

# An Overview of Modeling Bottlenecks in Healthcare Delivery



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# Introduction

## **Notes from: Building a better delivery system**

- **A New Engineering/Health  
Care Partnership**

National Academy of Engineering and Institute of Medicine



# Introduction

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The health care sector is now in deep crises related to safety, quality, cost and access that pose serious threats to the health and welfare of many Americans.

Relatively little technical talent or resources have been devoted to improve or optimize the operations, quality and productivity of the overall U.S. health system.



# Introduction

- Systems engineering tools that have transformed the quality and productivity performance of other large-scale complex systems could also be used to improve health care delivery.
- **SYSTEMS-ANALYSIS TOOLS**
  - ***Modeling and Simulation: Queuing Theory***

It deals with problems that involve waiting (queuing) lines that form because of limited resources. The purpose of queuing theory is to balance customer (patient) service and resource limitations.

# Recent Research Activities

- Mass Dispensing for Bioterrorism and disease outbreaks



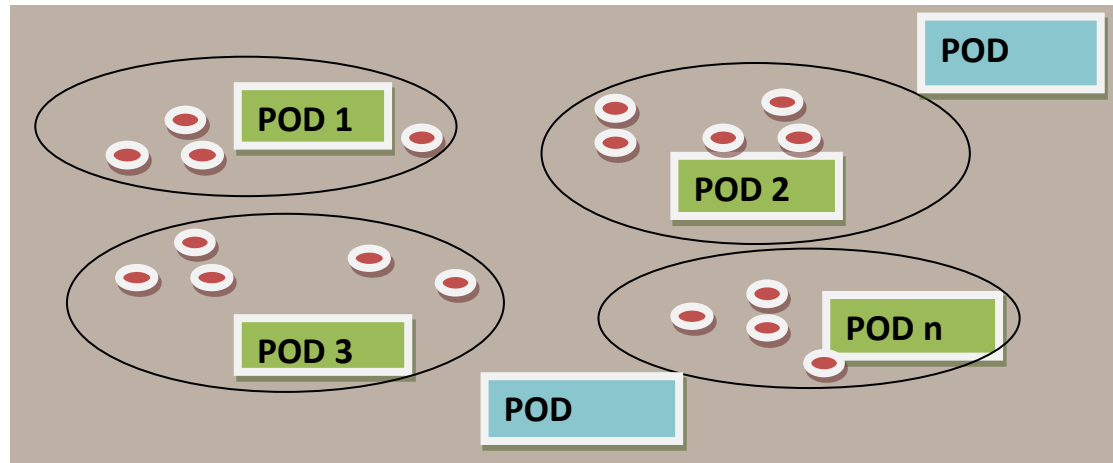
- Pandemic Influenza Modeling
  - Public Health Policy Making (Effectiveness and cost effectiveness of mitigation strategies)
  - Hospital Operations Management





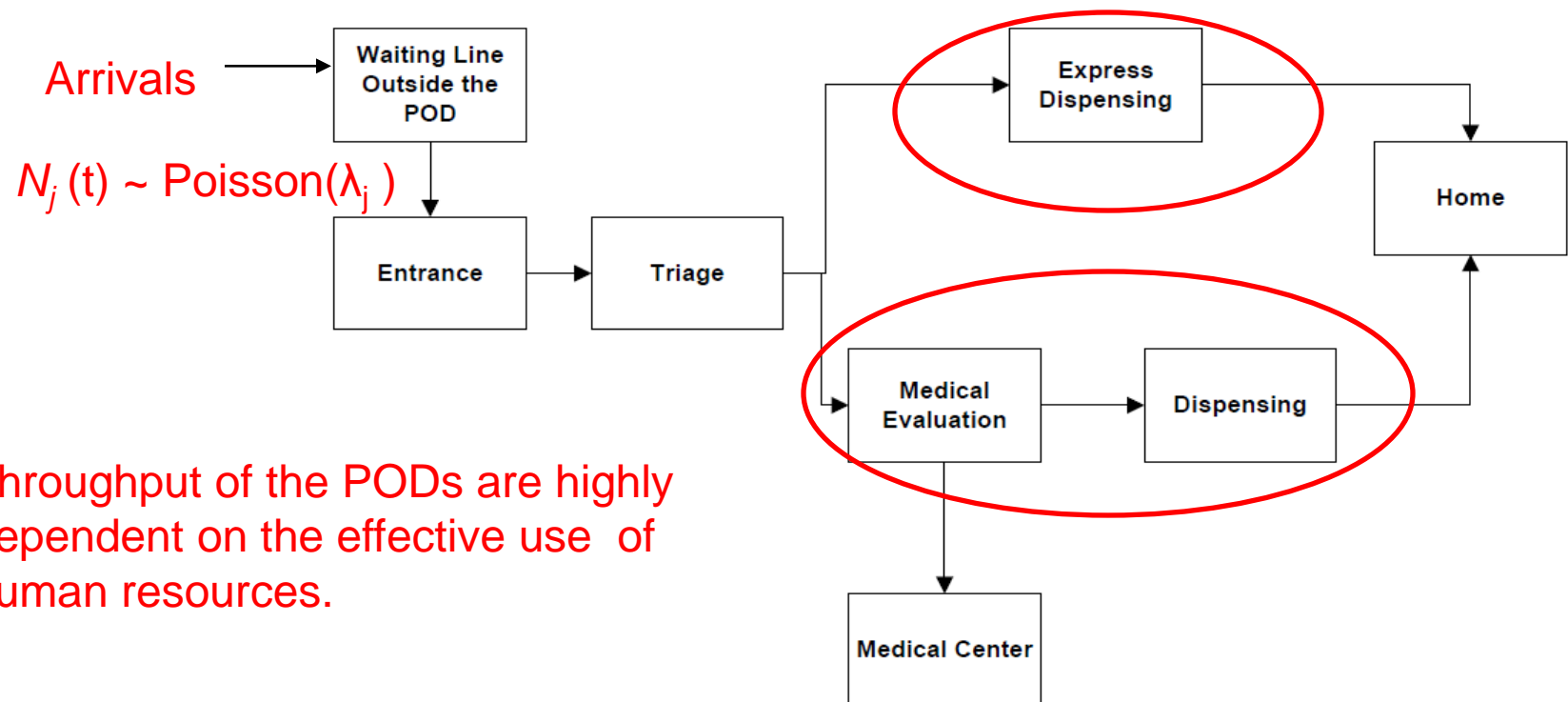
# Mass Dispensing-Problem Description

- Mass dispensing of antiviral and antibiotics requires rapid establishment of a network of dispensing facilities (PODs).
- Given a regional population, determine where to locate PODs for efficient dispensing.
- Determine the assignment of demand points (census block groups) to open PODs.
- Determine the staffing resources needed at each POD for minimizing the time to receive service.



# POD Flow Model

- PODs are usually designed with two different lines: individuals who do not require special screening for any allergic or other medical conditions and individuals who need additional screening before dispensing.
- The number of staff at the entrance-registration and triage stations are enough so that they are not the bottleneck.



Throughput of the PODs are highly dependent on the effective use of human resources.



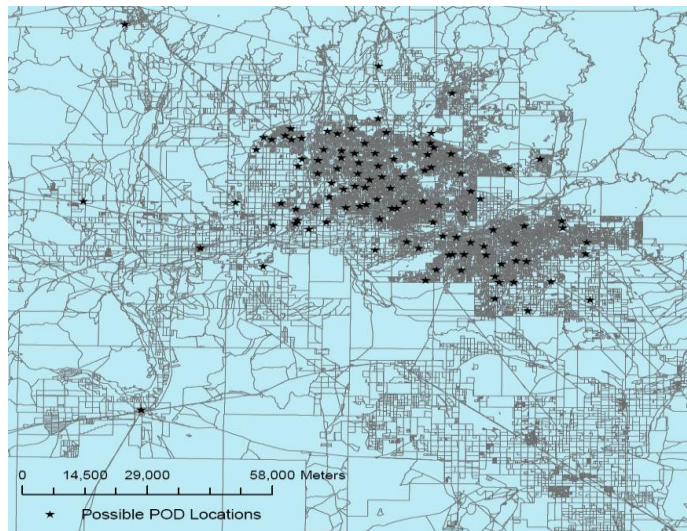
# Waiting Line Modeling

- Service time patterns
- Arrival patterns to each station in the POD
- A Queuing Model Formulation (M/G/s Queues)
- **POD Performance Measures**
  - Average waiting times at each station (i.e. express and regular dispensing)
  - Average utilization at each station
  - Average total time that a patient spends in each POD
- **System Performance Measures**
  - Average Total Service Times
    - Average travel times to PODs
    - Average total times spent in PODs

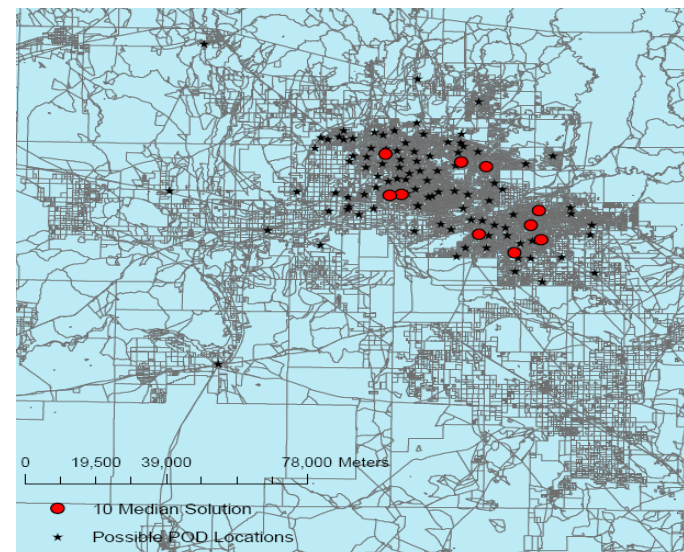


# Computational Results

- We solved the problem for Maricopa County with 105 possible POD locations.
- Maricopa County's 2000 census blocks are used as the aggregated demand locations in the problem.



Possible POD locations

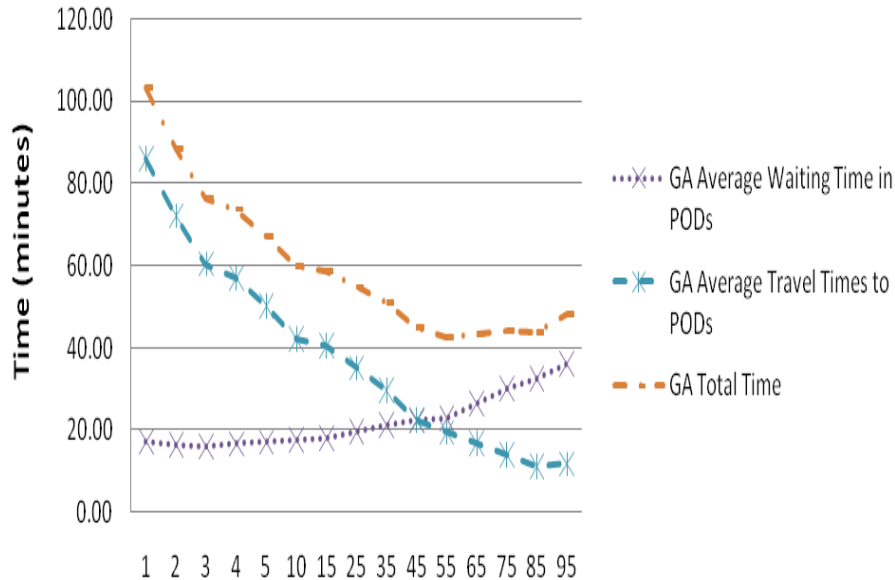


Optimal locations of 10 PODs problem

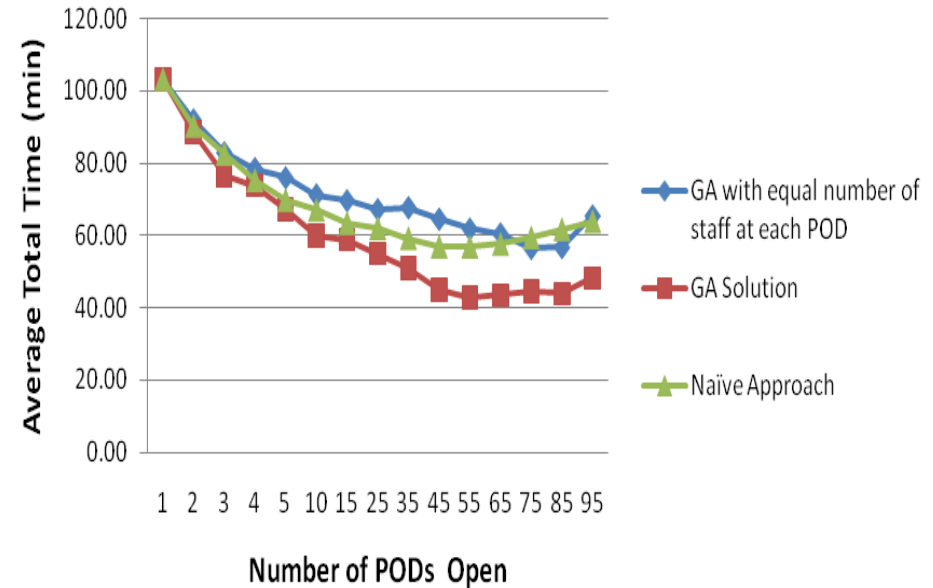
Model

# Results

### Total Time vs # of PODs Open



### Comparison of Different Solutions



- Using Genetic Algorithm (GA), for determining which PODs to open and how many staff to allocate to each POD, decreases the overall time for individuals to receive their required medication.
- Considering the demographics and allocating the staff accordingly decreases waiting times in PODs and increases the throughput values.



# Pandemic Influenza Preparedness

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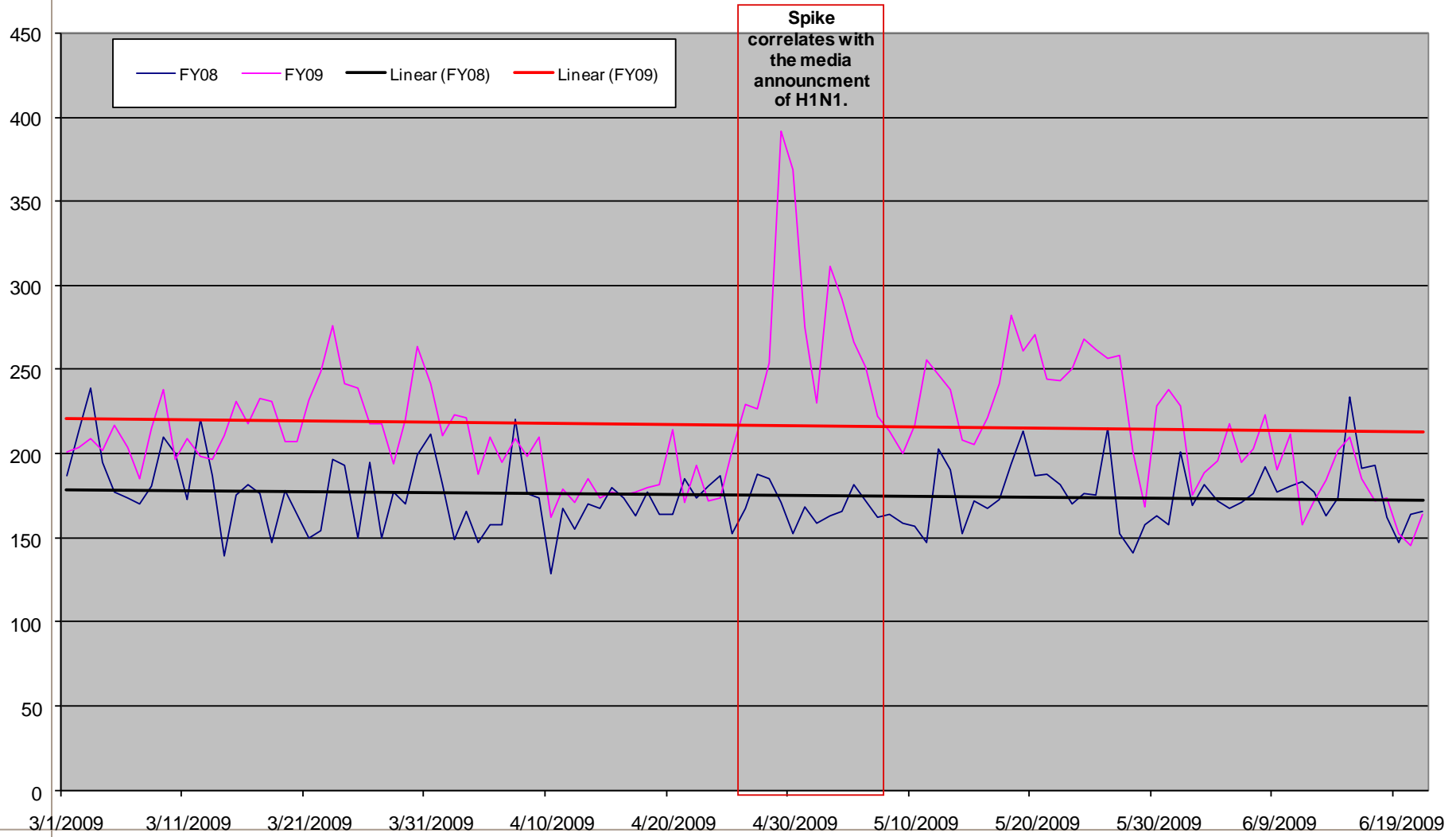
- Effectiveness and Cost effectiveness of school closure policies
- Correlation with ED visits and school closures during the Pandemic Influenza
- Hospital capacity planning for pandemic response
  - Human resources planning
  - Supply management

# Children's Memorial Hospital, Chicago, IL

Emergency Department - Number of Patients per Day by Fiscal Year  
March 1st to June 10th - FY2008 to FY2009

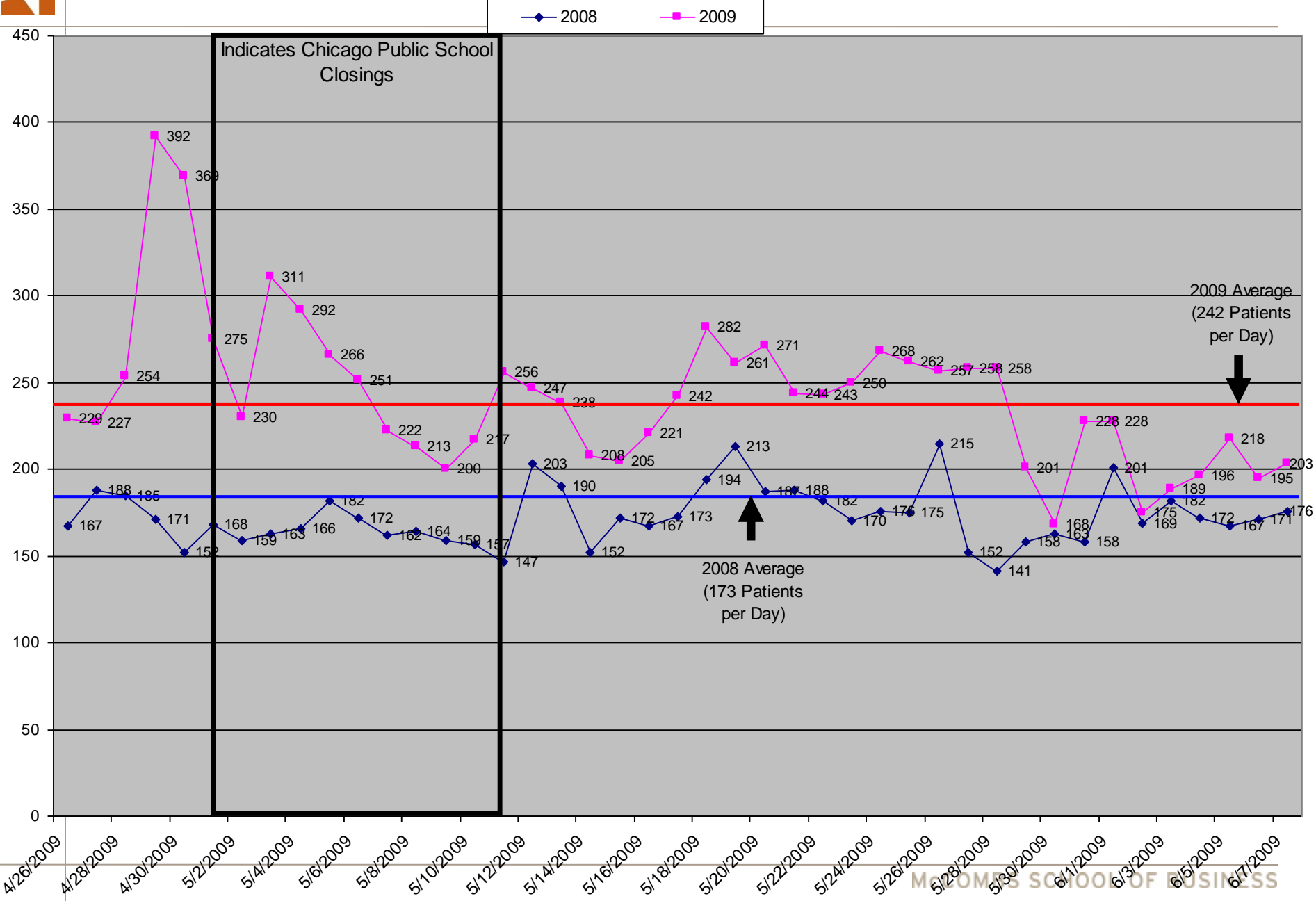


*Krug S. Pediatric Emergency Readiness and Pandemic Influenza. AAP 2009.*



# Children's Memorial Hospital ED Visits

Comparison 08 & 09 - April 26th to June 7th





# Conclusions and Future Works

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- Hospitals and especially the EDs are very likely to become overwhelmed during an outbreak.
- Even though policy decisions can change the dynamics of demand for medical services over time (e.g. school closures for pandemic influenza) effective resource usage and supply management are critical operations for EDs and hospitals.
- Queuing theory and simulation modeling can help improving the performance of EDs through policy evaluations, re-engineering and re-design of the systems.



**THANK YOU**

# New Facility Location Model

$$\text{Min } c_1 \left[ \left( \sum_{i \in I} \sum_{j \in J} \text{Pop}_i (t_{ij} + \bar{W}_j) \right) x_{ij} \right] + c_2 \left[ \left( \sum_{j \in J} \sum_{k \in K} s_k z_{kj} \right) + \left( \sum_{j \in J} f_j y_j \right) \right] \quad (1)$$

$$\sum_{j \in J} x_{ij} = 1 \quad \forall i \in I \quad (2)$$

$$\sum_{j \in J} y_j = p \quad (3)$$

$$x_{ij} \leq y_j \quad \forall i \in I, \forall j \in J \quad (4)$$

$$\sum_{j \in J} z_{kj} = k_k \quad \forall k \in K \quad (5)$$

$$\bar{W}_j = f(\alpha_j, \lambda_{E,j}, \mu_E, z_{E,j}, \lambda_{D,j}, z_{D,j}, \mu_D) \quad (6)$$

$$x_{ij}, y_j \in \{0,1\} \quad \forall i \in I, \forall j \in J \quad (7)$$

$$z_{kj} \in Z^+ \quad \forall j \in J, \forall k \in K$$

[Model](#)