rare conditions or poor handoffs but to the prevailing tendency of many hospitals and clinics to provide care for almost every type of medical problem. Such fragmentation of service lines introduces costly redundancy throughout the health care system. It can also lead to inferior outcomes when providers handle a low volume of cases of each type. Accurate costing gives managers a valuable tool for consolidating patient care for low-volume procedures in fewer institutions, which

would both reduce the high costs of unused capacity and improve outcomes.

Deliver the right processes at the right locations. Many services today are delivered in over-resourced facilities or facilities designed for the most complex patient rather than the typical patient. By accurately measuring the cost of delivering the same services at different facilities, rather than using figures based on averaged direct costs and inaccurate overhead allocations, providers are able to see opportunities to perform particular services at properly resourced and lower-cost locations. Such realignment of care delivery, already under way at Children's Hospital Boston, improves the value and convenience of more routine services for both patients and caregivers while allowing tertiary facilities to concentrate their specialized resources on truly complex care.

Match clinical skills to the process. Resource utilization can also be improved by examining whether all the processes currently performed by physicians and other skilled staff members require their level of expertise and training. The process maps developed for TDABC often reveal opportunities for appropriately skilled but lower-cost health care professionals to perform some of the processes currently performed by physicians without adversely affecting outcomes. Such substitutions would free up physicians and nurses to focus on their highest-value-added roles. (For an example from one of our pilot sites, see the sidebar "A Cancer Center Puts the New Approach to Work.")

Speed up cycle time. Health care providers have multiple opportunities to reduce cycle times for treating patients, which in turn will reduce demand for resource capacity. For example, reducing the time that patients have to wait will reduce demand for patient supervision and space. Speeding up cycle time also improves outcomes, both by minimizing the duration of patient uncertainty and discomfort and by reducing the risk of complications and minimizing disease progression. As providers improve

Myth #3
Most health care costs are fixed.

Many health care system participants, including economists and accountants, believe that most costs in health care are fixed because so much care is delivered using shared staff, space, and equipment. The result of this misguided thinking is that cost reduction efforts tend to focus on only the small fraction of costs seen as variable, such as drugs and supplies, which are sometimes referred to as marginal or incremental costs. This myth also motivates some health care organizations to expand through mergers, acquisitions, and organic growth in order to reap economies of scale by spreading their fixed costs over an increased volume of business.

But if most health care costs were truly fixed, we would not have the health care cost problem we do today. If most costs were fixed, growth in demand for health care would increase only that small fraction of costs that are variable, leading to lower average costs in the system, not the dramatically higher share of GDP now being devoted to health care.

To understand why most health care costs are not fixed, start with personnel costs, which are generally at least 50% of the total costs of health care providers, according to American Hospital Association statistics. Hint: Personnel costs are not fixed. Hospital executives can set the quantity, mix, and compensation of their personnel each year, or even more frequently. Personnel costs are fixed only when executives allow them to be. The claim that personnel costs are fixed is a reflection of management inattention, not of the nature of those costs.

Space costs are also not fixed. Space is perhaps an organization's most fungible resource. If demand for space is reduced, units can be consolidated into smaller space, and excess space can be repurposed, sold, or subleased. Similarly, equipment costs can be avoided if changes in processes, treatment protocols, or patient mix eliminate the demand for the resources. Equipment no longer needed can be retired or sold to other health care institutions that are expanding their capacity.

All told, we estimate that upwards of 95% of what health care managers think of as fixed costs are actually under their control and therefore not really fixed.

15

May 2010

RFID לשליטה באירוע רב נפגעים MCS

ד"ר שלומי ישראלית, מנהל מלר"ד רמב"ם, בשיתוף יריב מרמור, סטודנט לד"ר בתעו"נ, טכניון.

לקראת פרויקט במסגרת OCR: רמב"ם, IBM Research in Haifa, תעו"נ.

השימוש ב טכנולוגיית ה RFID בתחום הרפואה צוברת תאוצה. עיקר השימושים המדווחים הם

- זיהוי ומעקב אחר חולים
- זיהוי ומעקב אנשי צוות,
- מעקב אחר ציוד רפואי רגיש (מכונות הנשמה למשל)
- זיהוי ומעקב בדיקות דם
- זיהוי ומעקב תוצרי דם שנשלחים מבנק הדם (מנות דם פלסמה או מנות טסיות)
- זיהוי ומעקב אחר תרופות חשובות / יקרות.

הכוונה היא לנצל את המידע שניתן להפיק ממערכות ה RFID על מנת לייעל תהליכי טיפול, הן ברמת הקצעת המשאבים (כוח אדם וציוד), הן ברמת המעקב אחר הטיפול והן ברמת השליטה על זרימת החולים (עד לרזולוציה של זרימת החולה הבודד).

אירוע רב נפגעים, למתאריו השונים (אר"ן =אירוע רב נפגעים / אטה = אירוע טוקסיקולוגי המוני / חל"ך = חומרי לחימה כימיים / אירוע קרינה / אירוע ביולוגיה), מאופיין בהגעה של פצועים רבים בפרק זמן קצר, היערכות מיוחדת של בית החולים (על פי תורה מוסדרת מראש), פתיחת אתרי חירום, הקצאת כוח אדם וציוד ייעודי ועוד.

בד"כ במתארים השונים קיים פער בין הצרכים הרגעיים, לבין הדרישה – כוח אדם, ציוד ועוד. בשלבים הראשונים חשוב לקבל תמונה מהירה מדוייקת וזמינה של המשאבים ומאידך לרכז את הדרישות.

איסוף הנתונים יכלו להתבצע במספר דרכים:

רישום ידני, הקלדה למחשב, איסוף מבר קוד או מתויות זהוי אחרות, RFID.

ברישום הידני קיימות טעויות אינהרנטיות לשיטה, הנובעות מרישום שגוי. רישום ידני איטי ומצריך העברה למחשב על מנת שהמנהל יוכל לקבל תמונת מצב ברורה. לסיכום שיטה זו איטית ובעלת פוטנציאל גבוה לטעות.

הקלדה למחשב, גם היא איטית ובעלת סיכוי להקלדת טעות.

לשאיבת נתונים במערכת RFID שאינה תלויה בהקלדה ומתבצעת מיידית, יתרונות ברורים. הנתונים נשאבים בצורה אקטיבית, ללא צורך בהקלדה, מנותחים מיידית ומוצגים במערכות השליטה כמעט on-line.

ככל שהמידע אמין, זמין ומדוייק יותר, משתפרת יכולת השליטה של מנהלי האירוע.

ככלל במתערים שהוזכרו, יש חשיבות רבה לצבירת המידע החל מהדקות הראשונות. בכל האירועים הללו מופעל triage שמפנה חולים/פצועים לאזורים שונים ולעיתים מרוחקים של בית החולים.

הצלחה במתארים אלו תתקבל אם נוכל לשמור על "עקרון 7 הדברים הנכונים" (באנגלית נשמע יותר טוב):

"Seven rights": give the **right** medication to the **right** patient with the **right** dosage through the **right** route at the **right** time, and ensure that victims receive the **right** care at a mass casualty incident.

בסוף מאי מתקיים תרגיל חל"ך בביה"ח. התרגיל הינו פלטפורמה מצויינת, לבדוק היתכנות השימוש בטכנולוגיית ה RFID, במתאר מרובה נפגעים.

באופן פרקטי נרצה ידע על כמות החולים, כמות המטפלים (אחים ורופאים) ואנשי הלוגיסטיקה (מאבטחים, משנעים, מנהלנים), בכל אחד מהאתרים שנפרסים בתרגיל.

נבדוק את האפשרות של הצגת המידע בצורה שתעזור לשליטה.

נוכל להשוות את המידע שמופק בטכנולוגיה זו למידע שמופק בעזרים הרגילים (רישום ממוחשב).

MCE with RFID Support: Rambam Hospital, May 2010

Drill: Chemical **Mass Casualty Event** (MCE), Rambam Hospital

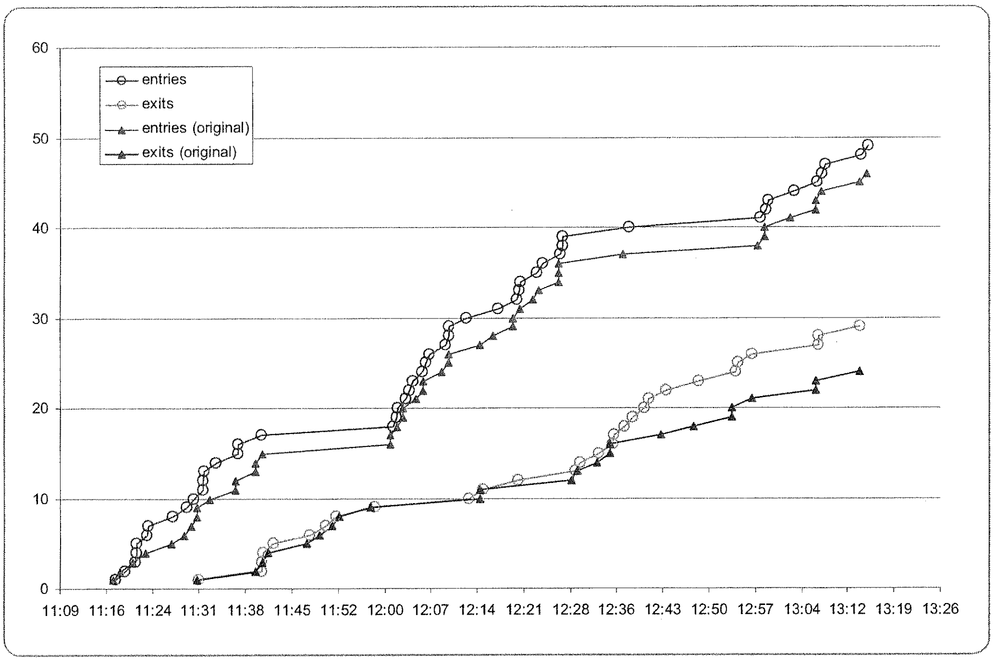
Focus on the **red** casualties - severely wounded (50+ in the drill)
Note: 20 observers taking real-time measurements (validation)

MCE with RFID Support: Data Cleaning

Data-base				Company report		comment
Asset id	order	**Entry date**	**Exit date**	Entry date	Exit date	
4	1	1:14:07 PM		1:14:00 PM		
6	1	12:02:02 PM	12:33:10 PM	12:02:00 PM	12:33:00 PM	
8	1	11:37:15 AM	12:40:17 PM	11:37:00 AM		**exit is missing**
10	1	12:23:32 PM	12:38:23 PM	12:23:00 PM		
12	1	12:12:47 PM	12:35:33 PM		12:35:00 PM	**entry is missing**
15	1	1:07:15 PM		1:07:00 PM		
16	1	11:18:19 AM	11:31:04 AM	11:18:00 AM	11:31:00 AM	
17	1	1:03:31 PM		1:03:00 PM		
18	1	1:07:54 PM		1:07:00 PM		
19	1	12:01:58 PM		12:01:00 PM		
20	1	11:37:21 AM	12:57:02 PM	11:37:00 AM	12:57:00 PM	
21	1	12:01:16 PM	12:37:16 PM	12:01:00 PM		
22	1	12:04:31 PM	12:20:40 PM			first customer is missing
22	2	12:27:37 PM		12:27:00 PM		
25	1	12:27:35 PM	1:07:28 PM	12:27:00 PM	1:07:00 PM	
27	1	12:06:53 PM		12:06:00 PM		
28	1	11:21:34 AM	11:41:06 AM	11:41:00 AM	11:53:00 AM	**exit time instead of entry time**
29	1	12:21:06 PM	12:54:29 PM	12:21:00 PM	12:54:00 PM	
31	1	11:40:54 AM	12:30:16 PM	11:40:00 AM	12:30:00 PM	
31	2	12:37:57 PM	12:54:51 PM	12:37:00 PM	12:54:00 PM	
32	1	11:27:11 AM	12:15:17 PM	11:27:00 AM	12:15:00 PM	
33	1	12:05:50 PM	12:13:12 PM	12:05:00 PM	12:15:00 PM	wrong exit time
35	1	11:31:48 AM	11:40:50 AM	11:31:00 AM	11:40:00 AM	
36	1	12:06:23 PM	12:29:30 PM	12:06:00 PM	12:29:00 PM	
37	1	11:31:50 AM	11:48:18 AM	11:31:00 AM	11:48:00 AM	
37	2	12:59:21 PM		12:59:00 PM		

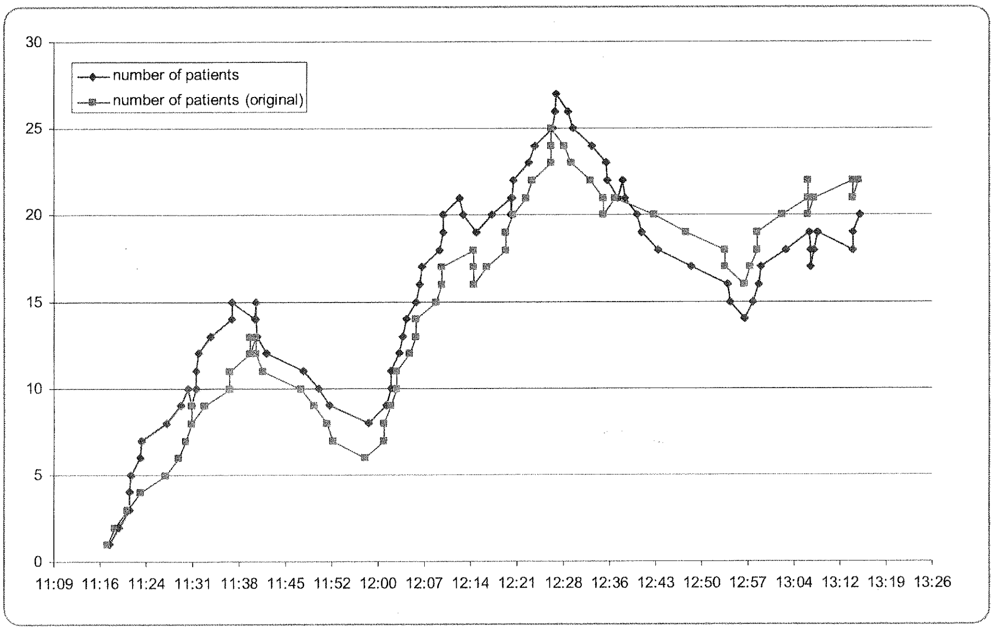
Think "Cleaning" 60,000+ customers/day (call centers)?

MCE with RFID Support: Arrivals, Departures



Operational Question: Predict **completion time** (rolling horizon)

MCE with RFID Support: # Severely Wounded Patients



- Paths of doctors, nurses, patients (100+, **1 sec.** resolution) ?
- What if **150+ casualties** severely wounded (feasible) ?

RFID JOURNAL : THE WORLD'S RFID AUTHORITY

THE WORLD'S RFID AUTHORITY

Where is RFID's ROI in Health Care?

The most strategic benefits for radio frequency identification in health care aren't necessarily found in applications with the most apparent return on investment.

Feb. 13, 2006—The U.S. health-care industry represents a large percentage of the overall U.S. economy and an area well known for being a late adopter of information technology. In fact, according to the U.S. Department of Health and Human Services (HHS), at the end of the 1990s, the health-care industry was investing only about $1,000 per worker on IT, compared with about $8,000 per worker for most other industries.

Yet, despite its late-adopter nature, the industry can benefit tremendously from IT innovation in order to improve patient safety and streamline business processes. The HHS estimates IT can reduce health-care costs up to 20 percent per year by saving time and reducing duplication and waste. IT innovation can come either in the form of established technologies deployed in new ways, or as emerging technologies applied to support new or existing processes.

The innovation that has traditionally occurred purely on the clinical side of health care is now starting to branch out into health-care IT (see The Importance of Industry Parallels). Within the broad context of IT innovation, RFID is just one area that shows promise for the future. According to BearingPoint's recent "RFID in Healthcare" survey of more than 300 health-care professionals, carried out in collaboration with the National Alliance for Health Information Technology (ITAA), we have found a wealth of application opportunity areas for RFID in organizations providing health care. Application areas include access control and security, asset tracking, laboratory order management, medical-equipment tracking, patient flow, patient safety (identification and medication administration), pharmaceutical order management, real-time location systems, supply chain, smart shelving, wireless commerce and worker identification. We have found that the top three applications, in terms of business benefit for today's provider organizations, are commonly mobile-asset tracking, patient-flow management and medication administration. Each of these application areas has its own unique business case, and we'll explore these here.

The business case for tracking mobile assets is related to the ability to find assets such as infusion pumps

quickly, and to minimize time searching for these assets within an emergency department or other hospital unit. Real-time location systems are able to locate these assets within a few feet, or within a particular room. The time savings may be realized by both clinical engineering staff and nursing staff, and can often amount to a couple of days per week per person. Additionally, these faster search times can help improve overall asset utilization and, in certain circumstances, enable more streamlined inventories of equipment and lower rental costs. Tracking technologies can help to lower shrinkage when items get accidentally misplaced for extended periods of time, while also serving as a deterrent to deliberate theft. The return on investment can be quantified by looking at all of these factors and comparing them with the initial and ongoing costs involved in implementation. In this example, the business case is fairly straightforward to determine, and investment decisions typically ride upon the infrastructure costs of the network deployment.

The business case for better patient-flow management is related to the ability to streamline patient flow, and thus patient throughput, throughout the continuum of care. If an emergency department can process more patients per year, it can help delay the need to expand the unit or build additional facilities. Improved patient flow can also have a positive effect on patient satisfaction and provider business processes and recordkeeping. The ability to capture procedure start and stop times and patient wait times can help automate previously manual measurement techniques. It can also be used for Six Sigma purposes and continuous improvement. An electronic record of patient flow greatly improves the time taken to perform chart audits and can feed into the patient electronic medical record. Patient status can be electronically communicated to family members in waiting rooms via displays, helping reduce call volumes and associated costs. Better flow management may also help to increase revenue by more accurately capturing services rendered, enabling full billing for those services and supplies.

Finally, diversions where patients are redirected to other hospitals can be reduced since optimizing patient flow provides more capacity in the system, allowing patients to be treated on the spot. In this example, the business case is more complex and the return on investment can be harder to estimate. Patient-flow management is a complex topic requiring strong knowledge of current health-care processes and a holistic approach to implementation that factors in change management and continuous improvement, along with the technical aspects of implementation.

The business case for RFID-enabled medication administration relates to the well-known "five rights" of medication administration: right patient, right medication, right dose, right time and right route. Like bar codes, RFID can help ensure these five rights are upheld and, hence, contribute toward reduced medical error rates. While only 7 percent of erroneously administered doses, on average, lead to "adverse drug events"—causes harm to the patient—these kinds of preventable events can lead to increased patient stays averaging over two extra days and costing around $4,600 per event. Litigation from ADEs can be much more significant in terms of cost, and negative publicity is equally damaging. In this example, the business case is again harder to determine in terms of hard ROI numbers, but it is obviously an area of the most importance, since it directly relates to patient safety.

To execute on these three business cases, it is important to take a holistic approach and consider which initiatives are quick wins versus longer-term strategies. Tracking assets and improving patient flow can be implemented in parallel in order to leverage the same infrastructure—typically indoor positioning systems utilizing active RFID.

To measure success before a widespread rollout, providers can also target subsets of patients and assets. We have found that many providers are pursuing a phased approach from the emergency department to the operating room and beyond. This strategy helps focus deployments first where they have maximum benefit, and to expand later into other areas of value.

The business case for RFID-enabled medication administration, on the other hand, is more of a longer-term strategy because it requires more infrastructure to be in place, such as RFID-tagging at the item level, RFID-enabled patient wristbands for positive patient identification, and wireless devices and networks available to nursing staff throughout a facility. It also requires integration with existing clinical systems and software that supports RFID-enabled point of care.

These three application areas have strong business cases with the potential to improve patient safety and health-care service delivery significantly. While the return on investment is often readily apparent for quick wins such as mobile-asset tracking, the most strategic benefits appear to be found when RFID is applied to clinical transformation in terms of patient-flow management and medication administration. The return on investment is harder to quantify, yet the business benefits to patients and providers are immense.

Nicholas D. Evans is the global lead of emerging technology at BearingPoint. *He is the author of* Business Innovation and Disruptive Technology *(Financial Times, Prentice Hall) and chairs the RFID Standards Task Group for the* Information Technology Association of America *(ITAA). He can be reached at* mailto:nicholas.evans@bearingpoint.com?subject=.

| Back to normal page view | Send this article to a friend |

Telephone

22

Telephone Service: Call-by-Call Data

vru+line	call_id	customer_id	priority	type	date	vru_entry	vru_exit	vru_time	q_start	q_exit	q_time	outcome	ser_start	ser_exit	ser_time	server
AA0101	44749	27644400	2	PS	990901	11:45:33	11:45:39	6	11:45:39	11:46:58	79	AGENT	11:46:57	11:51:00	243	DORIT
AA0101	44750	12887816	1	PS	990905	14:49:00	14:49:06	6	14:49:06	14:53:00	234	AGENT	14:52:59	14:54:29	90	ROTH
AA0101	44967	58660291	2	PS	990905	14:58:42	14:58:48	6	14:58:48	15:02:31	223	AGENT	15:02:31	15:04:10	99	ROTH
AA0101	44968	0	0	NW	990905	15:10:17	15:10:26	9	15:10:26	15:13:19	173	HANG	00:00:00	00:00:00	0	NO_SERVER
AA0101	44969	63193346	2	PS	990905	15:22:07	15:22:13	6	15:22:13	15:23:21	68	AGENT	15:23:20	15:25:25	125	STEREN
AA0101	44970	0	0	NW	990905	15:31:33	15:31:47	14	00:00:00	00:00:00	0	AGENT	15:31:45	15:34:16	151	STEREN
AA0101	44971	41630443	2	PS	990905	15:37:29	15:37:34	5	15:37:34	15:38:20	46	AGENT	15:38:18	15:40:56	158	TOVA
AA0101	44972	64185333	2	PS	990905	15:44:32	15:44:37	5	15:44:37	15:47:57	200	AGENT	15:47:56	15:49:02	66	TOVA
AA0101	44973	3.06E+08	1	PS	990905	15:53:05	15:53:11	6	15:53:11	15:56:39	208	AGENT	15:56:38	15:56:47	9	MORIAH
AA0101	44974	74780917	2	NE	990905	15:59:34	15:59:40	6	15:59:40	16:02:33	173	AGENT	16:02:33	16:26:04	1411	ELI
AA0101	44975	55920755	2	PS	990905	16:07:46	16:07:51	5	16:07:51	16:08:01	10	HANG	00:00:00	00:00:00	0	NO_SERVER
AA0101	44976	0	0	NW	990905	16:11:38	16:11:48	10	16:11:48	16:11:50	2	HANG	00:00:00	00:00:00	0	NO_SERVER
AA0101	44977	33689787	2	PS	990905	16:14:27	16:14:33	6	16:14:33	16:14:54	21	HANG	00:00:00	00:00:00	0	NO_SERVER
AA0101	44978	23817067	2	PS	990905	16:19:11	16:19:17	6	16:19:17	16:19:39	22	AGENT	16:19:38	16:21:57	139	TOVA
AA0101	44764	0	0	PS	990901	15:03:26	15:03:36	10	00:00:00	00:00:00	0	AGENT	15:03:35	15:06:36	181	ZOHARI
AA0101	44765	25219700	2	PS	990901	15:14:46	15:14:51	5	15:14:51	15:15:10	19	AGENT	15:15:09	15:17:00	111	SHARON
AA0101	44766	0	0	PS	990901	15:25:48	15:26:00	12	00:00:00	00:00:00	0	AGENT	15:25:59	15:28:15	136	ANAT
AA0101	44767	58859752	2	PS	990901	15:34:57	15:35:03	6	15:35:03	15:35:14	11	AGENT	15:35:13	15:35:15	2	MORIAH
AA0101	44768	0	0	PS	990901	15:46:30	15:46:39	9	00:00:00	00:00:00	0	AGENT	15:46:38	15:51:51	313	ANAT
AA0101	44769	78191137	2	PS	990901	15:56:03	15:56:09	6	15:56:09	15:56:28	19	AGENT	15:56:28	15:59:02	154	MORIAH
AA0101	44770	0	0	PS	990901	16:14:31	16:14:46	15	00:00:00	00:00:00	0	AGENT	16:14:44	16:16:02	78	BENSION
AA0101	44771	0	0	PS	990901	16:38:59	16:39:12	13	00:00:00	00:00:00	0	AGENT	16:39:11	16:43:35	264	VICKY
AA0101	44772	0	0	PS	990901	16:51:40	16:51:50	10	00:00:00	00:00:00	0	AGENT	16:51:49	16:53:52	123	ANAT
AA0101	44773	0	0	PS	990901	17:02:19	17:02:28	9	00:00:00	00:00:00	0	AGENT	17:02:28	17:07:42	314	VICKY
AA0101	44774	32387482	1	PS	990901	17:18:18	17:18:24	6	17:18:24	17:19:01	37	AGENT	17:19:00	17:19:35	35	VICKY
AA0101	44775	0	0	PS	990901	17:38:53	17:39:05	12	00:00:00	00:00:00	0	AGENT	17:39:04	17:40:43	99	TOVA
AA0101	44776	0	0	PS	990901	17:52:59	17:53:09	10	00:00:00	00:00:00	0	AGENT	17:53:08	17:53:09	1	NO_SERVER
AA0101	44777	37635950	2	PS	990901	18:15:47	18:15:52	5	18:15:52	18:16:57	65	AGENT	18:16:56	18:18:48	112	ANAT
AA0101	44778	0	0	NE	990901	18:30:43	18:30:52	9	00:00:00	00:00:00	0	AGENT	18:30:51	18:30:54	3	MORIAH
AA0101	44779	0	0	PS	990901	18:51:47	18:52:02	15	00:00:00	00:00:00	0	AGENT	18:52:02	18:55:30	208	TOVA
AA0101	44780	0	0	PS	990901	19:19:04	19:19:17	13	00:00:00	00:00:00	0	AGENT	19:19:15	19:20:20	65	MEIR
AA0101	44781	0	0	PS	990901	19:39:19	19:39:30	11	00:00:00	00:00:00	0	AGENT	19:39:29	19:41:42	133	BENSION
AA0101	44782	0	0	NW	990901	20:08:13	20:08:25	12	00:00:00	00:00:00	0	AGENT	20:08:28	20:08:41	13	NO_SERVER
AA0101	44783	0	0	PS	990901	20:23:51	20:24:05	14	00:00:00	00:00:00	0	AGENT	20:24:04	20:24:33	29	BENSION
AA0101	44784	0	0	NW	990901	20:36:54	20:37:14	20	00:00:00	00:00:00	0	AGENT	20:37:13	20:38:07	54	BENSION
AA0101	44785	0	0	PS	990901	20:50:07	20:50:16	9	00:00:00	00:00:00	0	AGENT	20:50:15	20:51:32	77	BENSION
AA0101	44786	0	0	PS	990901	21:04:41	21:04:51	10	00:00:00	00:00:00	0	AGENT	21:04:50	21:05:59	69	TOVA
AA0101	44787	0	0	PS	990901	21:25:00	21:25:13	13	00:00:00	00:00:00	0	AGENT	21:25:13	21:28:03	170	AVI
AA0101	44788	0	0	PS	990901	21:50:40	21:50:54	14	00:00:00	00:00:00	0	AGENT	21:50:54	21:51:55	61	AVI
AA0101	44789	9103060	2	NE	990901	22:05:40	22:05:46	6	22:05:46	22:09:52	246	AGENT	22:09:51	22:13:41	230	AVI
AA0101	44790	14558621	2	PS	990901	22:24:11	22:24:17	6	22:24:17	22:26:16	119	AGENT	22:26:15	22:27:28	73	VICKY
AA0101	44791	0	0	PS	990901	22:46:27	22:46:37	10	00:00:00	00:00:00	0	AGENT	22:46:36	22:47:03	27	AVI
AA0101	44792	67158097	2	PS	990901	23:05:07	23:05:13	6	23:05:13	23:05:30	17	AGENT	23:05:29	23:06:49	80	VICKY
AA0101	44793	15317126	2	PS	990901	23:28:52	23:28:58	6	23:28:58	23:30:08	70	AGENT	23:30:07	23:35:03	296	DARMON
AA0101	44794	0	0	PS	990902	00:10:47	00:12:05	78	00:00:00	00:00:00	0	HANG	00:00:00	00:00:00	0	NO_SERVER
AA0101	44795	0	0	PS	990902	07:16:52	07:17:01	9	00:00:00	00:00:00	0	AGENT	07:17:01	07:17:44	43	ANAT
AA0101	44796	0	0	PS	990902	07:50:05	07:50:16	11	00:00:00	00:00:00	0	AGENT	07:50:16	07:53:03	167	STEREN

Command Center Intraday Report

Updated Through: All Day

Date 06/13 - Tue		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%

Notes:

∃ 35 large - medium Call Centers
~ 100 total

33

3.

Internet

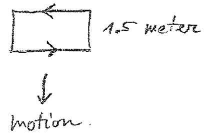
Web Access Log

(From a CD that accompanies
"Capacity Planning for Web Performance", by
Menasce, D.A. and Almeida, V.A.F., Prentice Hall, 1998.)

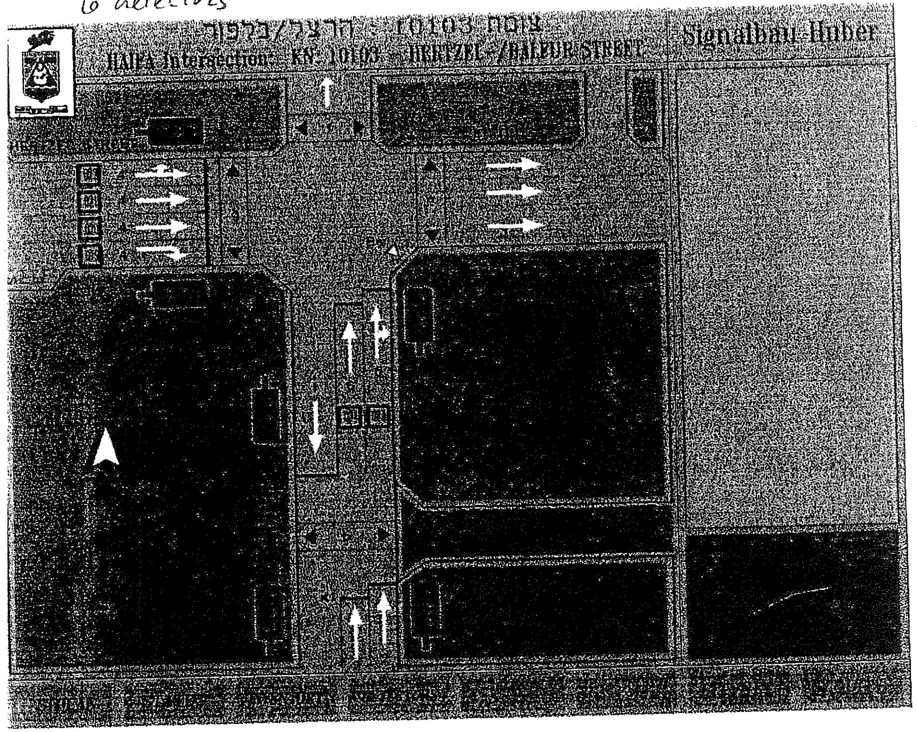
```
local [24/Oct/1994:13:41:41   -0600]   """GET"   "index.html HTTP/1.0"" 200 150"
local [24/Oct/1994:13:41:41   -0600]   """GET"   "1.gif HTTP/1.0"" 200 1210"
local [24/Oct/1994:13:43:13   -0600]   """GET"   "index.html HTTP/1.0"" 200 3185"
local [24/Oct/1994:13:43:14   -0600]   """GET"   "2.gif HTTP/1.0"" 200 2555"
local [24/Oct/1994:13:43:15   -0600]   """GET"   "3.gif HTTP/1.0"" 200 36403"
local [24/Oct/1994:13:43:17   -0600]   """GET"   "4.gif HTTP/1.0"" 200 441"
local [24/Oct/1994:13:46:45   -0600]   """GET"   "index.html HTTP/1.0"" 200 3185"
local [24/Oct/1994:13:46:45   -0600]   """GET"   "2.gif HTTP/1.0"" 200 2555"
local [24/Oct/1994:13:46:47   -0600]   """GET"   "3.gif HTTP/1.0"" 200 36403"
local [24/Oct/1994:13:46:50   -0600]   """GET"   "4.gif HTTP/1.0"" 200 441"
local [24/Oct/1994:13:47:19   -0600]   """GET"   "index.html HTTP/1.0"" 200 150"
local [24/Oct/1994:13:47:19   -0600]   """GET"   "1.gif HTTP/1.0"" 200 1210"
local [24/Oct/1994:13:47:41   -0600]   """GET"   "index.html HTTP/1.0"" 200 3185"
local [24/Oct/1994:13:47:50   -0600]   """GET"   "5.html HTTP/1.0"" 200 2065"
local [24/Oct/1994:13:48:11   -0600]   """GET"   "6.html HTTP/1.0"" 200 1124"
local [24/Oct/1994:13:48:23   -0600]   """GET"   "7.html HTTP/1.0"" 200 1538"
local [24/Oct/1994:13:48:51   -0600]   """GET"   "8.html HTTP/1.0"" 200 322"
local [24/Oct/1994:13:49:01   -0600]   """GET"   "index.html HTTP/1.0"" 302 -"
local [24/Oct/1994:13:49:01   -0600]   """GET"   "index.html HTTP/1.0"" 200 999"
local [24/Oct/1994:13:49:14   -0600]   """GET"   "9.html HTTP/1.0"" 200 1248"
local [24/Oct/1994:13:49:20   -0600]   """GET"   "index.html HTTP/1.0"" 200 3185"
local [24/Oct/1994:13:49:21   -0600]   """GET"   "2.gif HTTP/1.0"" 200 2555"
local [24/Oct/1994:13:49:25   -0600]   """GET"   "3.gif HTTP/1.0"" 200 36403"
local [24/Oct/1994:13:49:27   -0600]   """GET"   "4.gif HTTP/1.0"" 200 441"
local [24/Oct/1994:13:49:39   -0600]   """GET"   "index.html HTTP/1.0"" 200 150"
local [24/Oct/1994:13:49:49   -0600]   """GET"   "10.html HTTP/1.0"" 200 2286"
local [24/Oct/1994:13:50:33   -0600]   """GET"   "index.html HTTP/1.0"" 200 150"
local [24/Oct/1994:13:55:03   -0600]   """GET"   "11.html HTTP/1.0"" 200 1213"
local [24/Oct/1994:13:55:04   -0600]   """GET"   "11.html HTTP/1.0"" 200 1213"
local [24/Oct/1994:13:55:08   -0600]   """GET"   "12.gif HTTP/1.0"" 200 191"
local [24/Oct/1994:13:55:21   -0600]   """GET"   "13.gif HTTP/1.0"" 200 33974"
local [24/Oct/1994:13:59:48   -0600]   """GET"   "index.html HTTP/1.0"" 200 3185"
local [24/Oct/1994:13:59:55   -0600]   """GET"   "14.html HTTP/1.0"" 304 0"
local [24/Oct/1994:14:00:06   -0600]   """GET"   "index.html HTTP/1.0"" 200 3100"
local [24/Oct/1994:14:00:20   -0600]   """GET"   "index.html HTTP/1.0"" 302 -"
local [24/Oct/1994:14:00:20   -0600]   """GET"   "index.html HTTP/1.0"" 200 631"
local [24/Oct/1994:14:00:25   -0600]   """GET"   "15.html HTTP/1.0"" 200 861"
local [24/Oct/1994:14:00:49   -0600]   """GET"   "index.html HTTP/1.0"" 200 631"
local [24/Oct/1994:14:00:52   -0600]   """GET"   "16.html HTTP/1.0"" 200 1006"
local [24/Oct/1994:14:01:02   -0600]   """GET"   "index.html HTTP/1.0"" 200 150"
local [24/Oct/1994:14:01:11   -0600]   """GET"   "17.html HTTP/1.0"" 200 881"
local [24/Oct/1994:14:01:24   -0600]   """GET"   "18.html HTTP/1.0"" 200 709"
local [24/Oct/1994:14:01:42   -0600]   """GET"   "19.html HTTP/1.0"" 200 1357"
local [24/Oct/1994:14:02:01   -0600]   """GET"   "index.html HTTP/1.0"" 200 391"
remote        [24/Oct/1994:14:03:32   -0600]   ""GET"   "T 20.html HTTP/1.0"" 200 1530"
remote        [24/Oct/1994:14:03:36   -0600]   ""GET"   "T 21.gif HTTP/1.0"" 200 59975"
local [24/Oct/1994:14:03:39   -0600]   """GET"   "index.html HTTP/1.0"" 200 410"
remote        [24/Oct/1994:14:03:49   -0600]   ""GET"   "T 22.html HTTP/1.0"" 200 7151"
local [24/Oct/1994:14:04:22   -0600]   """GET"   "index.html HTTP/1.0"" 200 410"
local [24/Oct/1994:14:05:17   -0600]   """GET"   "index.html HTTP/1.0"" 200 419"
remote        [24/Oct/1994:14:05:31   -0600]   ""GET"   "T 23.html HTTP/1.0"" 200 3787"
remote        [24/Oct/1994:14:06:07   -0600]   ""GET"   "T 24.html HTTP/1.0"" 200 4326"
```

(On measurement methodology + metrics: see www.xiwt.org)

Transportation: detectors



6 detectors



Transportation ("Smart" Highways)

3/5.0

Transportation

17-mar-1993 VOLUMES REPORT Page:1

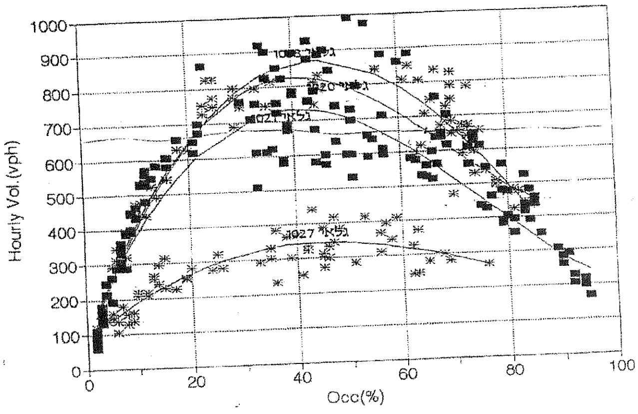
Group#1: 1013
Group#2: 1014
Group#3: 1015
Group#4: 1017

Date	Time	Vol1	vol2	vol3	vol4	
Sun-21-feb-1993						
	00:00:00	49	75	19	0	143
	00:15:00	34	49	12	0	95
	00:30:00	24	46	13	0	83
	00:45:00	10	36	7	0	53
	01:00:00	11	47	3	0	61
	01:15:00	12	45	2	0	59
	01:30:00	10	46	5	0	61
	01:45:00	6	37	3	0	46
	02:00:00	9	36	3	0	48
	02:15:00	8	27	3	0	38
	02:30:00	15	21	0	0	36
	02:45:00	12	22	5	0	39
	03:00:00	13	35	2	0	50
	03:15:00	2	18	1	0	21
	03:30:00	9	24	1	0	34
	03:45:00	7	21	1	0	29
	04:00:00	4	11	3	0	18
	04:15:00	3	8	1	0	12
	04:30:00	6	11	3	0	20
	04:45:00	4	17	1	0	22
	05:00:00	9	21	5	0	35
	05:15:00	7	22	8	0	37
	05:30:00	13	43	15	0	71
	05:45:00	17	40	22	0	79
	06:00:00	26	64	28	0	118
	06:15:00	36	84	46	0	166
	06:30:00	34	79	41	0	154
	06:45:00	40	88	66	0	194
	07:00:00	46	91	72	0	209
	07:15:00	48	99	67	0	214
	07:30:00	51	93	64	0	208
	07:45:00	60	113	58	0	231
	08:00:00	56	134	60	0	250
	08:15:00	58	133	82	0	273
	08:30:00	40	154	34	0	228
	08:45:00	67	147	84	0	298
	09:00:00	88	132	99	30	349
	09:15:00	68	126	71	131	396
	09:30:00	71	140	98	122	431
	09:45:00	83	159	89	147	478
	10:00:00	78	144	85	135	442
	10:15:00	85	160	42	137	424
	10:30:00	78	156	88	100	422
	10:45:00	83	160	54	117	414
	11:00:00	84	139	72	132	427
	11:15:00	92	169	78	156	495
	11:30:00	82	165	[illegible]	144	495
	11:45:00	97	169	69	136	471
	12:00:00	91	129	103	154	477
	12:15:00	81	171	40	164	456
	12:30:00	85	112	85	136	418
	12:45:00	85	83	88	102	358
	13:00:00	93	96	90	120	399
	13:15:00	65	98	116	73	352
	13:30:00	86	101	104	106	397
	13:45:00	76	171	87	177	511
	14:00:00	80	176	83	170	509
	14:15:00	66	142	66	129	403
	14:30:00	81	173	79	144	477
	14:45:00	87	163	62	179	491
	15:00:00	94	179	91	196	560
	15:15:00	82	168	75	174	499
	15:30:00	80	160	74	200	514
	15:45:00	107	191	81	169	548
	16:00:00	96	167	86	150	499
	16:15:00	111	182	33	190	516
	16:30:00	108	140	37	151	436
	16:45:00	98	154	101	126	479
	17:00:00	78	96	102	150	426
	17:15:00	78	124	95	108	405
	17:30:00	78	95	105	105	383
	17:45:00	96	118	106	126	446
	18:00:00	81	114	103	113	411
	18:15:00	84	144	111	141	480
	18:30:00	89	136	107	140	472
	18:45:00	96	156	67	168	487
	19:00:00	102	144	102	142	490
	19:15:00	93	147	102	124	466
	19:30:00	92	156	83	85	416
	19:45:00	84	157	63	158	462
	20:00:00	78	170	69	132	449
	20:15:00	79	162	24	122	387
	20:30:00	62	128	46	109	345
	20:45:00	75	122	46	107	350
	21:00:00	69	117	51	93	330
	21:15:00	63	97	34	99	293
	21:30:00	43	104	31	80	258
	21:45:00	53	113	38	80	284
	22:00:00	43	61	27	69	200
	22:15:00	46	68	26	57	197
	22:30:00	49	73	30	70	222
	22:45:00	28	63	26	36	153
	23:00:00	31	61	29	44	165
	23:15:00	43	92	26	65	226
	23:30:00	42	68	24	49	183
	23:45:00	0	0	0	0	0

Date	Time	Vol1	vol2	vol3	vol4	
Mon-22-feb-1993						
	00:00:00	25	32	10	37	104
	00:15:00	21	43	13	32	109

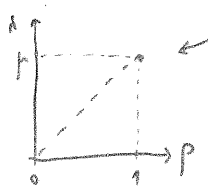
Puzzle: transportation
communication

HERZEL - BALFUR
KN010103-4 1020-1-7-8 27-28/9/93



Occupancy

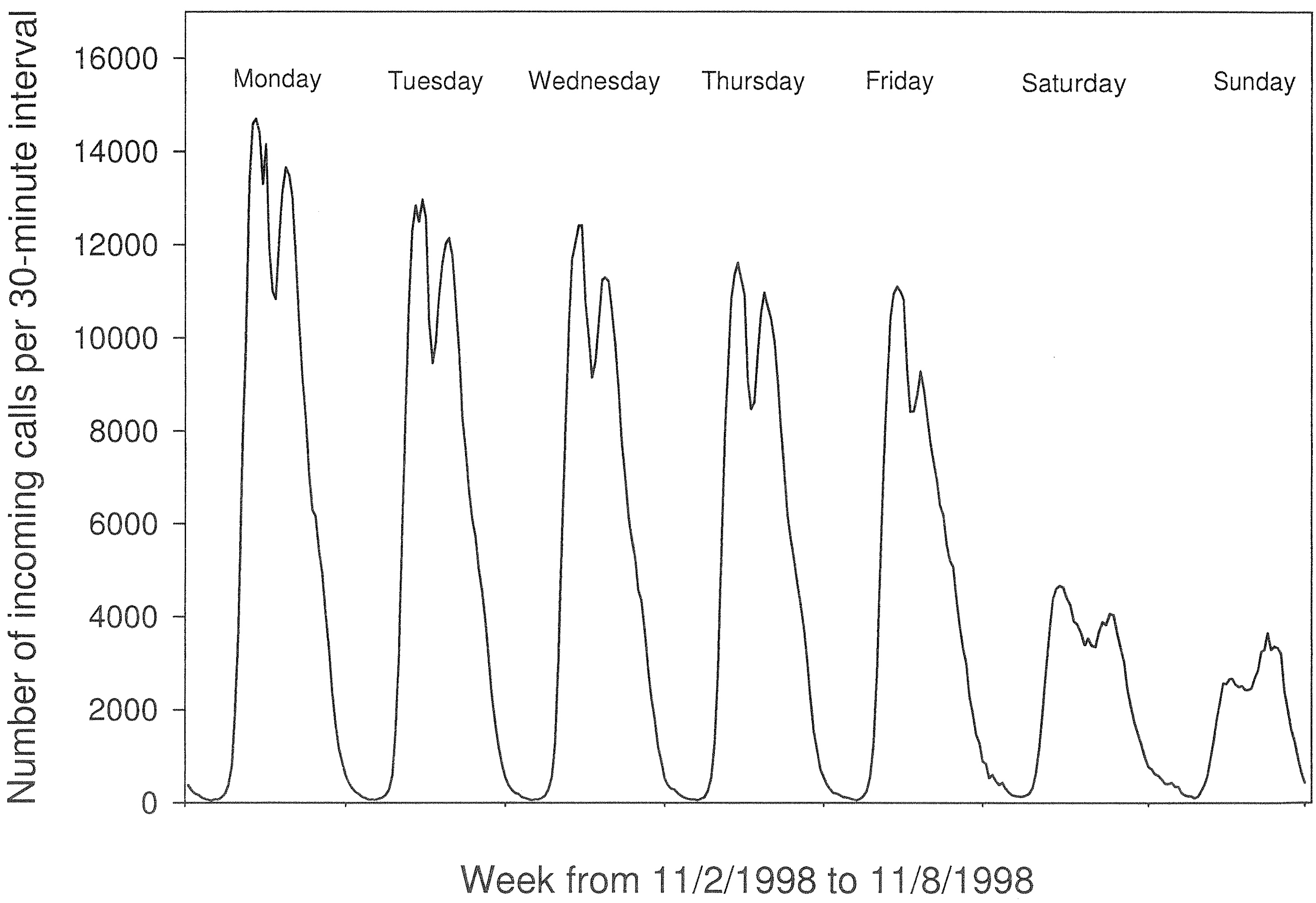
תרגיל: הסבר לתופעה המתוארת ע"י הגרף „הרצל-בלפור".



Charlotte – Center

6/13/00 - Tue

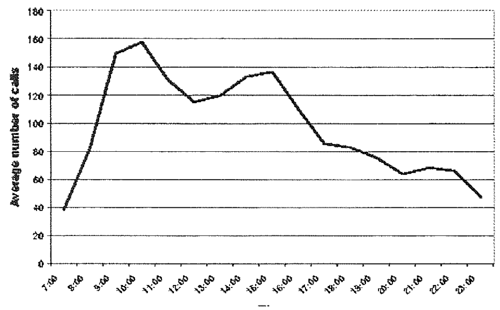
Time	Recvd	Answ	Abn %	ASA	AHT	Occ %	On Prod%	On Prod FTE	Sch Open FTE	Sch Avail %
Total	**20,577**	**19,860**	**~3.0%**	**30**	**307**	**95.1%**	**85.4%**	**222.7**	**234.6**	**95.0%**
8:00	332	308	7.2%	27	302	87.1%	79.5%	59.3	66.9	88.5%
8:30	653	615	5.8%	58	293	96.1%	81.1%	104.1	111.7	93.2%
9:00	866	796	8.1%	63	308	97.1%	84.7%	140.4	145.3	96.6%
9:30	1,152	1,138	1.2%	218	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%



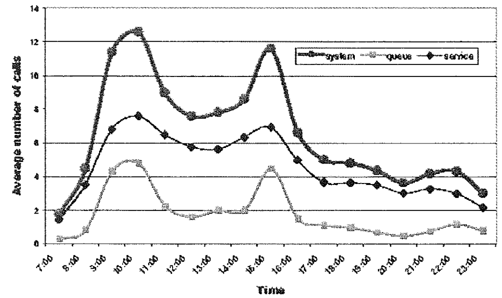
Time-Varying Queues: Predictable Variability

(with Jennings, Massey, Whitt)

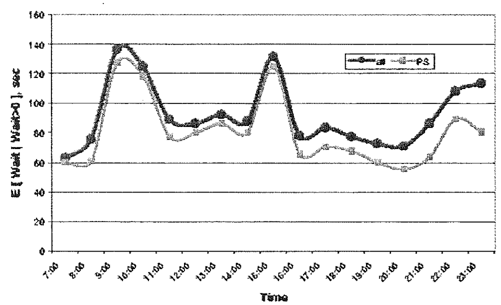
Arrivals



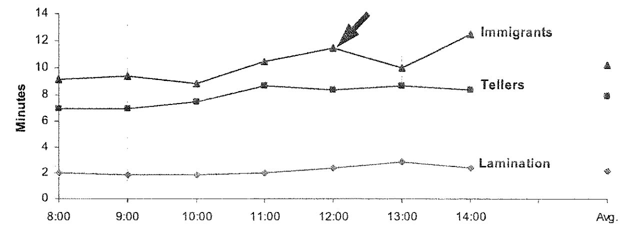
Queues



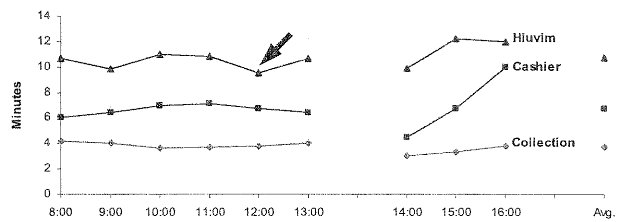
Waiting



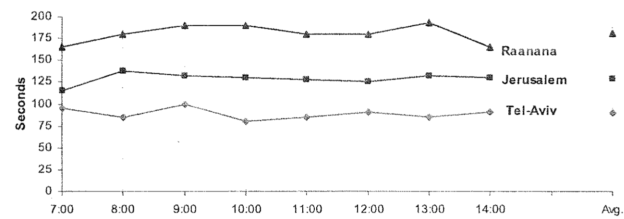
Average Service Durations Over The Day



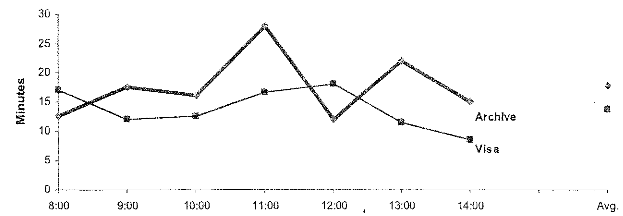
Time or State Dependent ?



3 Patterns



3 Branches Provide the Same Tele-Service

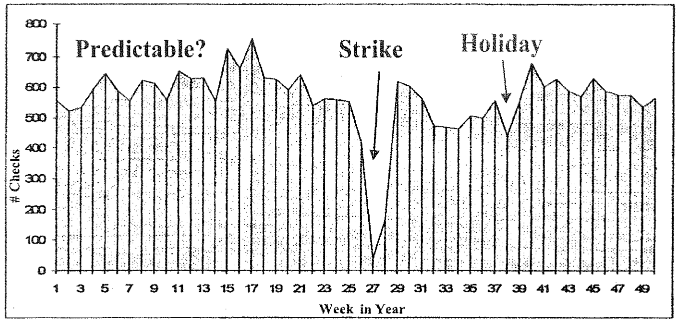


? Sample Size !

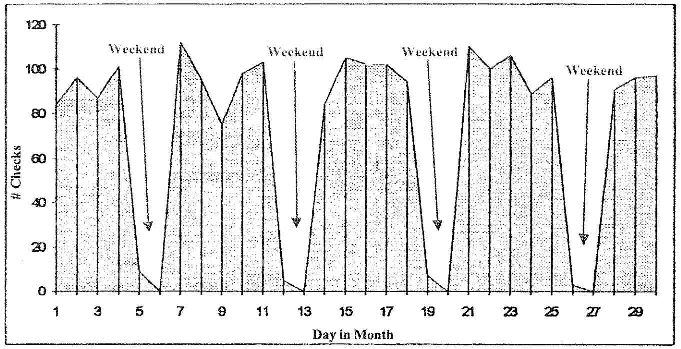
"Fluid" – view, but …

Custom Inspections at an Airport

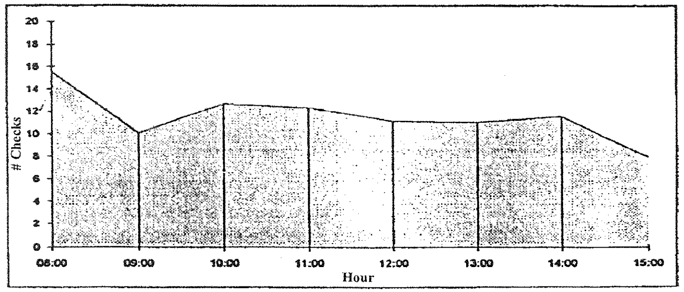
Number of Checks Made During 1993:



Number of Checks Made in November 1993:

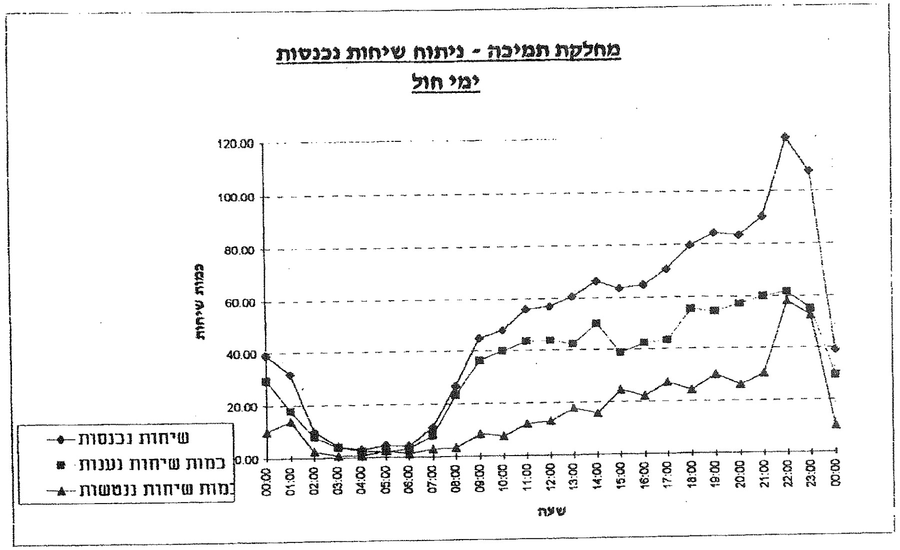


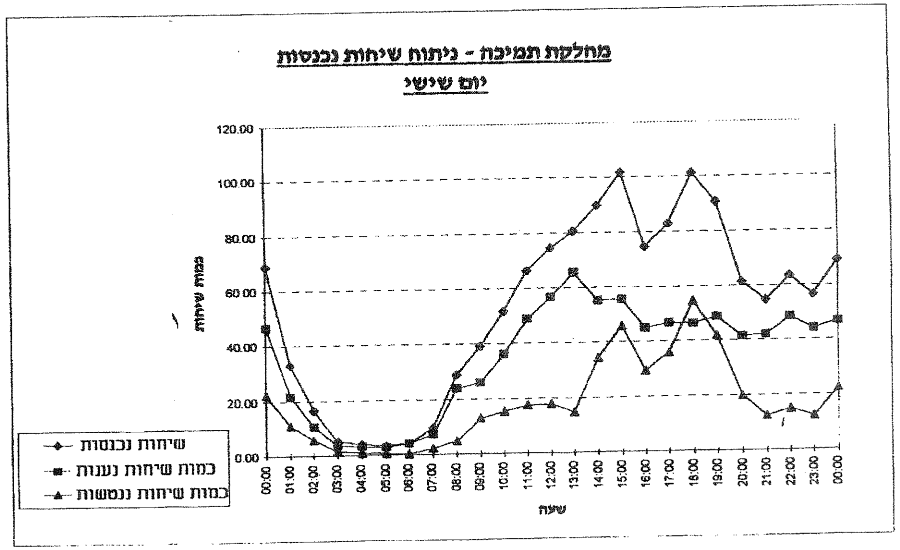
Average Number of Checks During the Day:



Source: Ben-Gurion Airport Custom Inspectors Division

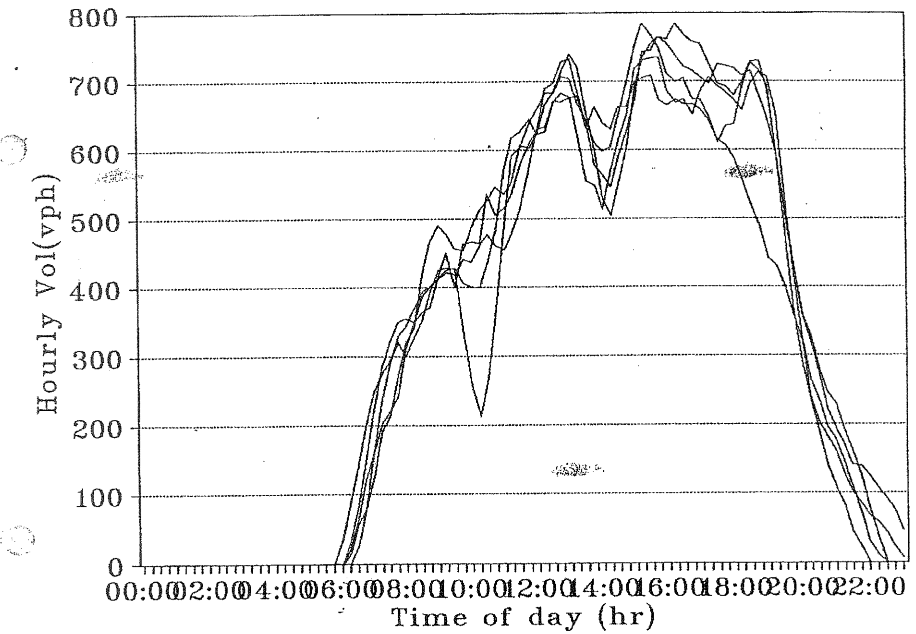
מחלקת תמיכה





מדידות בתחבורה

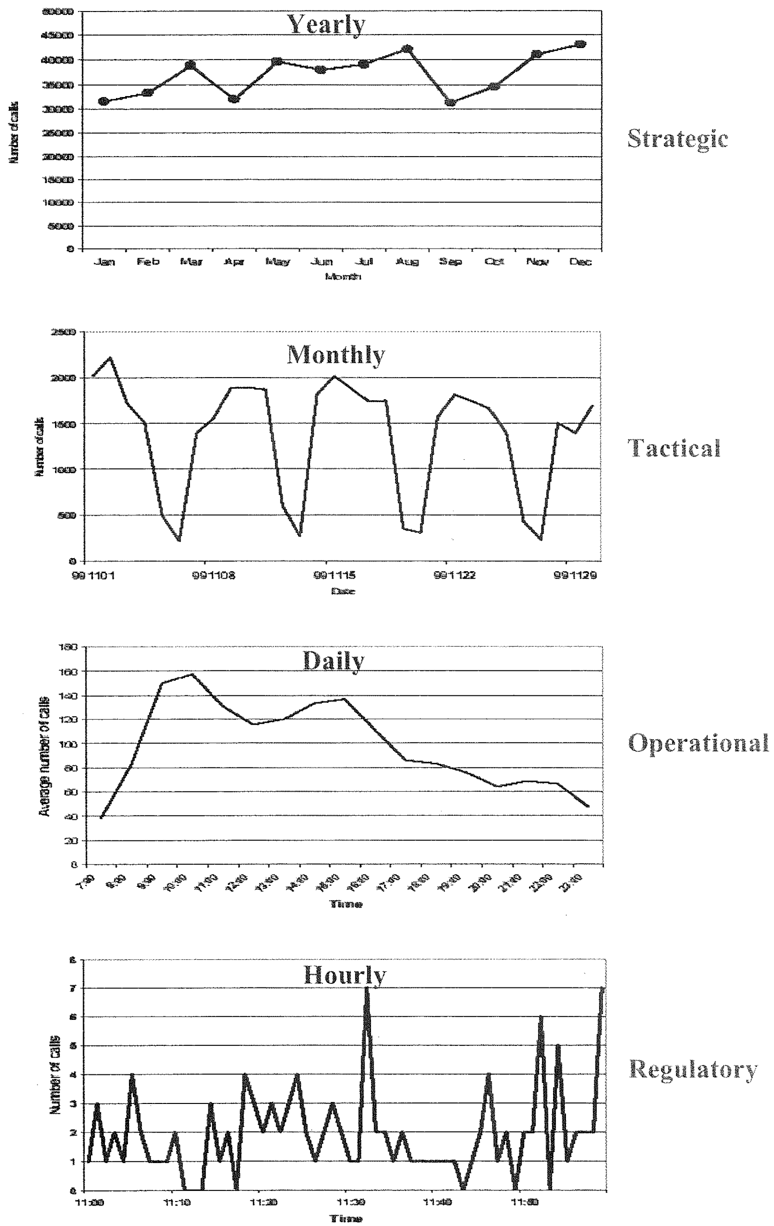
גלאי תנועה : גלאי על מסלול



Data via one of six detectors

Each graph displays 1-day data (predictable variability)

Arrival Process: Time Scales



Q-Science

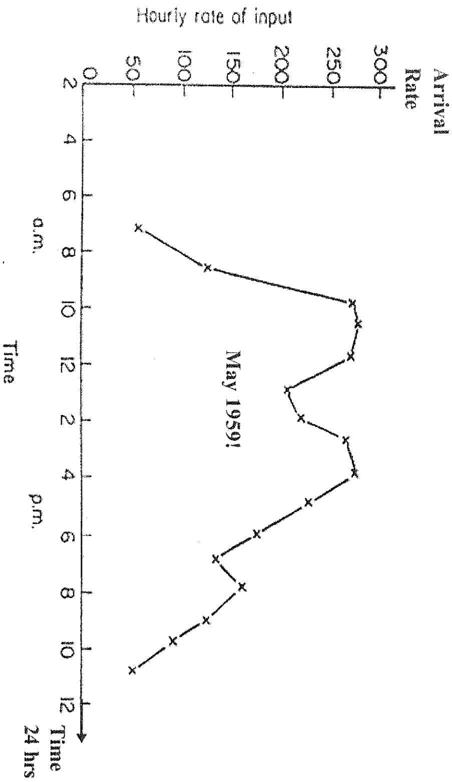
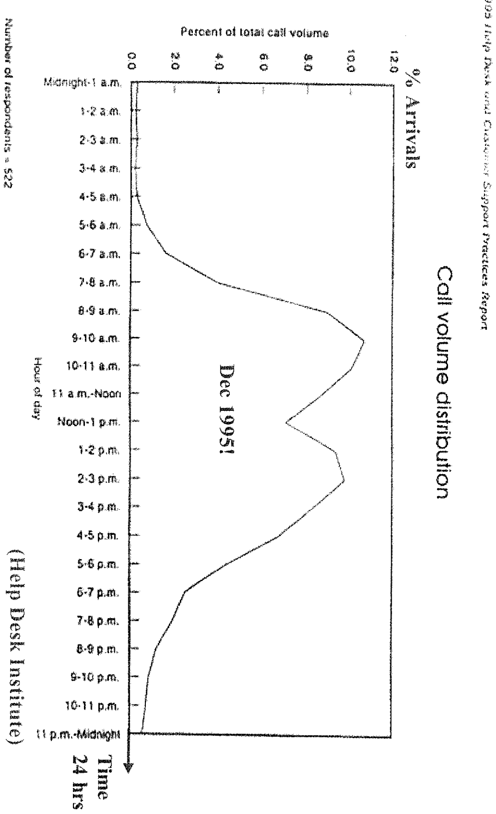


Fig. 15.1 The variation in the hourly input rates of reservations calls during a typical day (in May 1959)

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



1995 Help Desk and Customer Support Practices Report

(Help Desk Institute)

Arrival Process, in 1976

(E. S. Buffa, M. J. Cosgrove, and B. J. Luce, "An Integrated Work Shift Scheduling System", Decision Sciences, 7, 620-630 (1976))

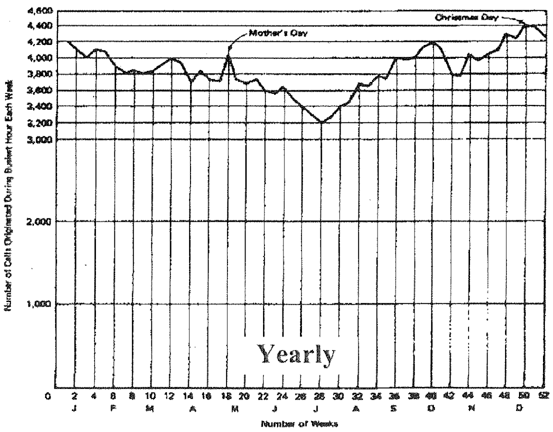


Figure 1 Typical distribution of calls during the busiest hour for each week during a year.

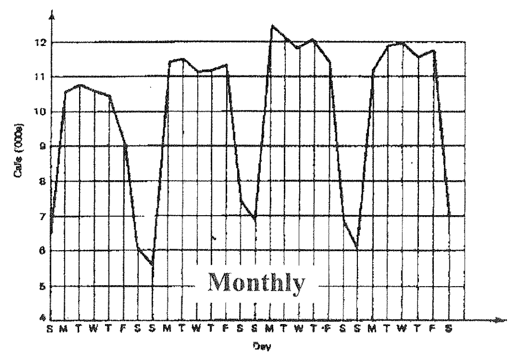


Figure 2 Daily call load for Long Beach, January 1972.

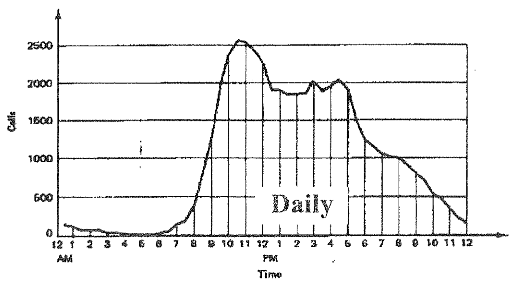


Figure 3 Typical half-hourly call distribution (Bundy D A).

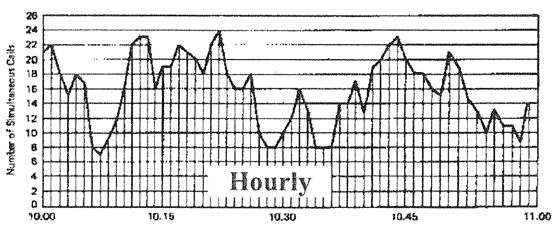
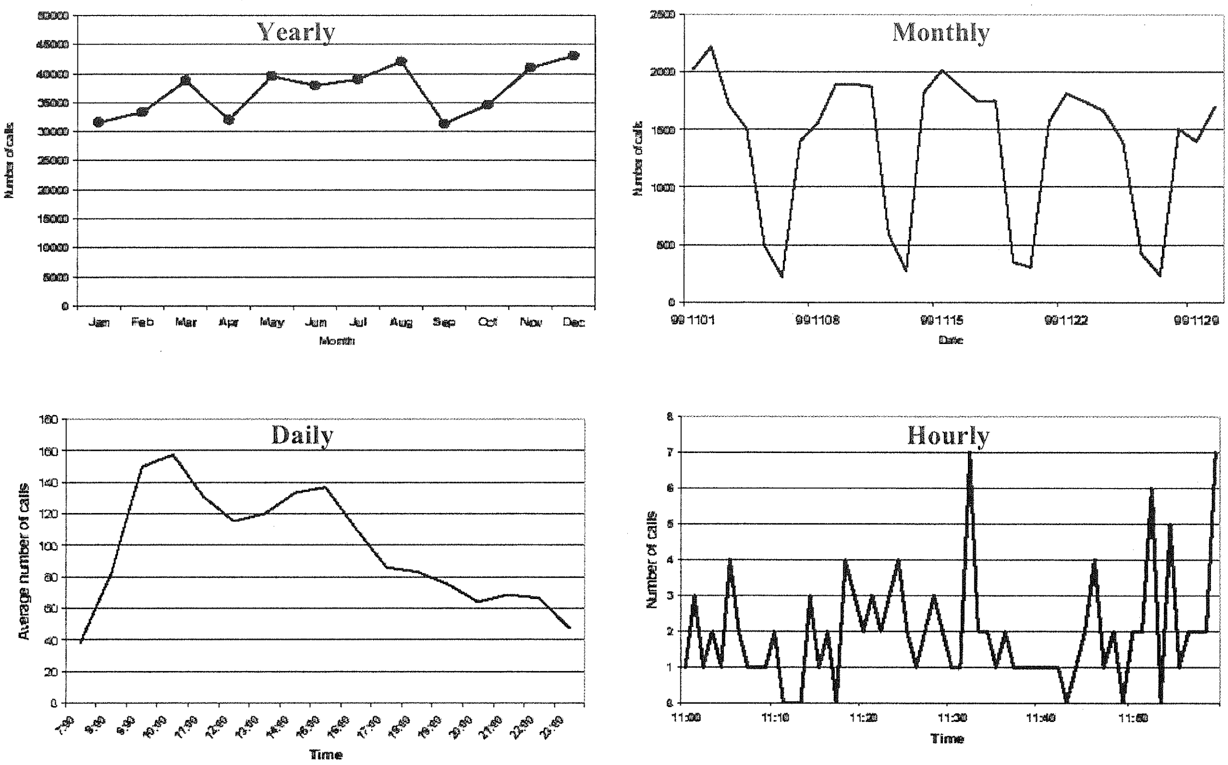


Figure 4 Typical intrahour distribution of calls, 10:00–11:00 A.M.

Arrival Process, in 1999



Arrivals: Inhomogeneous Poisson

Figure 1: Arrivals (to queue or service) – "Regular" Calls

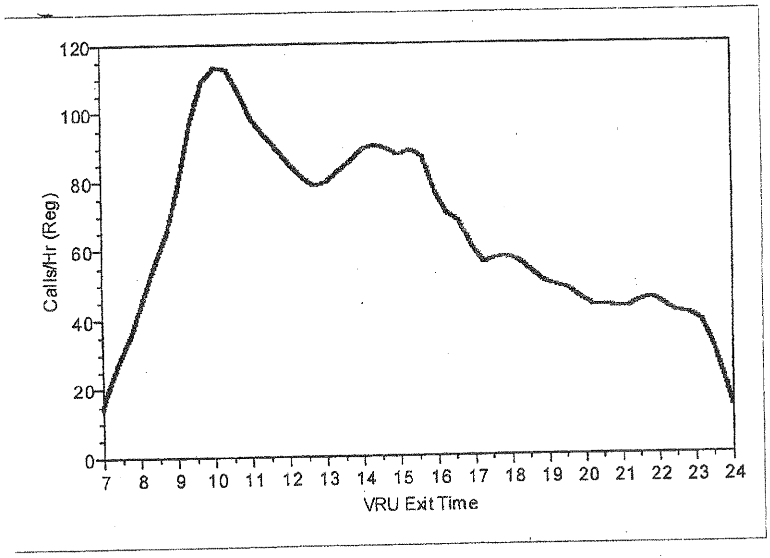
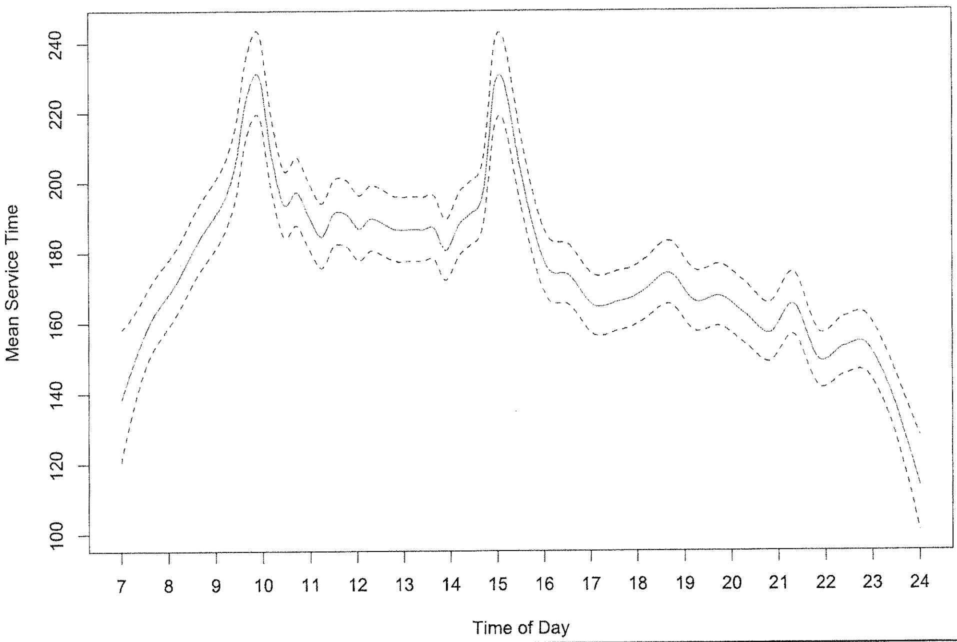


Figure 12: Mean Service Time (Regular) vs. Time-of-day (95% CI) ($n =$ 42613)



Measurements

- Data is the Language of Nature
- Prerequisite for Science, Engineering and Mangement, yet
- Empirical "Axiom" = Problems with Historical Records
  - The data you need is not there for you to use:
    - Not collected or erased, contaminated, ...
  - If there is data, it has 'frequencies" but no "times":
    - Fires, Courts, Hospitals, Projects, ...
  - If "times", typically aggregated means but no std's:
    - Let alone histograms / distributions,
    - Typically small samples, too short time-periods
    - Often paper-archives, not computerized
- Challenges – not Technological
  - Too little: "Complete" Data (QIE, Abandons)
  - Too much: Transaction-mgt., Big-Brother, Data Mining
- Scope
  - Face-to-face services
  - Tele-services (Telephony, Hopefully Internet)
  - Administrative processes
  - Healthcare

משרד הפנים

נציבות כבאות והצלה

סקר סטטיסטי של שריפות וארועים

לתקופת ינואר — ספטמבר 1992

1.1

4 – פרוט לוחות סטטיסטיים

עמוד

4.1 לוחות ארציים:

4.2 לוחות לפי רשויות כיבוי

1.2

32

בכל דקה מוזעקת ניידת מגן דוד אדום

הלו"ז הצפוף של מד"א: בכל 9 דקות מפנים נפגע מתאונת דרכים ■ בכל 7 דקות מפנים פצוע טראומה ■ ובכל שעתיים לוקחים יולדת לביה"ח

מאת דן אבן

לניידות מגן דוד אדום אין רגע מנוח. לפי חוברת השנתון שפרסם הארגון לפעילותו בשנת 2005, בכל דקה מוזעק אמבולנס כדי לטפל בפצועים מאירוע כלשהו.

בכל דקה וחצי מפנה אמבולנס חולה לבית חולים. בכל שבע דקות מפונה נפגע מהתאבדות, התחשמלות, טביעה, נפילה מגובה, חנק ופציעה מידי או מאירוע טרור. בכל תשע דקות מפונה פצוע מתאונת דרכים. בכל שעתיים מעביר אמבולנס מד"א לבית החולים אישה הכורעת ללדת, ובכל חמש שעות מוזעק לטיפול פצוע תאונת עבודה.

444,691 נסיעות מבצעיות מסכם מד"א בשנה החולפת, בממוצע 1,218 נסיעות ביום. בסיכום כולל חלה עלייה של שלושה אחוזים וחצי בכמות הנסיעות המבצעיות של מד"א בהשוואה לשנת 2004.

במספר חולדות שפונו באמבולנס בשנה החולפת חלה דווקא ירידה של 2.2 אחוזים (בהשוואה לנתונים בשנת 2004), אבל במספר הלידות בתוך האמבולנסים חלה עלייה חדה (של 12 אחוז) – 440 תינוקות נולדו בתוך הניידת בדרך לבית החולים.

282,955 מנות דם הותרמו בשנת 2005 על ידי שירותי בנק הדם של מד"א, כרבע מהן נתרמו על ידי חיילי צה"ל. 89 אחוז ממנות הדם נאספו בהתרמות חוץ ו־11 אחוז נאספו מתורמים שהגיעו למתקני מד"א.

בבנק הדם מדווחים על עלייה של 37 אחוז בדרישה למנות ומרכיבי דם מוקרנים המיועדים לפגים, חולים המטולוגים ומועמדים להשתלות מח עצם עם מערכת חיסונית חלשה.

מעריב
7/3/2006

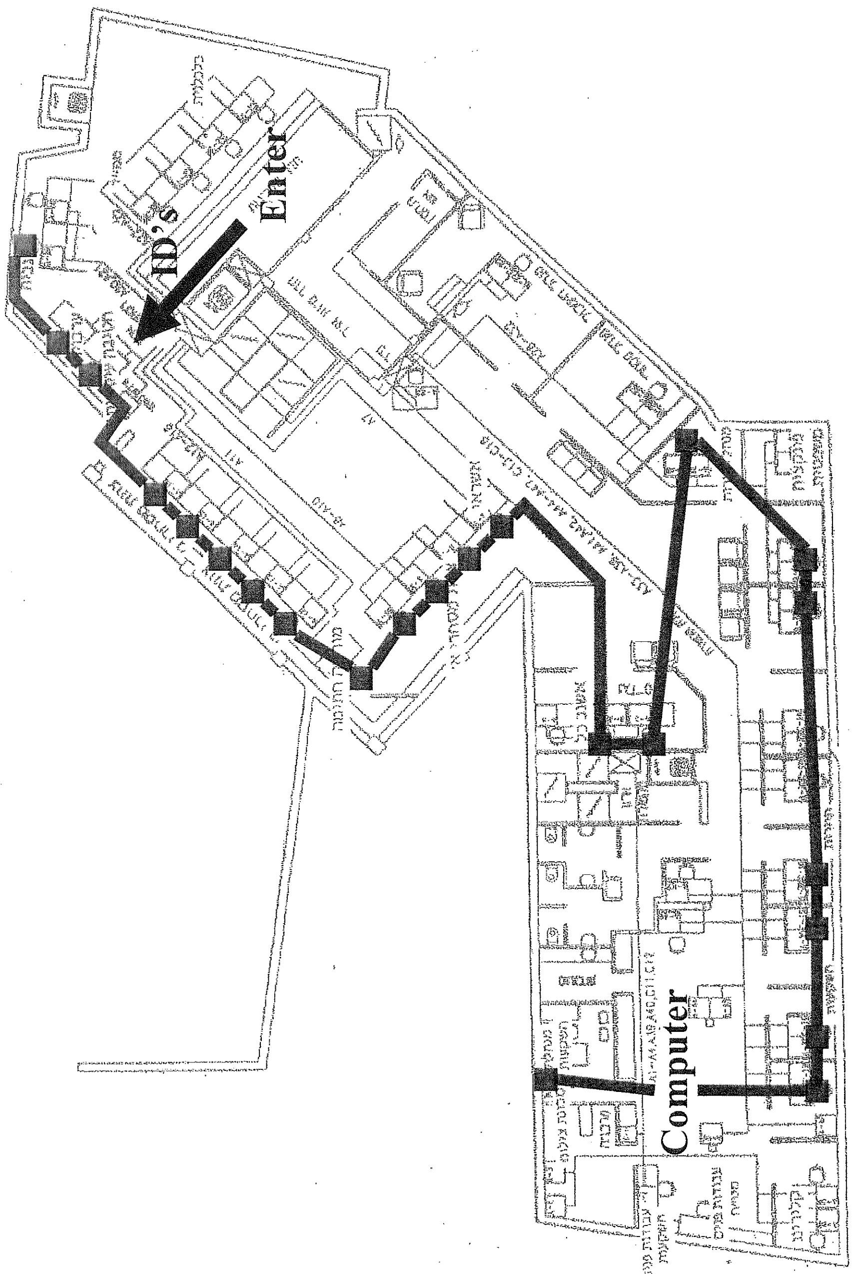
	אירועים אחרים OTHER EVENTS		סיוע לרשות אחרת ASSISTANCE TO OTHER AUTHORITY		יציאת שווא FALSE ALERT		שמירה, אבטחה, סיור וכוננות GUARDING, PATROLLING, AND ALERTNESS		אספקת מים ושטיפת כבישים WATER SUPPLY AND ROAD FINISHING		פריצת דלת BREAKING THROUGH DOORS		חילוץ מפולת COLLAPSE		הצפה, שאיבת מים INUNDATION AND WATER PUMPING		שריפות שכובו לפני בוא הכבאים FIRES EXTINGUISHED BEFORE FIRE-MEN'S ARRIVAL		שריפות FIRES		שריפות ואירועים אחרים - סה"כ FIRES AND OTHER EVENTS - TOTAL		
	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	
1991 - TOTAL		4567		157		3162		1408		2258		1863		1151		205		1630		12511		28932	1991 - סך הכל
1992 - TOTAL	4933		134		3568		965		2594		2121		1349		340		1873		16173		34050		1992 - סך הכל
DISTRICT																							מחוז
JERUSALEM	233		15		155		68		109		107		99		73		132		1940		2931	2337	ירושלים
NORTHERN	534		9		407		172		679		219		233		34		314		2969		5570	4700	הצפון
HAIFA	732		15		283		107		131		103		161		20		179		1709		3440	2692	חיפה
CENTRAL	1049		34		558		240		505		440		364		76		362		3223		6851	5935	המרכז
TEL AVIV	1840		61		1499		234		785		865		299		115		514		3327		9539	8595	תל אביב
SOUTHERNH	545				666		144		385		387		193		22		372		3005		5719	4673	הדרום
FIRE EXTIN. AUTHO.																							רשות כיבוי
JERUSALEM	142		10		76		50		26		85		68		58		106		1528		2149	1819	ירושלים
ELON	127		5		117		36		96		42		43		11		56		648		1181	1051	איילון
ELAT	39				77		15		40		3		38				40		202		444	409	אילת
ASHQELON	241				293		54		173		163		78		5		152		1148		2307	2107	אשקלון
BEER SHEVA	275				296		75		172		221		77		17		180		1655		2968	2157	באר שבע
BET SHEMESH	91		5		79		18		83		22		31		15		26		412		782	518	בית שמש
BENE BERAQ	175		8		192		61		76		38		60		11		116		735		1472	1310	בני ברק
GIVATAYIM	191		20		52		20		53		147		31		12		26		45		597	546	גבעתיים
WESTERN GALILEE	350				130		48		170		145		30		5		55		789		1722	1215	גליל מערבי
EASTERN GALILEE	84		2		66		43		151		26		36		7		74		719		1208	1543	גליל עליון
HERZELIYYA	89		16		45		55		51		49		38		4		56		222		625	548	הרצליה
HASHARON	66		2		150		69		77		145		32		27		55		448		1071	810	השרון
HADERA	123		5		81		27		103		13		88		14		71		458		983	825	חדרה
HOLON	249		1		374		39		201		226		55		11		101		771		2028	1665	חולון
HAIFA	609		10		202		80		28		90		73		6		108		1251		2457	1867	חיפה
TIBERIAS	72		2		60		17		42		6		30		9		41		497		776	648	טבריה
YIZREEL	28		5		151		64		316		42		137		13		144		964		1864	1294	יזרעאל
NETANYA	183		3		3		6		60		62		29		7		21		600		974	765	נתניה
PETAH TIQWA	502		10		137		67		65		74		116		18		109		746		1844	1611	פתח תקוה
RISHON LEZIYYON	101		7		77		33		113		76		87		8		54		370		926	878	ראשון לציון
REHOVOT	70		7		74		29		94		41		57		5		67		411		855	820	רחובות
RAMAT GAN	360		14		109		20		113		107		39		49		33		243		1087	1250	רמת גן
TEL AVIV	776		2		727		39		291		298		76		28		182		1311		3730	3276	תל אביב
MONTH																							חודשים
JANUARY	548		11		289		96		234		249		176		136		172		683		2594	2478	ינואר
FEBRUARY	688		7		274		46		164		202		152		102		173		638		2445	1826	פברואר
MARCH	524		5		264		63		263		258		112		24		156		995		2664	2567	מרץ
APRIL	453		13		363		71		293		224		119		14		163		1439		3152	2697	אפריל
MAY	502		13		518		272		277		210		138		13		237		2792		4972	4116	מאי
JUNE	552		25		470		115		296		213		158		10		274		2906		5019	4143	יוני
JULY	578		27		469		105		334		273		187		17		289		2644		4943	3990	יולי
AUGUST	534		17		488		93		369		239		155		13		220		2210		4338	3668	אוגוסט
SEPTEMBER	554		16		413		104		364		253		152		11		190		1866		3923	3226	ספטמבר
																							אוקטובר
																							נובמבר

6

4.3

33

Bank – 2nd Floor Measurements



Measurements of Queues : Example of Face-to-Face

DATE	CUST ID	ARRIVAL	SERVICE BEG	SERVICE END	SERVICE TIME	WAIT TIME	SERVICE POS	SERVER ID	SERVICE TYPE
040293	1005	8:03:11	8:03:46	8:14:17	10:31	0:35	10	10	27
040293	1006	8:05:23	8:11:33	8:12:45	1:12	6:09	12	12	29
040293	1007	8:07:01	8:07:16	8:09:47	2:32	0:14	12	12	11
040293	1008	8:07:10	8:09:34	8:15:51	6:18	2:24	6	6	20
040293	1009	8:07:19	8:09:47	8:11:33	1:45	2:28	12	12	11
040293	1006	8:12:45	8:19:32	8:19:44	0:12	6:48	5	5	29
040293	1010	8:14:04	8:14:17	8:15:51	1:34	0:13	10	10	27
040293	1008	8:15:51	8:15:51	8:15:55	0:04	0:00	10	10	20
040293	1006	8:19:44	8:19:44	8:44:25	24:41	0:00	5	5	12
040293	1012	8:26:55	8:28:37	8:30:53	2:16	1:42	12	12	11
040293	1013	8:27:37	8:33:31	8:34:16	0:45	5:55	10	10	27
040293	1014	8:29:05	8:30:14	8:31:33	1:19	1:10	6	6	20
040293	1014	8:31:33	8:35:36	8:35:39	0:03	4:03	12	12	20
040293	1016	8:33:52	8:34:16	8:44:49	10:33	0:24	10	10	27
040293	1014	8:35:39	8:35:39	8:41:12	5:33	0:00	12	12	11
040293	1018	8:39:01	8:43:29	8:50:31	7:02	4:28	12	12	11
040293	1019	8:39:57	8:41:12	8:43:29	2:18	1:15	12	12	11
040293	1021	8:43:20	8:50:31	8:53:07	2:36	7:11	12	12	11
040293	1022	8:47:21	8:53:07	8:58:18	5:11	5:46	12	12	11
040293	1023	8:47:24	8:49:06	8:54:32	5:26	1:42	6	6	20
040293	1024	8:50:07	8:51:54	8:54:32	2:38	1:48	10	10	27
040293	1025	8:50:58	8:58:18	8:59:29	1:11	7:20	12	12	11
040293	1021	8:53:07	8:54:52	8:55:05	0:13	1:45	5	5	11
040293	1027	8:53:11	8:59:29	9:12:33	13:04	6:18	12	12	11
040293	1023	8:54:32	8:54:32	8:54:35	0:03	0:00	10	10	20
040293	1023	8:54:35	8:54:35	9:03:02	8:27	0:00	10	10	27
040293	1021	8:55:05	8:55:05	9:02:49	7:44	0:00	5	5	12
040293	1028	9:00:57	9:03:02	9:09:38	6:36	2:05	10	10	27
040293	1029	9:01:56	9:06:27	9:39:48	33:21	4:30	6	6	21
040293	1030	9:08:51	9:10:02	9:12:41	2:39	1:11	2	2	26
040293	1031	9:08:54	9:09:38	9:13:35	3:56	0:44	10	10	27
040293	1032	9:09:06	9:12:33	9:16:29	3:56	3:27	12	12	11
040293	1030	9:12:41	9:15:18	9:21:50	6:32	2:37	5	5	26
040293	1020	9:13:35	9:13:35	9:13:37	0:03	0:00	10	10	12
040293	1020	9:13:38	9:13:38	9:20:39	7:01	0:00	10	10	27
040293	1034	9:17:07	9:21:50	9:27:39	5:48	4:43	5	5	12
040293	1036	9:19:43	9:27:39	9:32:04	4:25	7:55	5	5	12
040293	1037	9:20:07	9:20:39	9:22:37	1:57	0:32	10	10	27
040293	1030	9:21:50	9:22:37	9:22:39	0:03	0:47	10	10	26
040293	1030	9:22:39	9:22:39	9:34:05	11:25	0:00	10	10	27
040293	1036	9:32:04	9:32:11	9:32:12	0:02	0:07	12	12	12
040293	1036	9:32:12	9:32:12	9:46:30	14:17	0:00	12	12	11

T - traditional (IE work measurements)

Above: I - method (Israel) : comprehensive

vs. S - method (Sweden) : tickets

or C - method (Canada + U.S.) : sensors

But F - method (Future) : only service - transactions

or O - online (eg. Key Corp, F-Bay)

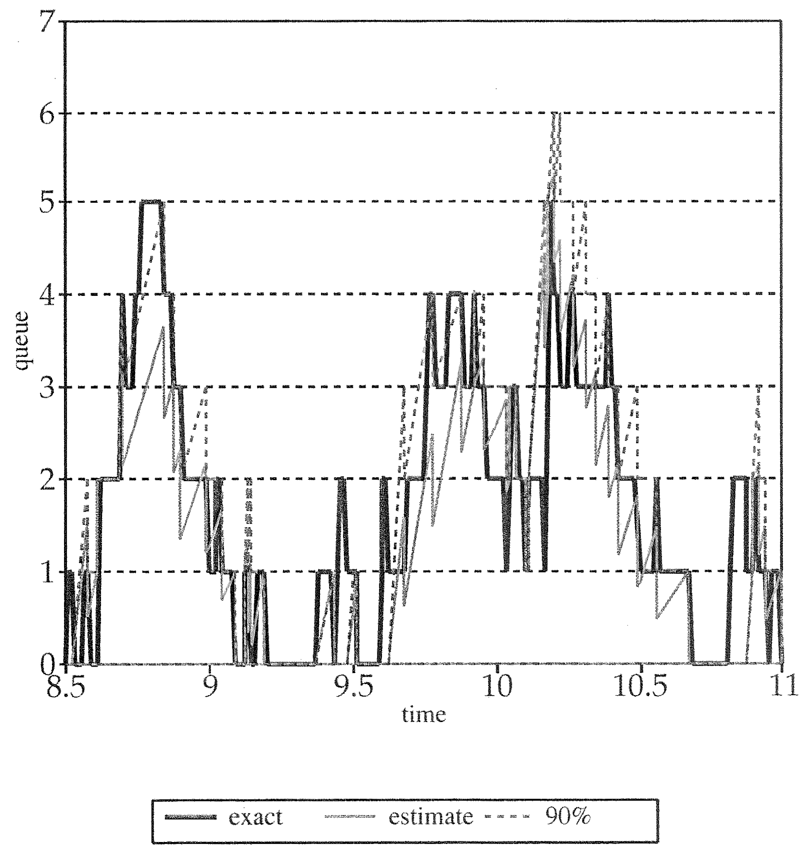
(see next page)

Face-to-Face Services
Measurement & Control

- Traditional work measurements
  - Stop-watch: utilization profiles, times
- C-method 1-station
  - Sensors of arrivals and service-starts
  - Queues physically ordered, standing
- S-method 1-station
  - Tickets upon arrival (#, type)
  - Queues logically ordered, sitting
- I-method Network
  - Ticket upon arrival (#, type)
  - Sensors at servers
  - Diagnostic / Research-device
- F-method 1 station/Network
  - Transactions (automatically) recorded
  - Off-line (end-of-day) and Real-time
  - Inference of missing details
- Online global control exists (eg. KeyCorp, F-Bay)

F-Method

Exact Queue Vs. Estimate



35

Bank: A Queuing Network

Transition Frequencies Between Units in The Private and Business Sections:

	To Unit / From Unit	Private Banking: Bankers	Private Banking: Authorized Personal	Private Banking: Compens - - ations	Private Banking: Tellers	Business: Tellers	Business: Overdrafts	Business: Authorized Personal	Business: Full Service	Exit
Private Banking	Bankers		1%	1%	4%	4%	0%	0%	0%	90%
	Authorized Personal	12%		5%	4%	6%	0%	0%	0%	73%
	Compensations	7%	4%		18%	6%	0%	0%	1%	64%
	Tellers	6%	0%	1%		1%	0%	0%	0%	90%
Services	Tellers	1%	0%	0%	0%		1%	0%	2%	94%
	Overdrafts	2%	0%	1%	1%	[illegible]		5%	8%	64%
	Authorized Personal	2%	1%	0%	1%	11%	5%		11%	69%
	Full Service	1%	0%	0%	0%	8%	1%	2%		88%
	Entrance	13%	0%	3%	10%	[illegible]	2%	0%	14%	0%

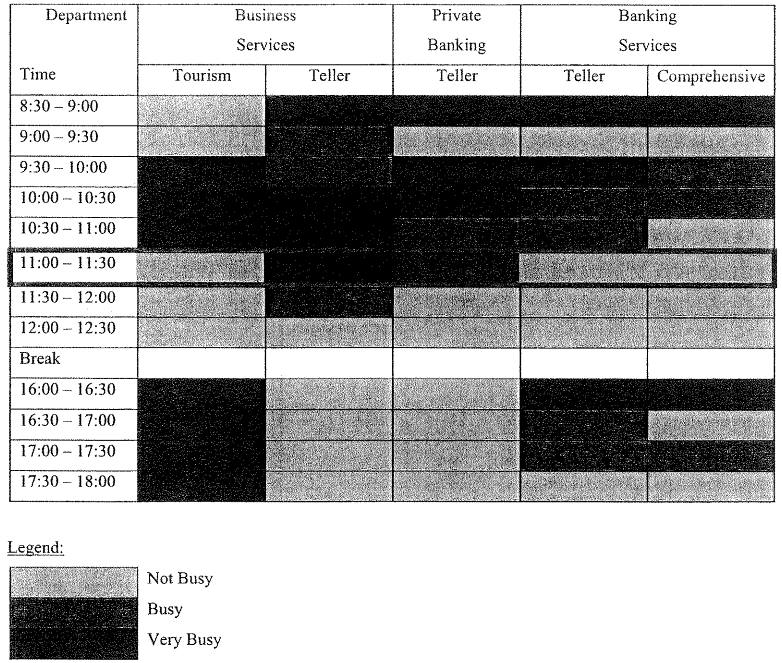
Legend: 0%-5% | 5%-10% | 10%-15% | >15%

Dominant Paths - Private:

Unit / Parameter	Station 1 Banker	Station 2 Teller	Total Dominant Path
Service Time	12.1	3.9	16.0
Waiting Time	6.5	5.7	12.2
Total Time	18.6	9.6	28.2
Service Index	**0.65**	**0.40**	**0.56**

Service Index = % time being served

Mapping Offered Load (Branch of a Bank)



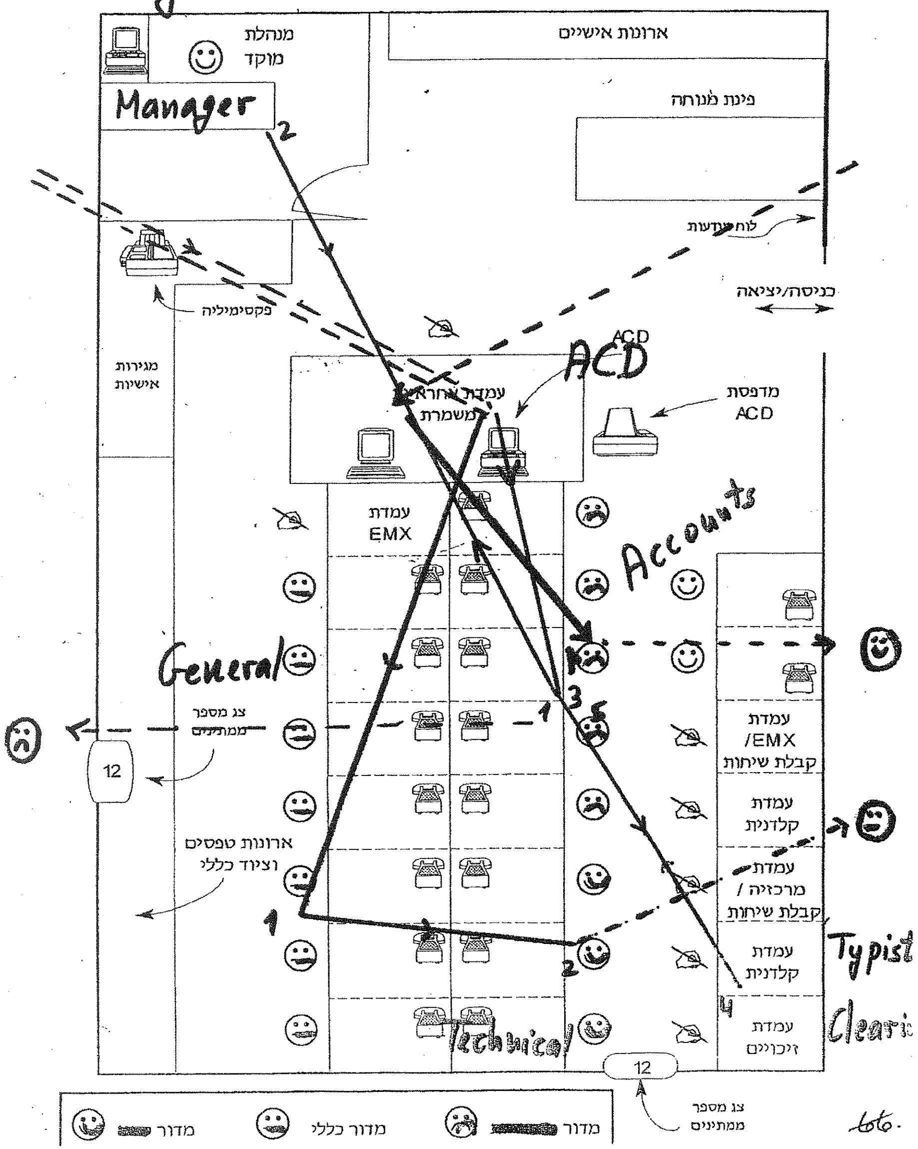
Note: What can / should be done at 11:00 ?

Conclusion: Models are not always necessary but measurements are !

36

Telephone Call-Center = Tele Net

=Queueing Network [redacted] תרשים סכמטי מוקד



66.
6.4

טבלה 2: ניתוח מצב קיים -

חקר ביצועים

	Accounts מוקד אישורים	General מוקד בירורים	Technical מוקד [redacted]
ימי עומס בשבוע	א', ו'	א'	א'
ימי עומס בחודש	12	8-14 ; 2-3	10-20
מספר פניות ביום	4136	2476	1762
מופע שעתי ממוצע	253.6	193	167 ג
שעות עומס (Peak Hour)	11:00-12:00	10:00-11:00	9:00-10:00
מופע בשעות עומס	422	313	230 λmax
זמן המתנה (שניות)	10.9	20.0	55.9
זמן שירות (שניות)	83.5	131.3	143.2
אינדקס שירות	0.88	0.87	0.72
אחוז נטישה	2.7	5.6	11.2
זמן המתנה ממוצע עד לנטישה (שניות)	9.7	16.8	43.2
רמת איוש ממוצעת בפועל	9.7	10.3	5.2
יעד - זמן המתנה	12	25	-

67.
6.5

37

Queues in Hospitals: Empirical Study

Mor Armony

Joint work with: Avi Mandelbaum, Yariv Marmor, Yulia Tseytlin and Galit Yom-Tov

NYU, Technion, Mayo, IBM, Columbia

Patient Flow in Hospitals as a Queueing Network

Network features:

- Customers: Patients
- Servers: Beds, equipments, medical staff
- Stations: Medical units

Research Questions:

- Special features of this network
- Implications on queueing modeling and theory

Methodology:

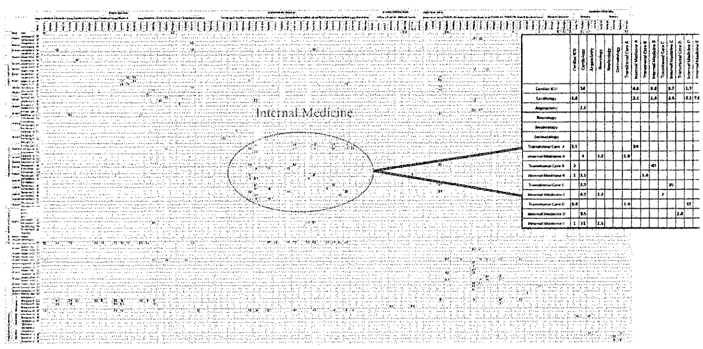
- Exploratory Data Analysis (EDA)

Our data

Data description:

- Anonymous Israeli hospital with 1000 beds and 45 medical units
- 75,000 patients are admitted annually
- Years data collected: 2004 - 2008
- Individual patient level data, time stamps (admission, transfers and discharge)
- Acknowledgement: Anonymous Hospital and

90 X 90 Matrix, Sub-Ward Resolution

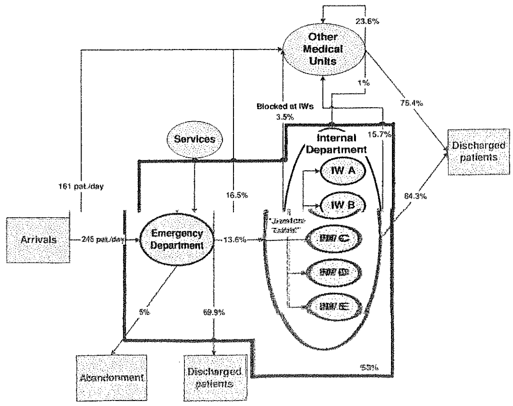


Our focus

Subnetwork including: ED, IW and ED $\rightarrow$ IW

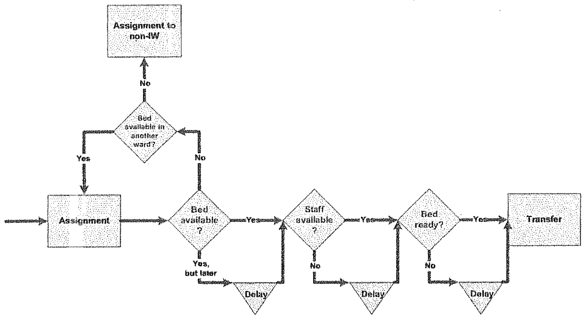
- Substantial size:
  - 53% patients entering the hospital stay within this subnetwork.
  - 21% of those, are hospitalized in an IW
- Nearly isolated:
  - ED Arrival are all external
  - 93% of IW arrivals are either external or from within the subnetwork.
- Relatively simple:
  - One ED
  - Five IWs (A-E)
  - IW A-D identical in scope capabilities

A Queueing Network View

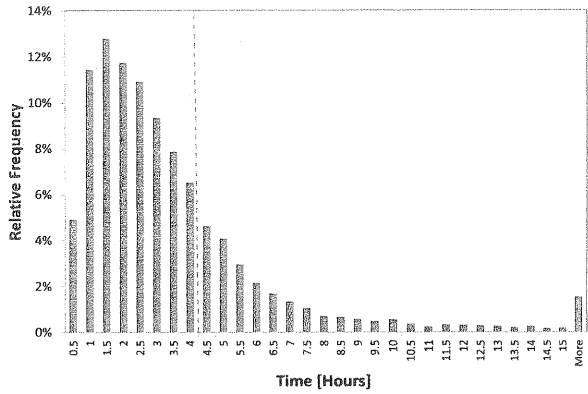


38

Transfer Process

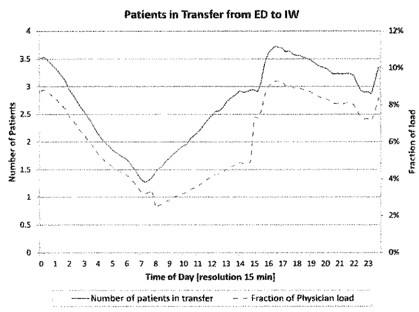


Transfer waiting times



Why are delays problematic?

- Patients do not receive proper care.
- They are exposed to other diseases.
- ED overcrowding.
- Impose extra load on ED medical staff.

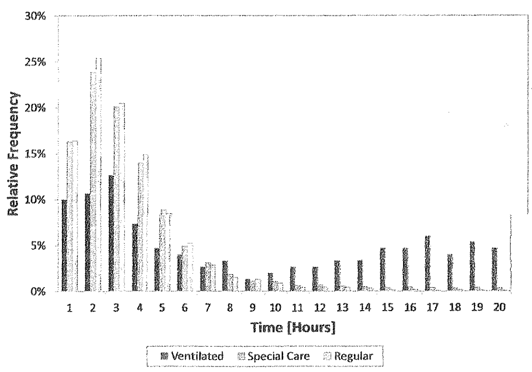


Average Transfer Delays per Patient Type

Patient Type	Average Delay (hrs)	Standard Deviation	% delayed up to 4 hours	% Delayed more than 10 hours
Regular	3.00	2.53	77%	2%
Special Care	3.33	3.16	74%	5%
Ventilated	8.39	6.59	41%	41%
All Types	3.22	2.98	75%	4%

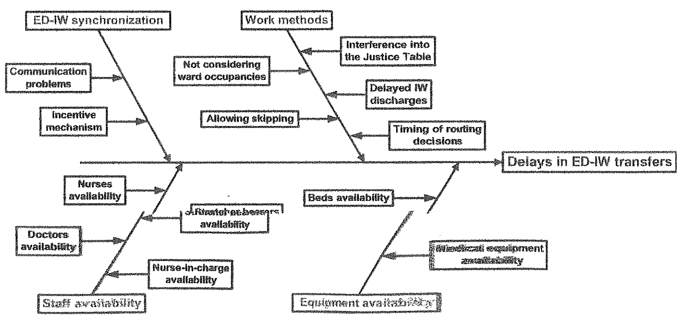
Ventilated patients should have lowest delay, but experience the highest!

Transfer waiting times by patient type

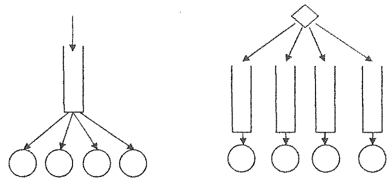


Patients need to wait for a bed, equipment, and medical staff.

Delays in transfer: Cause and effect diagram



Routing: Input versus output queues



- Single line system is more efficient
- Reality requires multiple lines
- Patients require care even when in queue
- Push versus Pull
- Fairness towards patients?

(Un)fairness towards patients

IW \ Type	Regular	Special care	Ventilated	Total
Ward A	7.57%	7.33%	0.00%	7.37%
Ward B	3.86%	5.72%	0.00%	4.84%
Ward C	7.09%	6.62%	0.00%	6.80%
Ward D	8.18%	7.48%	2.70%	7.81%
Total within wards	6.91%	6.80%	0.67%	6.80%
Total in ED-to-IW	31%	31%	5%	

Percentage of FCFS violations per type within each IW

Internal Wards operational measures

	Ward A	Ward B	Ward C	Ward D
ALOS (days)	6.5	**4.5**	5.4	5.7
Mean occupancy	97.8%	94.4%	86.8%	91.1%
Mean # patients per month	205.5	187.6	210.0	209.6
Standard capacity (# beds)	45	**30**	44	42
Mean # patients per bed per month	4.58	**6.38**	4.89	4.86
Return rate (within 3 months)	16.4%	17.4%	19.2%	17.6%

- How does one explain these differences in performance?
- Is this work allocation fair?
- How is fairness defined?
- See Mandelbaum, Momcilovic, & Tseytlin (2010) and Tseytlin & Zviran (2008)

Unfairness towards wards: Patient mix

IW\Type	Regular	Special-care	Ventilated	Total
Ward A	2,316 (50.3%)	2,206 (47.9%)	83 (1.8%)	4,605 (25.2%)
Ward B	1,676 (43.0%)	2,135 (54.7%)	90 (2.3%)	3,901 (21.4%)
Ward C	2,310 (49.9%)	2,232 (48.2%)	88 (1.9%)	4,630 (25.4%)
Ward D	2,737 (53.5%)	2,291 (44.8%)	89 (1.7%)	5,117 (28.0%)
Total	9,039 (49.5%)	8,864 (48.6%)	350 (1.9%)	18,253

Justice Table allocation to IWs by patient type.

Conclusions

- Patient flow in hospitals as a queueing network
- Input versus Output queues
- Push versus Pull in routing
- Fairness towards customers (definition?)
- Customers served while in queue
- Fairness: Occupancy + Flux