Operations Research:
The Science of Better

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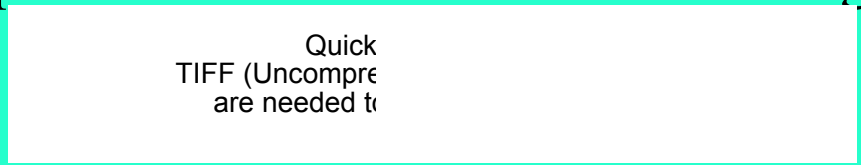


SmartWorld
December 8, 2004

Operations Research: The Science and Technology of Making Better Decisions

- Operations Research invented or co-invented:
  - Revenue Management (airlines, hotels, services industries)
  - Supply Chain Management (FEDX, UPS, containerized shipping)
  - Queue analysis
  - Marketing Science
  - Decision Analysis
  - Search Theory
  - Financial Engineering
  - Transportation Science

Operations Research is the

Science of Better

Better decisions….


O.R.
THE SCIENCE
OF BETTER

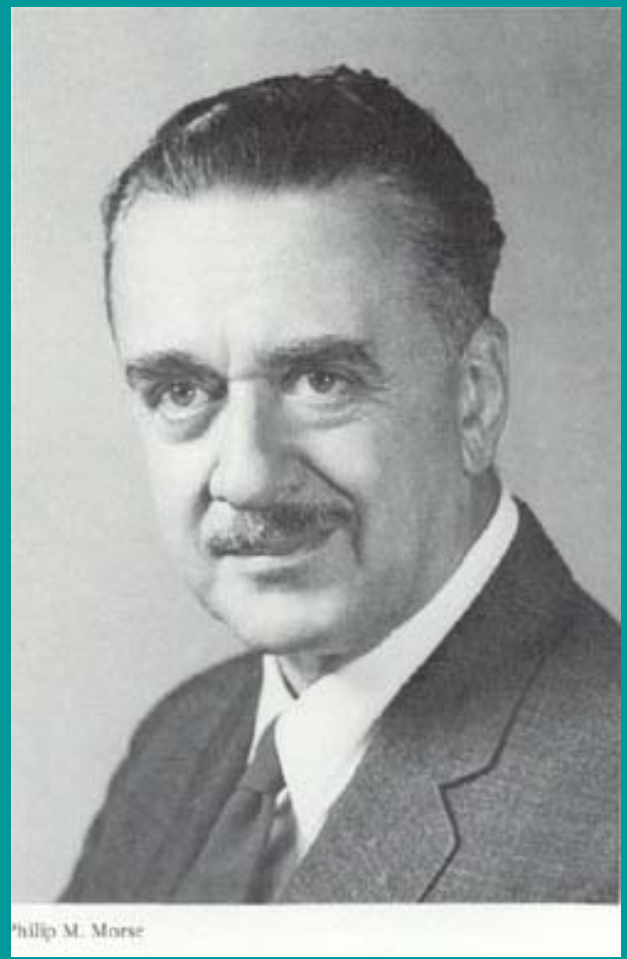
SmartWorld:

Using Technologies to Acquire More Data and then Using the Data Wisely

SmartWorld:
The Union of Data, Models, and Decisions

Operations Research Culture and History

- Operations Research started as a named field in WWII, thanks to physicists such as Philip M. Morse



http://hcohl.shell42.com/morse.jpg

Quotes from
Methods of Operations Research,
Morse and Kimball (1951)

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are needed to see this picture.

- **"Operations Research is a scientific method of providing executive departments with a quantitative basis for decisions regarding operations under their control."**
- "Operations Research … is *an applied science* utilizing all known scientific techniques as tools in solving a specific problem."
- **"Operations Research uses mathematics, but it is not a branch of mathematics."**
- "… Operations Research is often an experimental science as well as an observational one."
- **"It often occurs that the major contribution of the operations research worker is to decide what is the real problem."**

http://imagesus.seekbooks.com.au/0486432343.gif

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Why Can We Be Even Smarter Now?

Technologies -- Hardware and Software --
are Providing Us with
Orders-of-Magnitude More Data
Implies the Possibility of Vastly Improved Decisions

http://www.hawaii.edu/lruby/art400/THINKER.GIF


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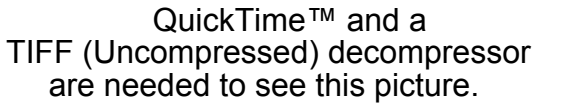
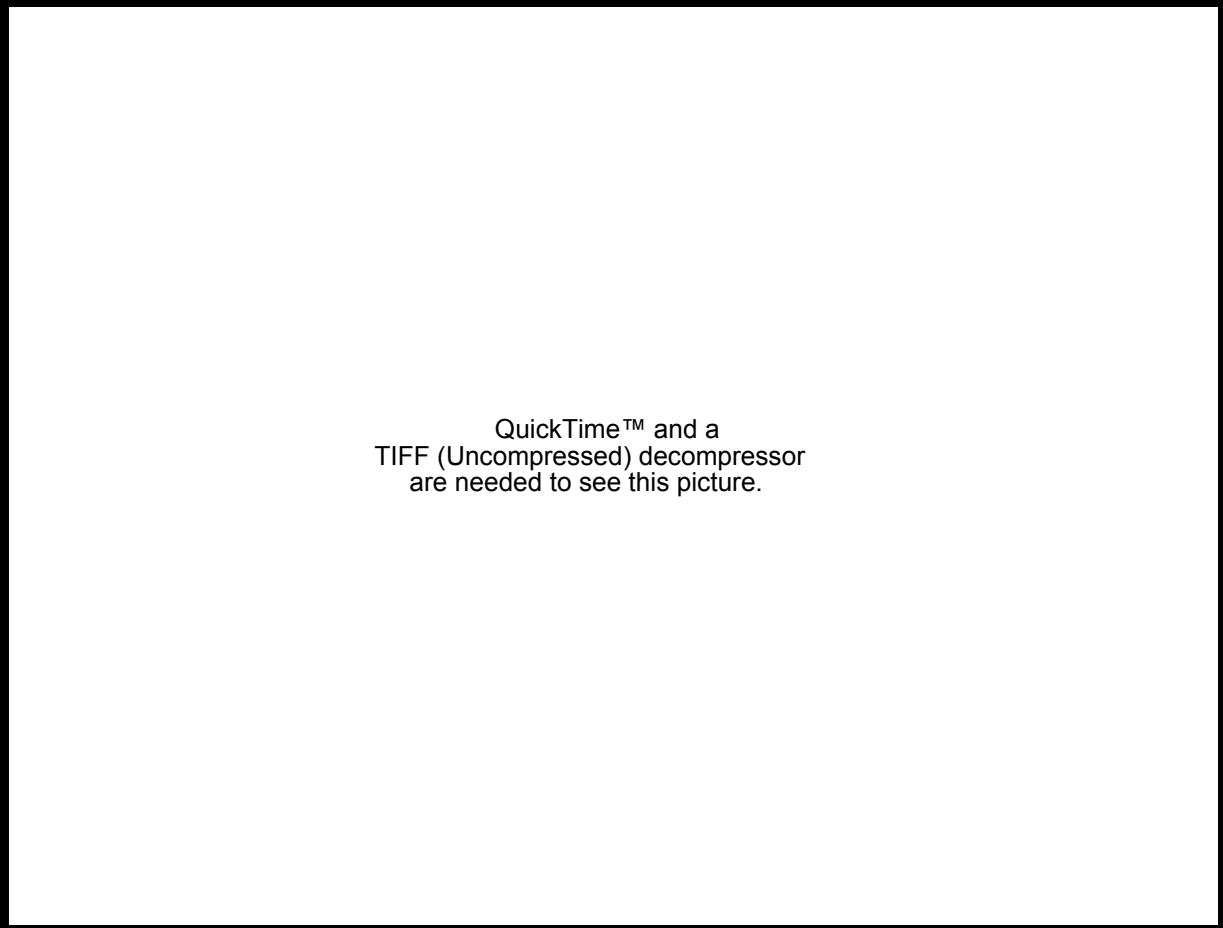
Example 1: Revenue Management

- Every scheduled US airline flight maintains data on all reservations, cancellations, no-show and go-show rates, etc.
- Each evening tens of thousands of flights are modified with respect to the numbers of discount seats available.
- For American Airlines alone, this has meant annually an additional One Billion dollars to the bottom line
- Concepts now applied in hotels, cruises, sports, movies, retailing, sales of marketing space, etc.



http://www.datavisiontech.com/Images/RevenueManagement2.gif



http://www.jacksonvillestory.com/Checkout%20Line%20at%20Setzer's.jpg

http://www.mycanberra.com.au/Braidwood_checkout.jpg

Example 2: Marketing Science

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are needed to see this picture.

- Use of barcode scanned supermarket data, pioneered by MIT Professor John D. C. Little.
- This has changed the operations of supermarkets in fundamental ways (e.g., shelf space, in-store marketing, supply chain management, micro personal marketing, etc.).
- New methods now applied to most retailing.

QuickTime™ and a
TIFF (Uncompressed) decompressor
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http://www.baxtek.com/img/barcodeinfoimage2.jpg
http://www.idautomation.com/imagers/P304IMG.jpg


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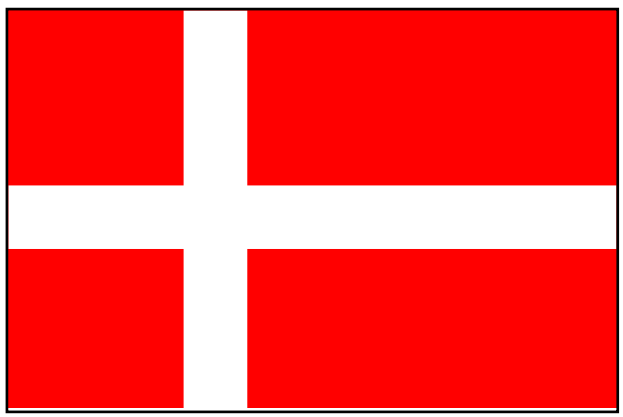
Example 3: Queue Analysis

- This goes back to Denmark, 1909 - 1915.



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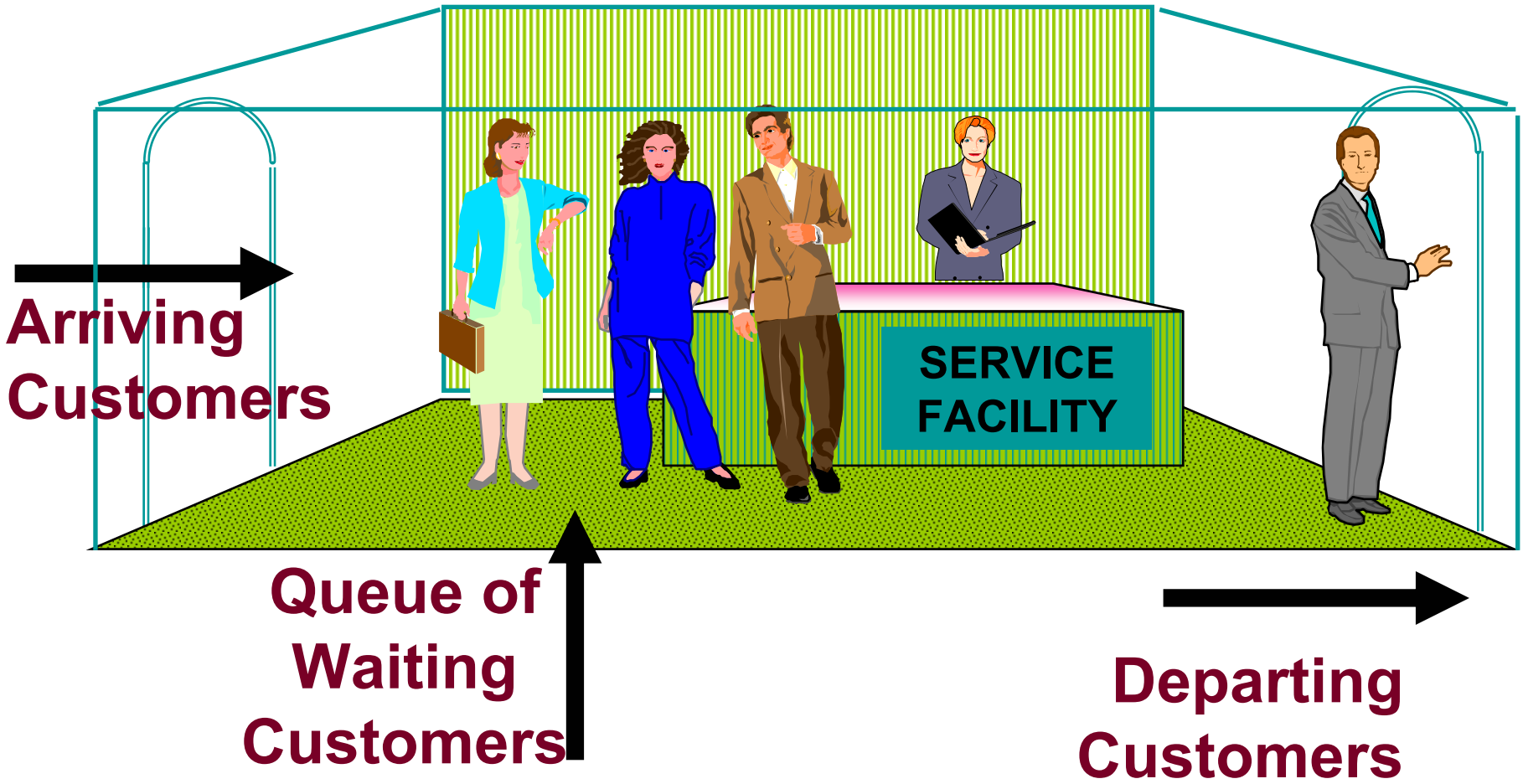
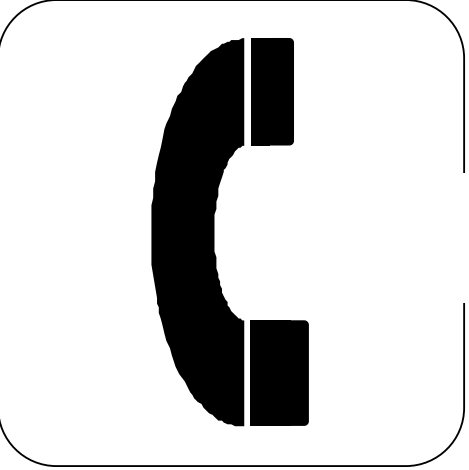
http://scouts.elysiumgates.com/map-denmark.gif

Queueing System

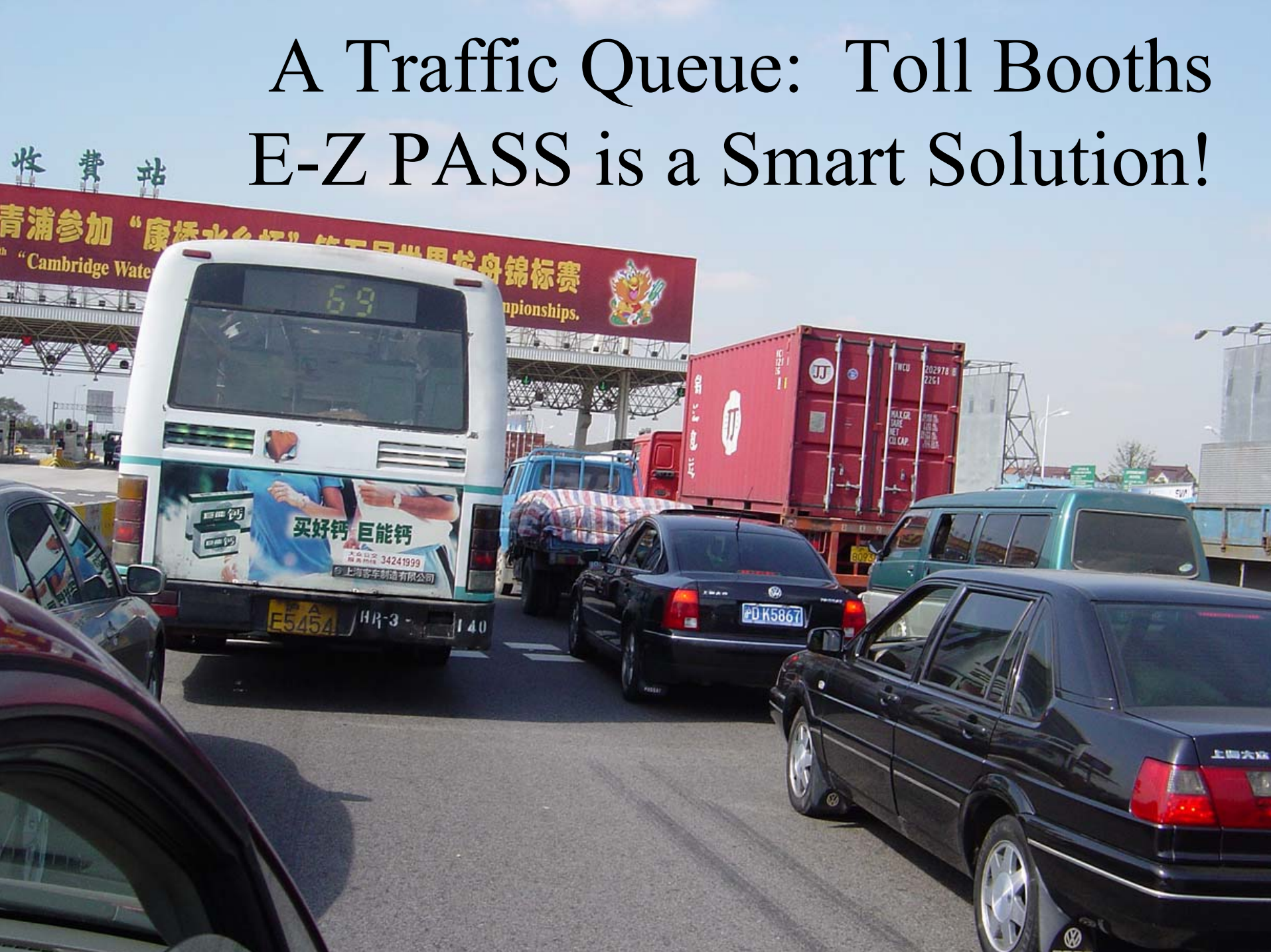




- **A. K. Erlang**, Danish telephone engineer -- **invented queueing theory** in work aimed to determine optimal capacity of newly invented central telephone switching centers (1915)

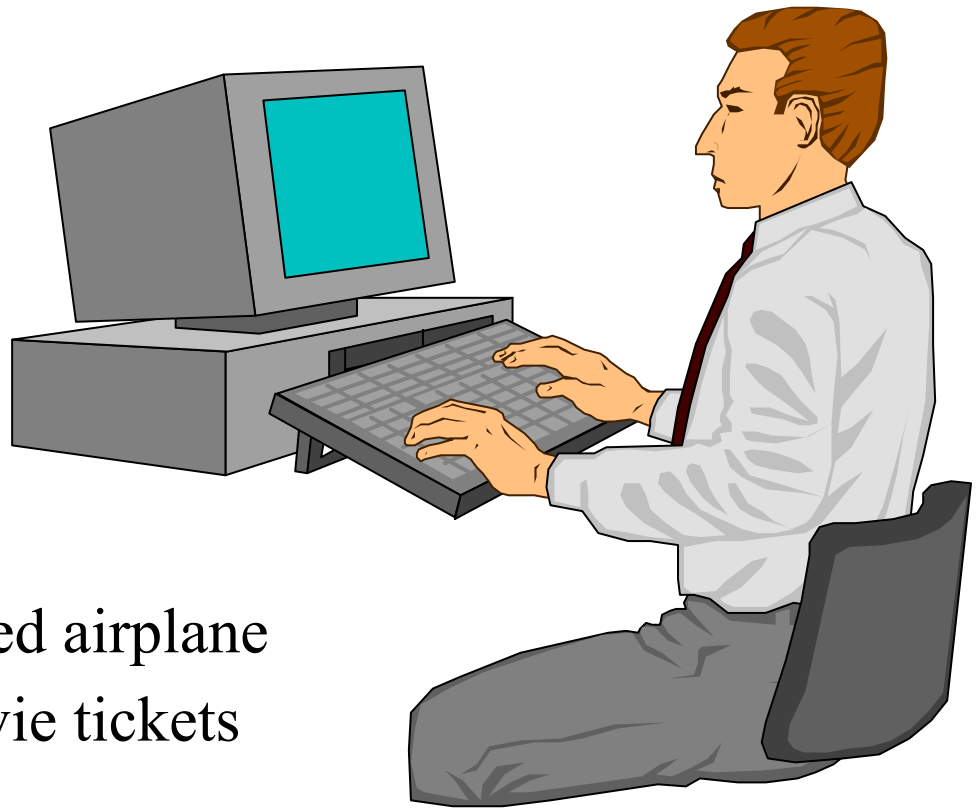
<http://www2.uwindsor.ca/~hlynka/queue.html>
http://www.polytechphotos.dk/pics/A.K_Erlang.jpg

A Traffic Queue: Toll Booths
E-Z PASS is a Smart Solution!



Use Technology to Avoid Queues: Use Alternate Procedures

- Express check-in and check-out (hotels, rental cars)
- Pay bills by email banking, not in person
- Don't visit Registry of Motor Vehicles, do business by email
- Your home printer-issued airplane boarding passes or movie tickets
- FASTPASS at Disney

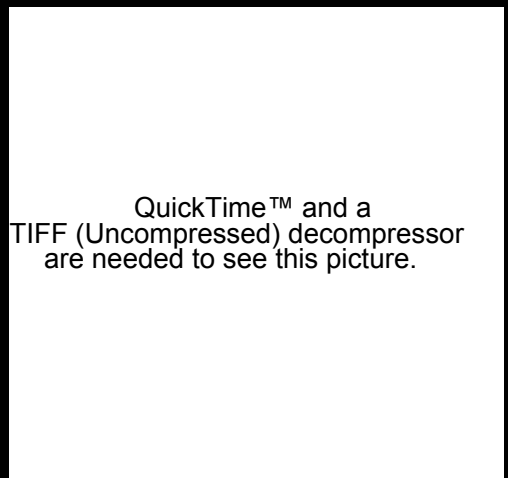


Use Technology to Speed Service

- ATM's for Banks (1:3 in cost/transaction)
- Bar code scanners
- ATM-like order taking machines (Burger Kings, Illinois Facility)
- Automated parking lot attendants
- E-Ticket boarding passes (airports)

Each of these leaves a data trail having potentially valuable information for management.

Sometimes mining through the data is akin to mining for gold: separating the nuggets from the muck is a real challenge.



http://www.vagoldandgems.com/gldnug1.jpg

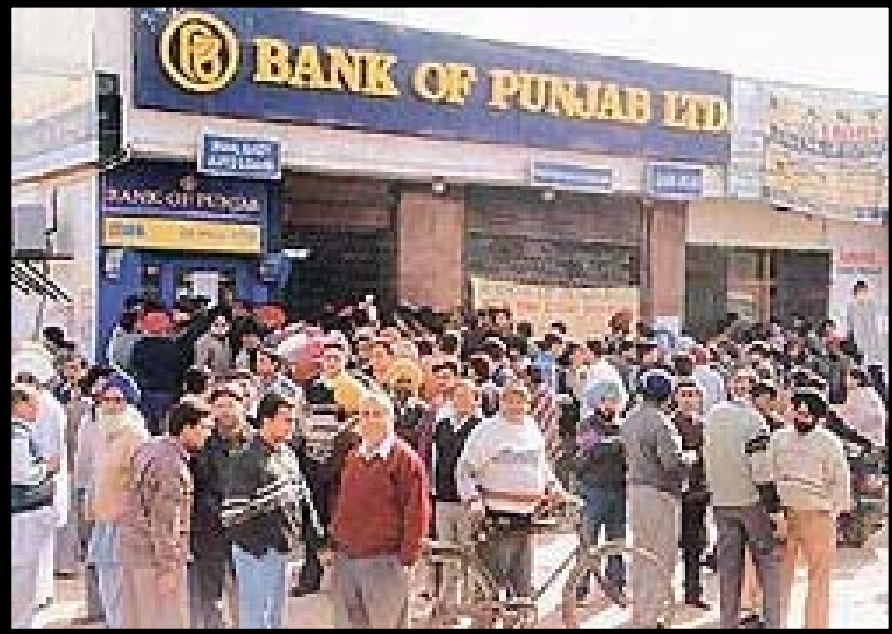
Let's Explore a Recent Example of Mining for Information in a Large Dataset, Armed with OR Models and Methods to "Refine" our Method

Queue Inference Engine ('QIE')

Consider at ATM

http://www.edrobertscampus.org/press_room/atm.jpg

Consider at ATM with Queueing, Lots of Queueing



Queue Inference Engine (QIE)

- Boston area ATMs: reams of data
- Standard queueing approach first
- Then the notion that there may be more golden nuggets in the transactional data

Management Decisions?

http://news.bbc.co.uk/olmedia/210000/images/_214989_bank_atm_queue150.jpg
http://europe.cnn.com/SPECIALS/2001/euro/stories/security.fears/story.france.atm.jpg

QIE: Assumptions

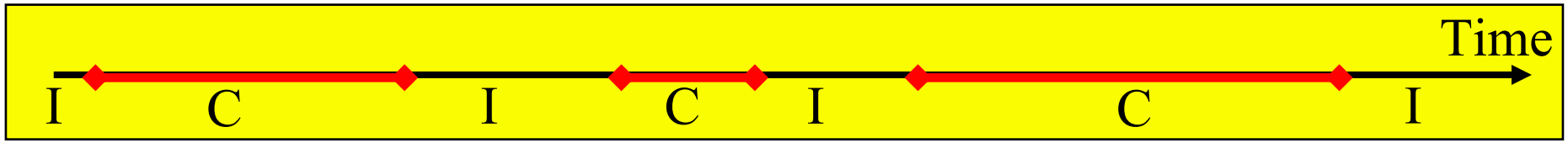
(1) A priori, arriving customers are generated by a slowly time varying Poisson process ('random arrival process').

(2) The 'signature' of a queue from the **transactional data** is a service stop time followed very shortly by a service start time.

(3) Any balking that occurs is dependent only on whether a positive queue delay will be experienced by the prospective customer, not on the line length.

QIE: Assumptions - continued

- Can have single or multiple servers
- Service times need not be independent.
- Queue discipline need not be First-Come, First-Served
- There is no parameter estimation! The rate parameter λ for the Poisson process does not appear in the analysis.



The Dataset

- The QIE works on one congestion period at a time.

C=Congestion period; I=Idle period

- A congestion period commences the instant that all servers become busy, thereby requiring subsequent arrivals to be delayed in queue, and terminates the first moment that one of the servers becomes idle after a service completion because the queue is empty.

The Performance Measures

. For each congestion period the QIE computes, conditioned on the transactional data set, the following quantities:

1. The time-dependent mean number of customers in queue.
2. The mean queue delay experienced by a random customer.
3. The average number of customers in queue over the duration of the congestion period.
4. The probability that a customer arriving during the congestion period experiences any given number customers ahead of her in line.

Transform this Theory into a Product and You get SmartWorld Reports!

SwiftLine : West Boca - [Forecasted Service Performance And Staffing for FullServ on Mar-04-1998]

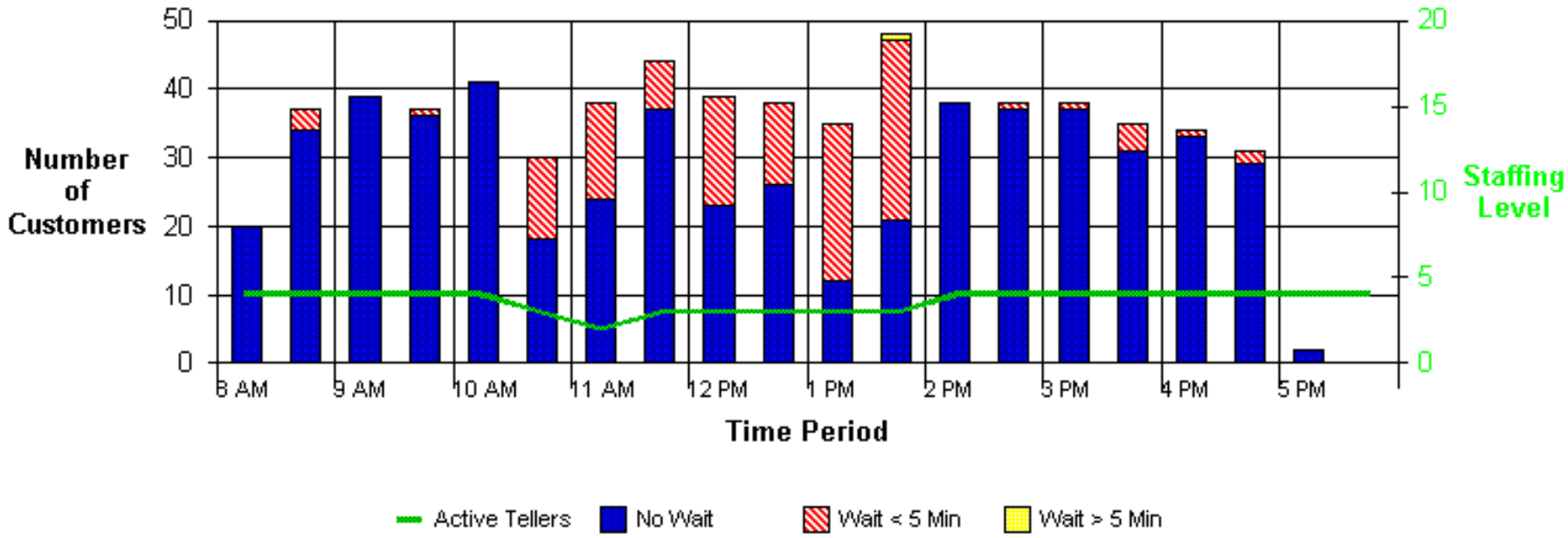
File Edit Reports Setup Window Help

Last Week | Schedules | Sch Reports | Calendar | Days Off | Tellers

USPS Retail
SwiftLine®
Forecasted Service Performance And Staffing

Boca Raton Retail Branch / Full Service Queue
Wednesday Mar-04-1998
Day Period

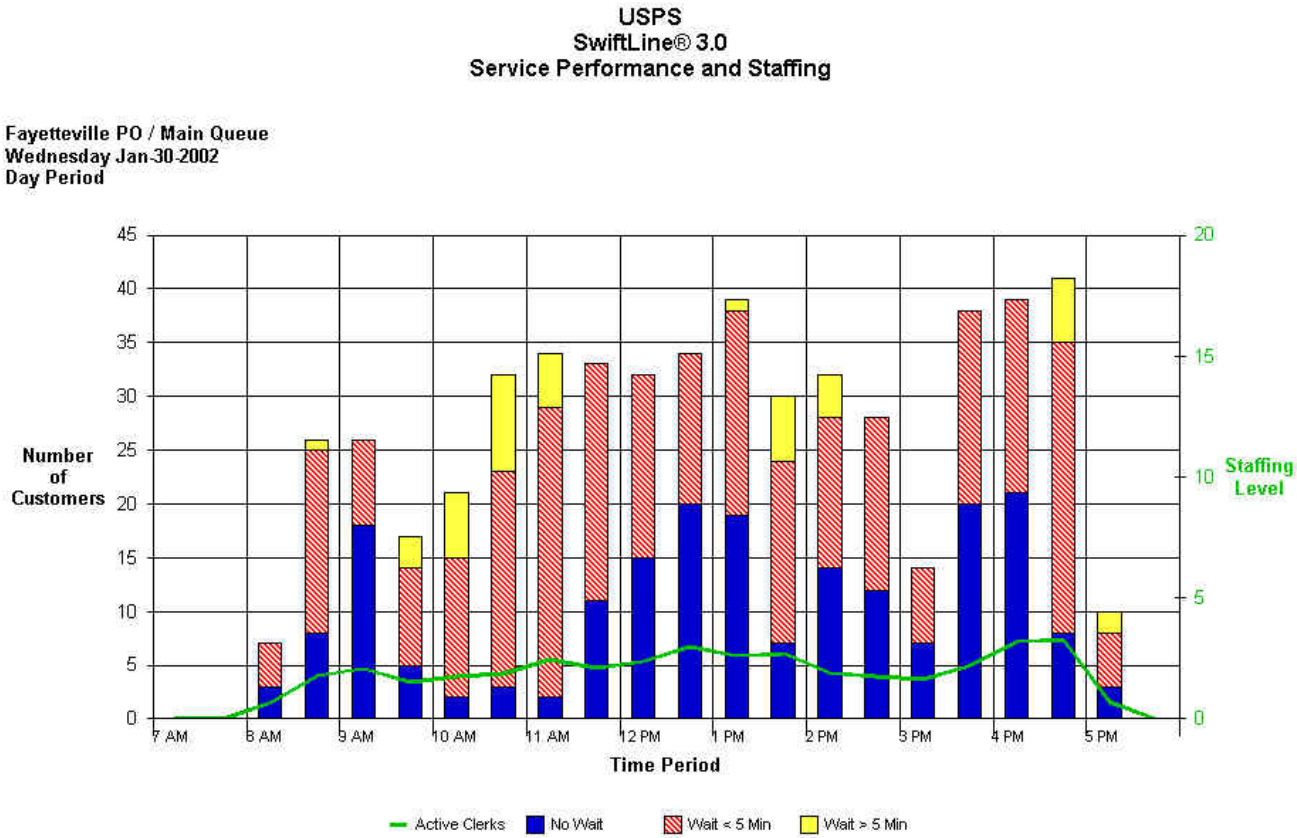
SPI = 9



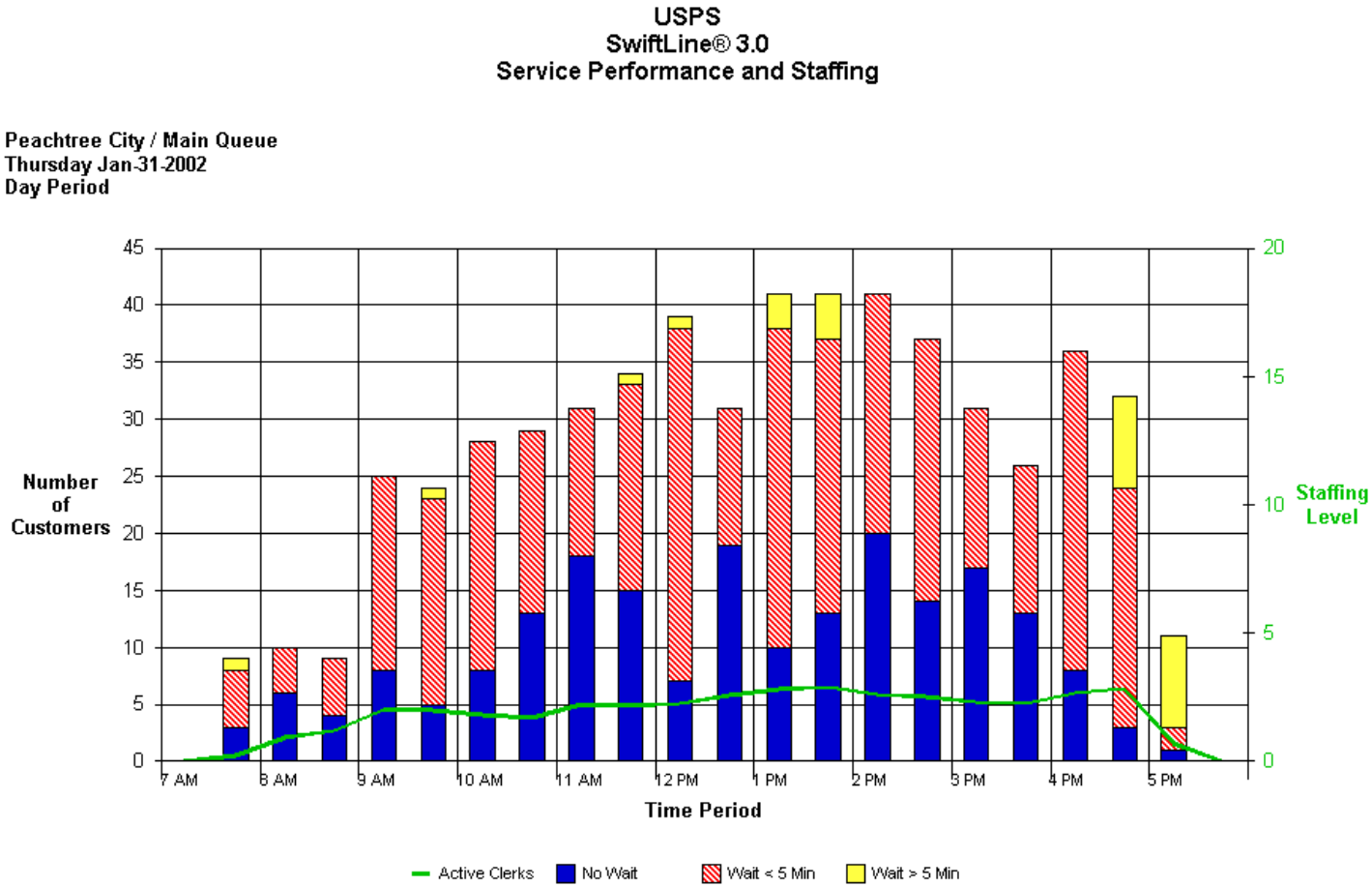
Service Performance | Print

Fri Feb-27-1998 | 12:20 PM

Fayetteville: *Weekday* Customer Service

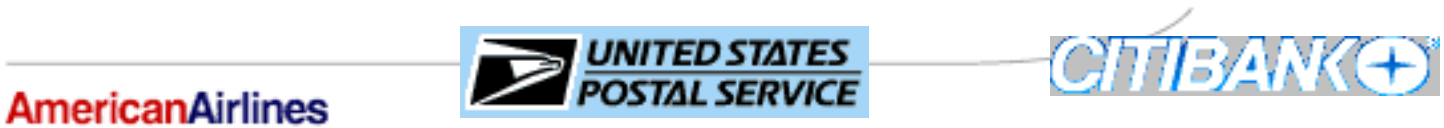


Peachtree: *Weekday* Customer Service



The Applications

- Servi: Air Phone
- Larson: Human server queues
  @ Logan Airport, Post Offices and Banks



http://www.aa.com/American?BV_Operation=Dyn_AAPage&referer=index.html

http://www.usps.gov/

http://www.citibank.com/corporate_affairs/y2000.htm

The QIE is an Operations - Research-Inspired Data Mining Method to Extract Golden Information from Otherwise "Useless Data."

Gets Management Customer Delay Information with

NO ADDED HARDWARE TECHNOLOGY

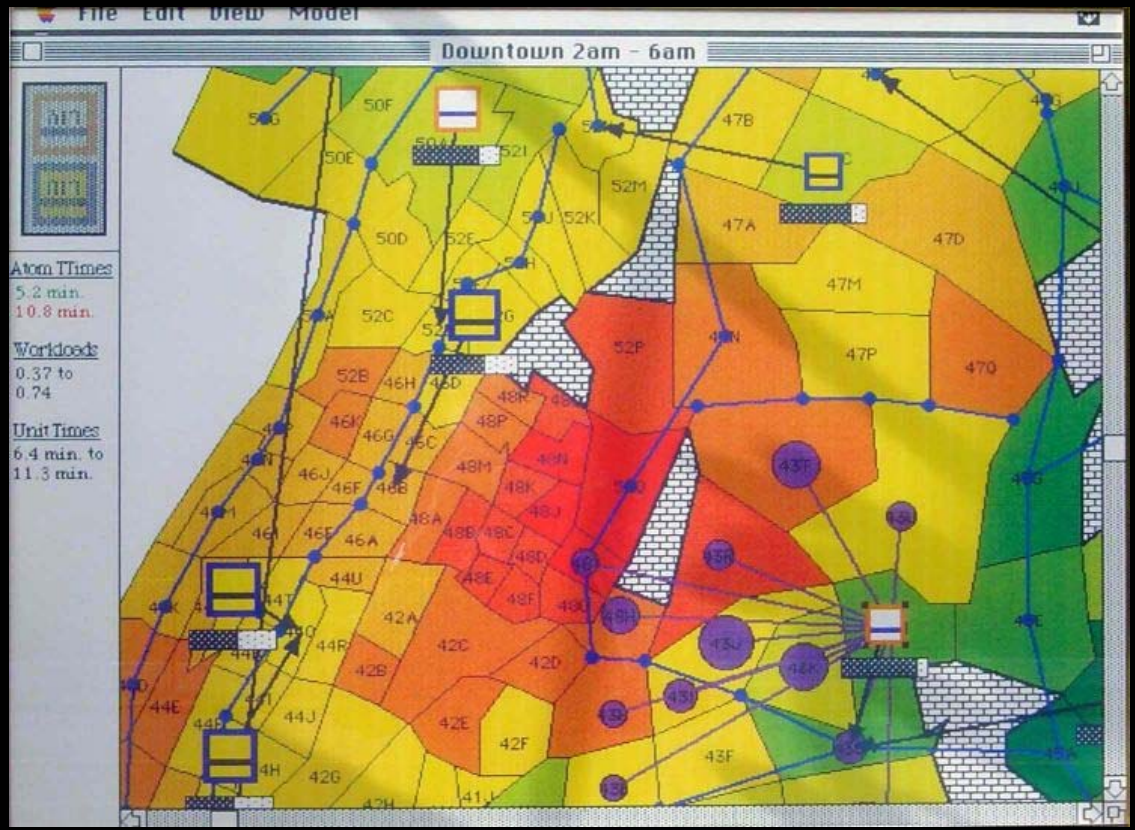
Let’s Go to Our Final Example…

Example 4: Transportation Science

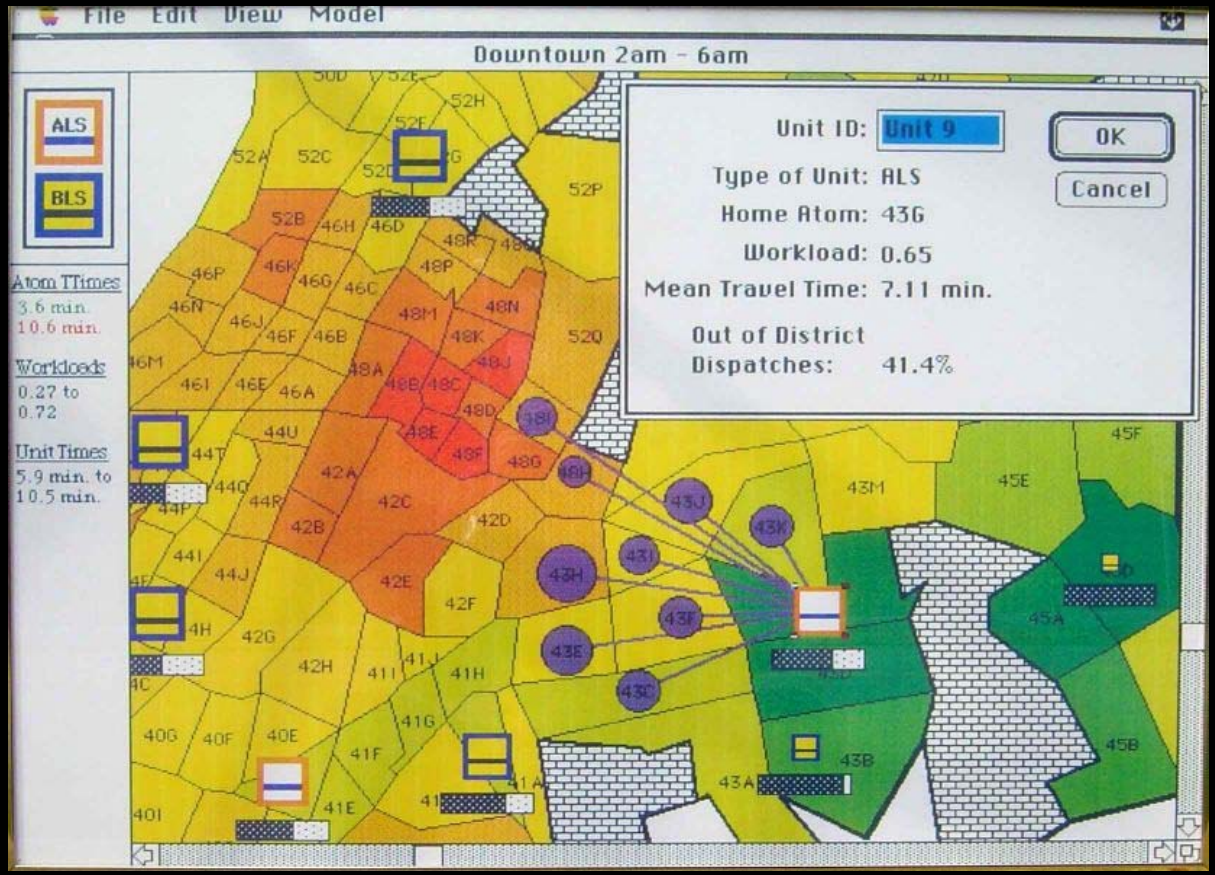
- Smart intersections
- Smart highways
- Smart ‘skyways’
- Smart dispatch of urban emergency vehicles
- Smart routing of people and vehicles

http://www.ci.houston.tx.us/hfd/general/images/ambulance.gif

New York City EMS Hypercube



New York City EMS Hypercube




119
瀬戸市
消防本部


FIRE DEPARTMENT
SEXTO
FIRE DEPARTMENT
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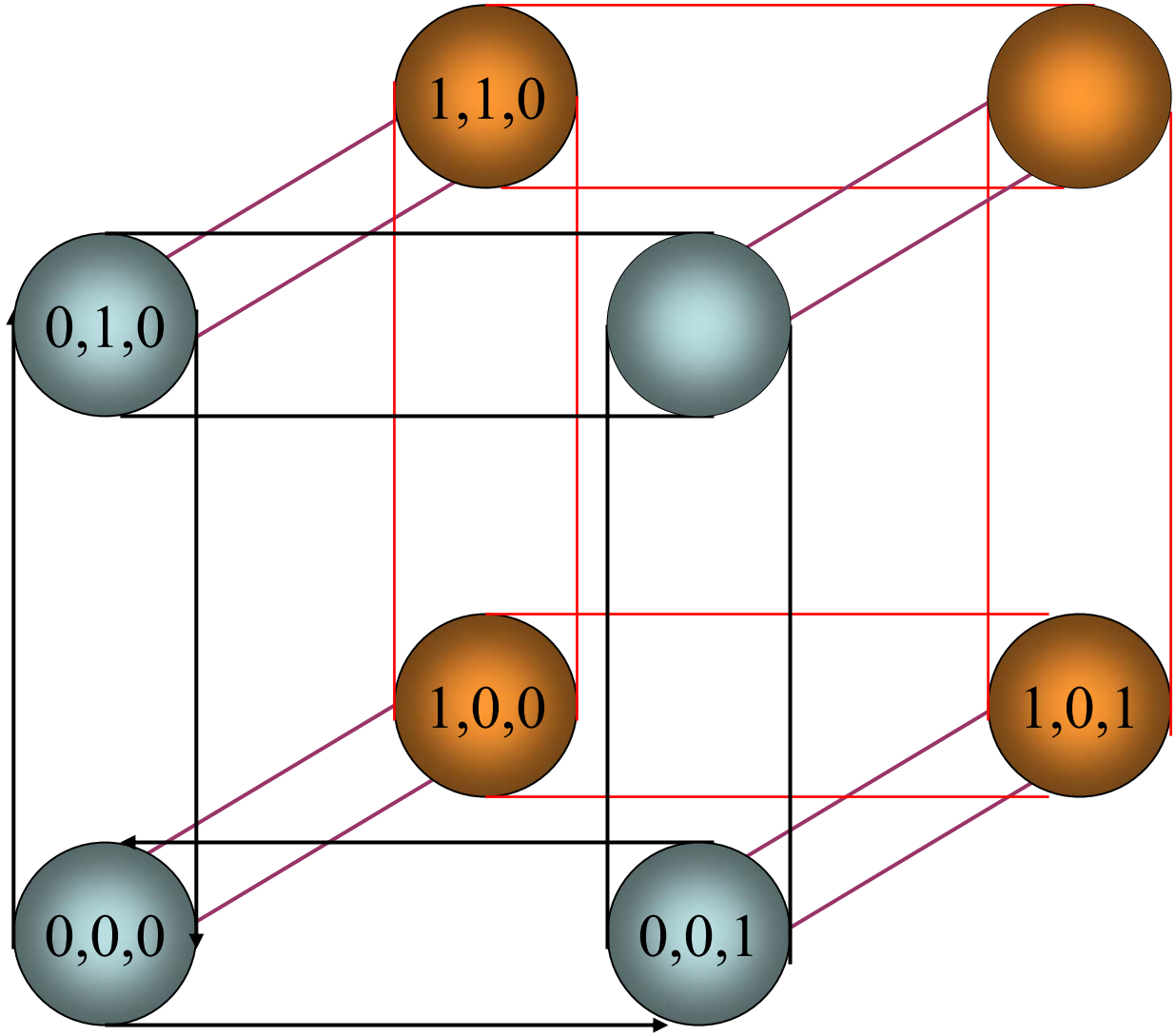
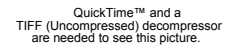
Hypercube Queueing Model



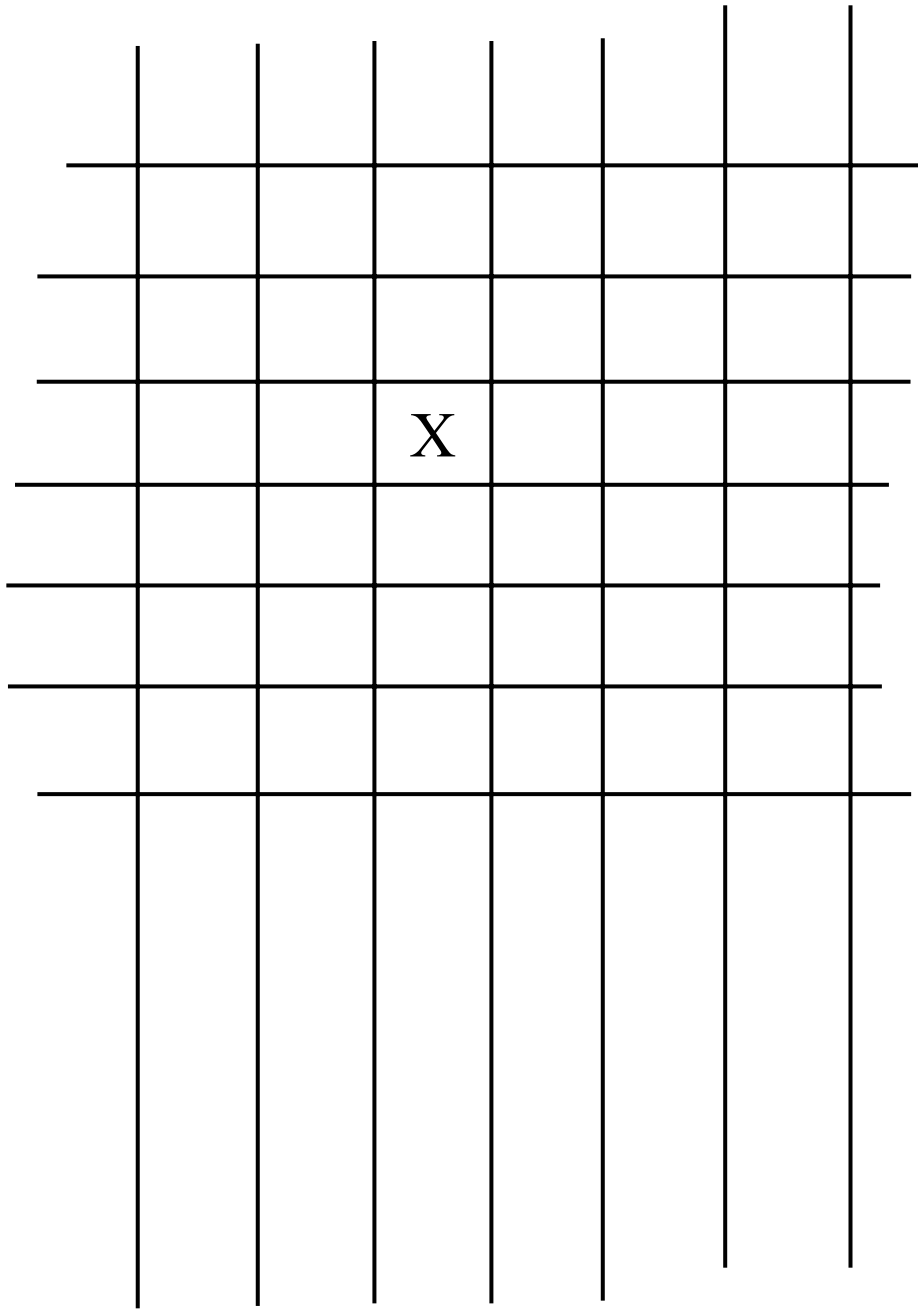
The Hypercube Queueing Model:



- Has been implemented in many comn
- Generated many graduate theses and journal articles
- Reduced via approximation a system with 2^N simultaneous linear equations to a set of N simultaneous nonlinear equations
- Incorporates a locate-allocate heuristic to locate optimally ambulances
- Is basis for new work in emergency response to major catastrophes, such as acts of nature, industrial accidents or terrorist attacks.

http://www.cs.virginia.edu/~mngroup/hypercast/images/hcube.gif

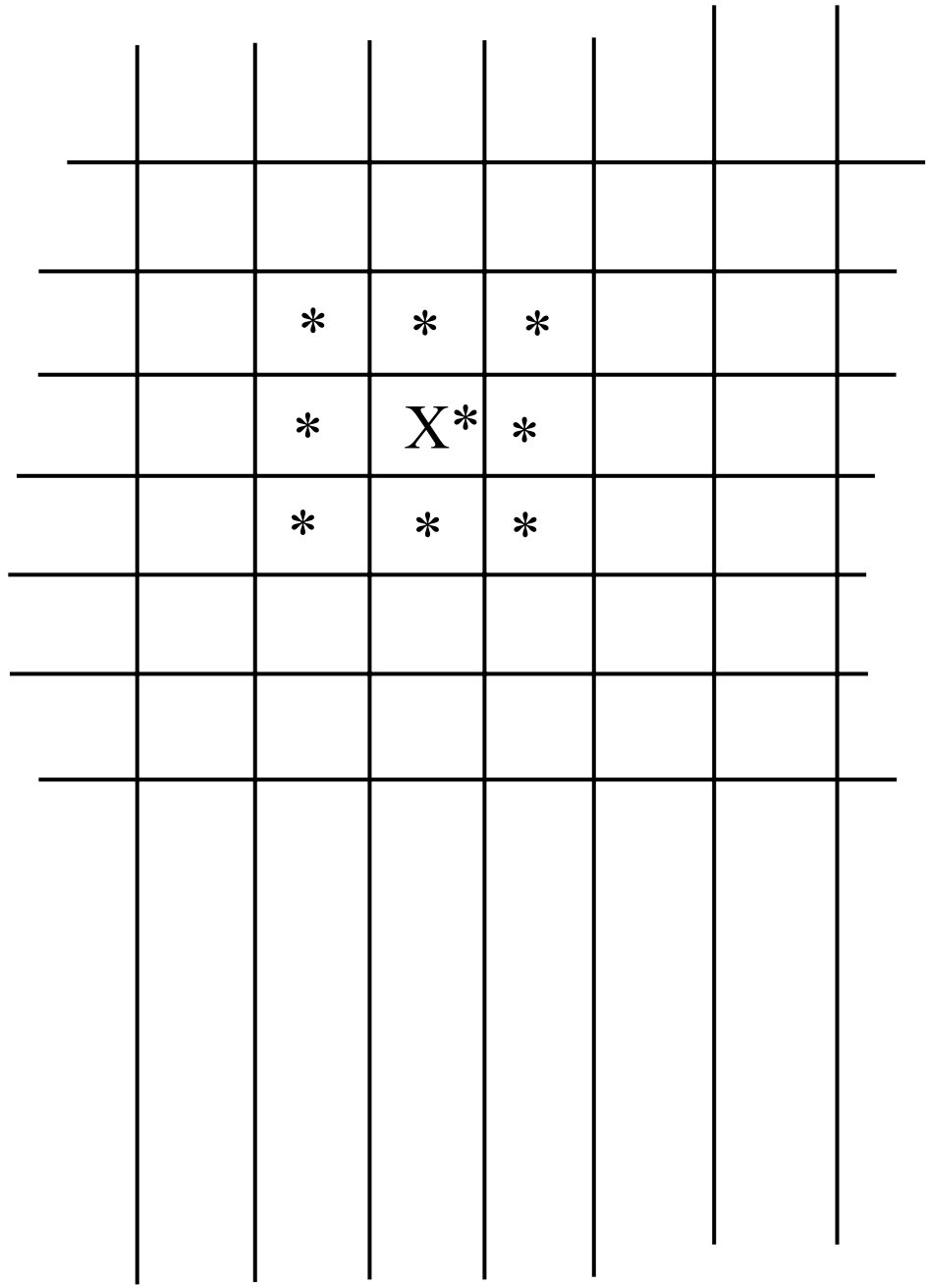
Smart Dispatch Using GPS



Customer in square marked X. Place an asterisk in each square that could have the closest police car. Assume each car is available and is located 'somewhere' in his/her square "police beat."

Question:

Now in a SmartWorld, in how many 'nearby' beats might there be the closest police car?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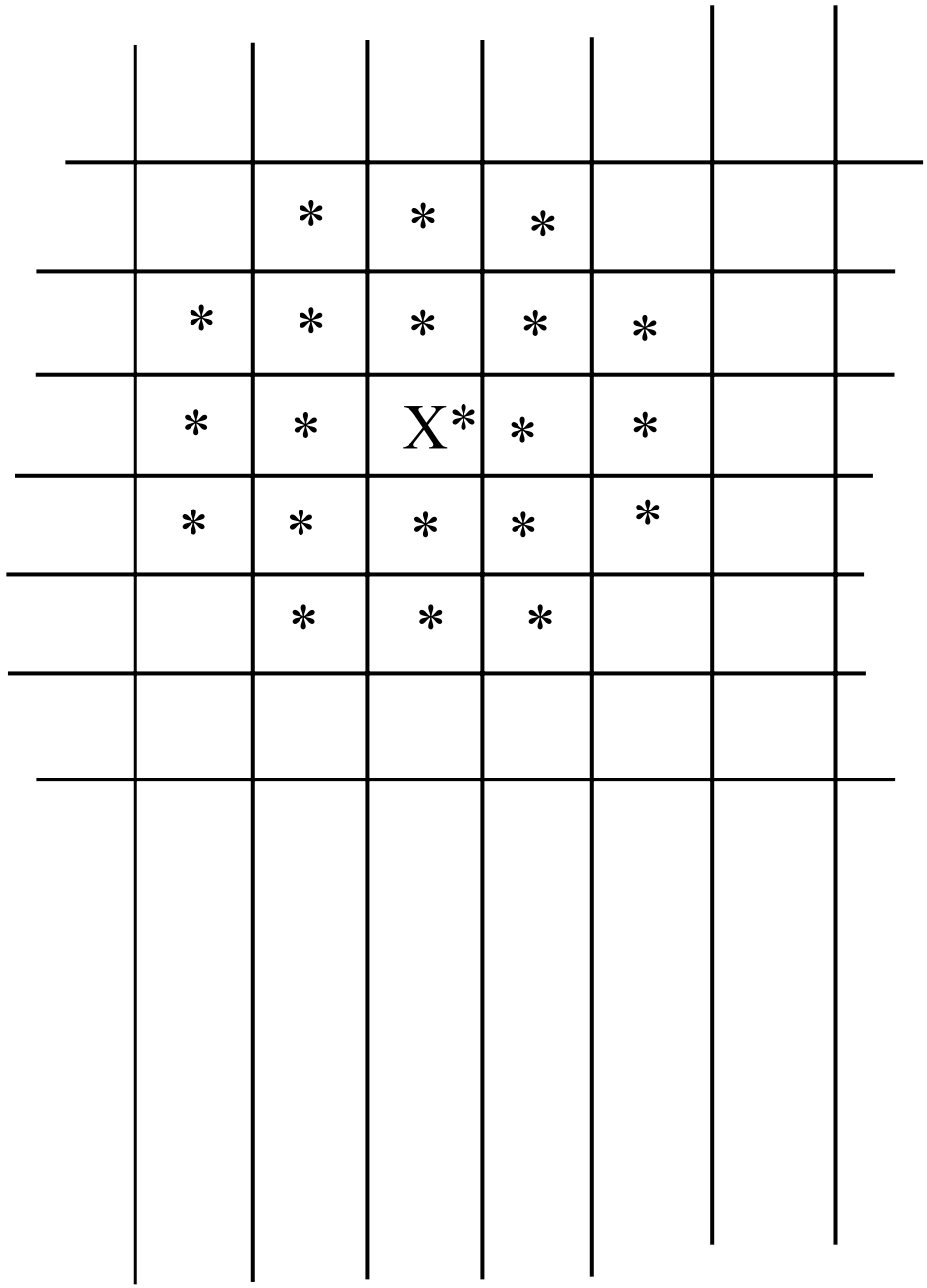


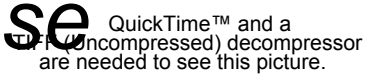
The closest police car
May be in any one of 21 different beats!

SmartWorld technology can locate the closest, often shaving precious minutes off response times.

Smart Routing of Postmen and Postwomen

Chinese Postman Problem

Mei-Ko Kwan ,Graphic Programming Using Odd or Even Points , *Chinese Mathematics,* 1:273-277, 1962.



"When the author was plotting a diagram for a mailman's route, he discovered the following problem: 'A mailman has to cover his assigned segment before returning to the post office. The problem is to find the shortest walking distance for the mailman.'" http://www16.big.or.jp/~nansya/ASCII-art/english/people/postman.gif

OR Solves Real Problems!

- OR's best theoretical work has been driven by real problems.
- Merger of data mining and models is the hottest topic today!

Today, INFORMS Members Continue the Tradition of Working of Real Problems

- And INFORMS has expanded in both depth and breadth.
- Yes, we still do focused, traditional OR work.
- But, we also do so much more, as special sub-societies have spun out new INFORMS journals.
- Take a look……

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Mathematics of Operations Research

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Marketing Science Journal

SmartWorld:
The Union of Data, Models, and Decisions

Leveraging
Data Acquisition Technologies

Can Anyone Think of Any Business or Governmental Activity that Cannot be Improved by SmartWorld Ideas and Methods?

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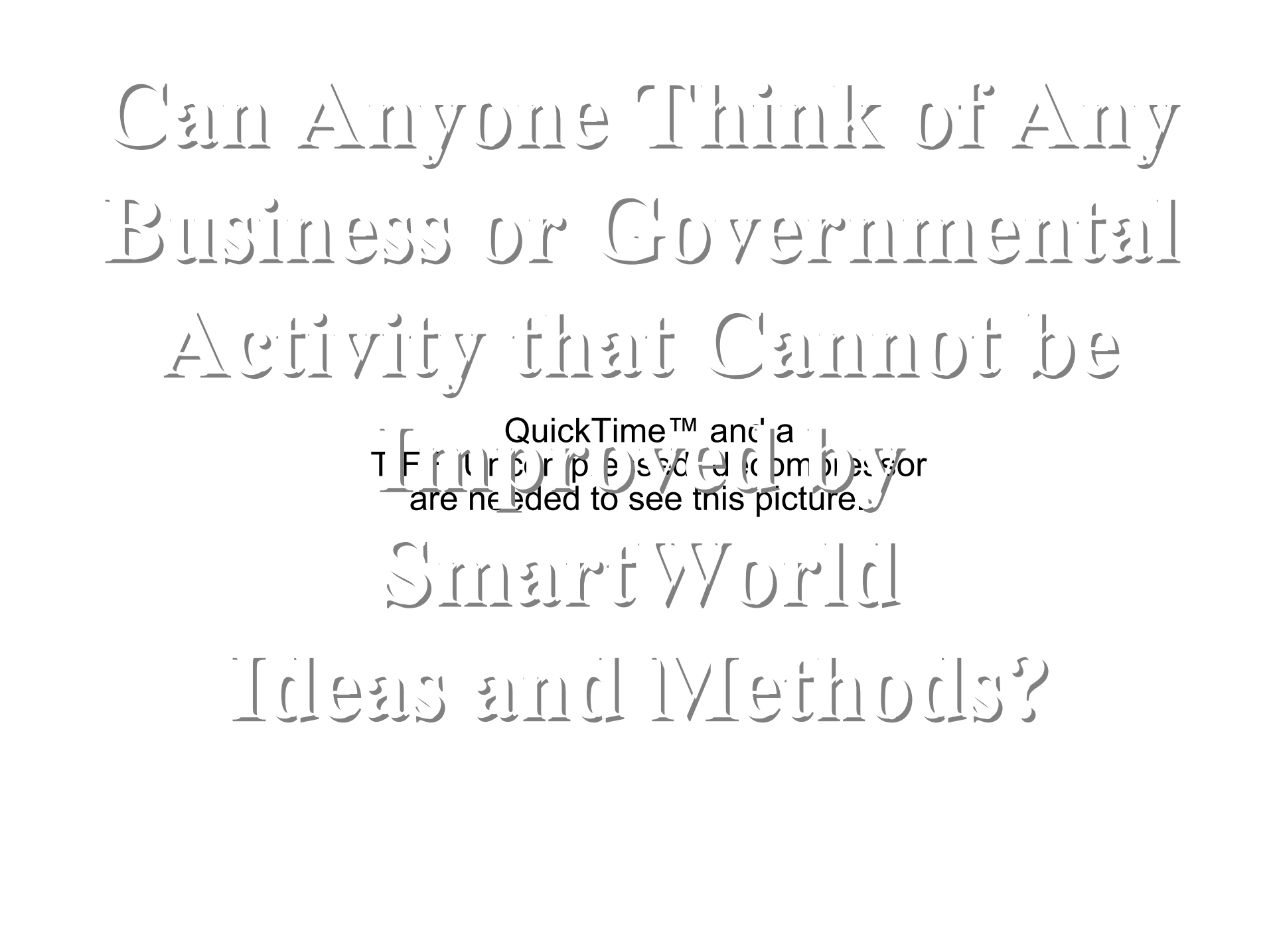

Thank You!

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