

# Service Engineering

## Class 4

### The Second Prerequisite: Operational Models; Service (Processing, Flow, Queueing) Networks, DSPERTs

- Review: The First Prerequisite - Data, Measurement;
- **Service Networks = Queueing Networks;**
- The Service (Processing, Flow, Queueing) Network Paradigm;
- Dynamic-Stochastic PERT/CPM models, or “Why Queues?”;
- **Operational Queues:** Synchronization, Scarce Resources;
- Analyzing DS-PERT/CPM's:
  1. **Can we do it?** Answer via “Capacity Analysis”
  2. **How long will it take?** via “Response-Time Analysis”
  3. **Can we do better?** “Parametric / Sensitivity (What-If) Analysis”
  4. **What is the best we (one) can do?** “Optimization”
- Multi-Project Management.

## Recall The First Prerequisite: Data & Measurements

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### Empirical “Axiom”:

The Data One Needs is **Never** There For One To Use !

**Averages** tell only a small part of the whole story (yet prevalent)

**Individual-Transaction Level Data:** Time-Stamps of Events

- **Face-to-Face:** T, C, S, I, O, F (QIE, **RFID**)
- **Telephone:** **ACD** Log-Files, CTI/CRM, Surveys
- **Internet:** Click-Stream Data (Log-Files)
- **Transportation:** Sensors at highways/intersections

**Our Databases: Operations** (vs. Marketing, Surveys, ...)

- Face-to-Face data (branch banking) – Recitations;
- Telephone data (small banking call center) – Homeworks;
- **DataMOCCA** (large cc’s: repository, interface) – class/research.

### Future Research:

DataMOCCA on the web; Operation+Marketing;  
Healthcare, Multimedia (Contact Centers), Field-Support.

## The Second Prerequisite: (Operational) Models

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### Empirical Models

- Conceptual
  - Service-Process **Data = Flow** Network
  - **Service Networks = Queueing Networks**
- Descriptive
  - QC-Tools: Pareto, Gantt, Fishbone Diagrams,...
  - Histograms, Hazard-Rates, ...
  - Data-MOCCA: Repository + Interface
- Explanatory
  - Nonparametric: Comparative Statistics, Regression,...
  - Parametric: Log-Normal Services, (Doubly) Poisson Arrivals, Exponential (Im)Patience

### Analytical Models

- Fluid (Deterministic) Models
- Stochastic Models (Birth & Death,  $G/G/n$ , Jackson,...)

## Conceptual Models: Service Networks = Queueing Networks

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- **People**, waiting for **service (resource)**: teller, repairman, ATM;
- **Telephone-calls**, to be answered: busy, music, information;
- **Forms**, to be sent, processed, printed; for a **partner (synchronization)**;
- **Projects**, to be planned, approved, implemented;
- **Justice**, to be made: pre-trial, hearing, retrial;
- **Ships**, for a pilot, berth, unloading crew;
- **Patients**, for an ambulance, emergency room, operation;
- **Cars**, in rush-hour, for parking;
- **Passengers** at Airports, security-check, check-in, taking-off;
- **Checks**, waiting to be processed, cashed.

**Operational Queues** (as opposed to, say, “weather queues”), due to:

- **Scarce Resources** (Resource Queues)
- **Synchronization Gaps** (Synchronization Queues)

Queues are costly, but (many) are **here to stay**.

## Conceptual Fluid Model

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Customers/units are modeled by **fluid (continuous) flow**.

### Labor-day Queueing at Niagara Falls



- Appropriate when **predictable variability** prevalent;
- Useful **first-order** models/approximations, often **suffice**;
- Rigorously justifiable via Functional Strong Laws of Large Numbers.

# The Service (Processing) Network Paradigm

**Dynamic Stochastic Networks** (Time, Uncertainty, System):  
Service- / Flow- / Processing- / Queueing-Networks.

## Building-Blocks:

1. **Customers** (jobs) are Served, **Flow**, Processed;  
Attributes: Arrivals, Services, Routes, Patience,...
2. **Activities** (tasks, services) are what the “jobs” are made of;  
Attributes: **Partially ordered** via Precedence-Constraints,  
summarized in an **Activity (Precedence) Graph** (nodes  
= activities, arcs = precedences).
3. **Resources** serve the Customers (perform the Activities);  
Attributes: **Scarce**, limited by **Processing (Dynamic)  
Capacity** (maximal sustainable service rate; in discrete events,  
capacity also equals the reciprocal of average service-time);  
Customers’ Constituency, Pools, ..., summarized in a **Resource-  
Graph** (nodes = queues + resource-pools, arcs = flows).
4. **Queues** (Buffers) are where activities (customers) wait for  
their service-process to continue; **Human** (vs. Inventories)  
Attributes: Storage (Static) Capacity, which could be infinity;  
Operational queues are either **Resource-Queues** (waiting  
for a resource to become available) or **Synchronization-  
Queues** (waiting for a precedence-constraint to be fulfilled).
5. **Protocols** embody **information** for admission, routing, schedul-  
ing, data-archival and retrieval, quality-monitoring, perfor-  
mance measures (definition, monitoring),...

## The Service-Network Paradigm - 2

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An attempt at a definition:

The **Service-System** is envisioned (modeled) as a **graph** whose nodes represent either **activities** or **resources+queues**; **customers** flow (routed) through the system as their **tasks** are being performed by the resources; tasks processing adheres to **precedence** constraints and each resource serves the tasks within its **constituency**, following the appropriate protocol.

**Schematic** (Conceptual) Descriptions (in Homework):

1. **Activity** Diagram (Graph)
2. **Resource** Diagram (Graph) (Resource + Synch. Q's)
3. **Combined** (Activity+Resource) Graph
4. **Information Flow**

Summarized as “**Service (Process) Flow**”,  
for example “Patient Flow” through hospitals (Standard **LD.3.15**  
of the **JCAHO** = Accreditation of Healthcare Organizations).

**Historical** Evolution, via buzz-words:

- **TQM** = Total Quality Management (80's)
- **BPR** = Business Process ReEngineering (90's)
- **CRM** = Customers Relationship (Revenue) Management (00's)
- **BI / BA** = Business Information / Analytics

Personally: From Project to Process Management  
(in New Product Development, Multi-Project Management)

## The Service-Network Paradigm - 3

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Three (sometimes Four) Steps in Analyzing a Service Networks (demonstrated in the sequel via DS-PERTs).

Gives rise to the following **Guiding Questions**:

1. **Can we do it?** Deterministic **capacity analysis**, via service (process) flow diagrams (spreadsheets, linear programming), which identifies resource-bottlenecks (or at least candidates) and yields **utilization profiles**.

2. **How long will it take?** Typically stochastic **response-time analysis**, via analytical queueing-network models (exact, approximations) or simulations, which yields **congestion curves**.

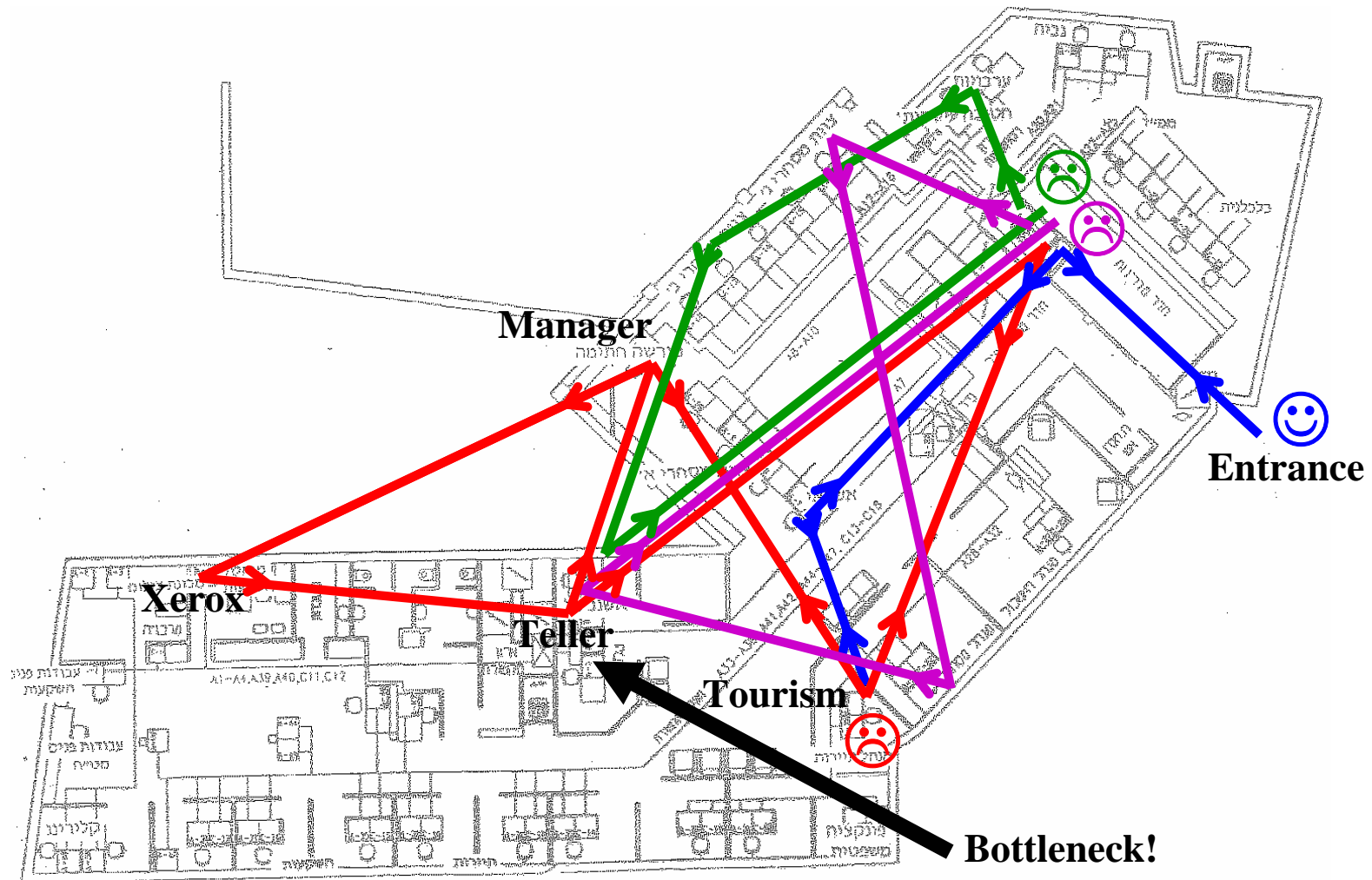
Note: When predictable variability prevails and dominates then the **Fluid View** is appropriate; the analysis is then deterministic, for example via queueing-buildup diagrams. (e.g. Recitation today, Trucks in National Cranberries next class.)

3. **Can we do better? Sensitivity and Parametric (what-if) analysis**, of MOPs or scenarios, which yields directions and magnitudes for **improvements**.

4. **How much better can we (one) do?** or simply: What is optimal to do? Optimal control (exact, asymptotic), typically difficult but more and more feasible, which yields optimal **protocols** (strategies, policies).



## Conceptual Model: Bank Branch = Queueing Network



# Bank Branch: A Queuing Network

## Transition Frequencies Between Units in The Private and Business Sections:

		Private Banking				Business				Exit
	To Unit From Unit	Bankers	Authorized Personal	Compens - - ations	Tellers	Tellers	Overdrafts	Authorized Personal	Full Service	
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%	19%		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%	58%	2%	0%	14%	0%

Legend:

0% - 5%	5% - 10%	10% - 15%	>15%
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## Dominant Paths - Business:

Unit Parameter	Station 1 Tourism	Station 2 Teller	Total Dominant Path
Service Time	12.7	4.8	17.5
Waiting Time	8.2	6.9	15.1
Total Time	20.9	11.7	32.6
Service Index	0.61	0.41	0.53

## 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 the Offered Load (Bank Branch)

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Department	Business Services		Private Banking	Banking Services	
Time	Tourism	Teller	Teller	Teller	Comprehensive
8:30 – 9:00					
9:00 – 9:30					
9:30 – 10:00					
10:00 – 10:30					
10:30 – 11:00					
11:00 – 11:30					
11:30 – 12:00					
12:00 – 12:30					
Break					
16:00 – 16:30					
16:30 – 17:00					
17:00 – 17:30					
17:30 – 18:00					

Legend:

	Not Busy
	Busy
	Very Busy

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

**Conclusion: Models are not always necessary but measurements are !**

## = Tele Net = Queueing Network



## Conceptual Model: Call-Center Network

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### Current Status - Analysis

	Accounts Center	General Center	Technical Center
Peak days in a week	Sun, Fri	Sun	Sun
Peak days in a month	12	8-14, 2-3	10-20
Avg. applications no. in a day	4136	2476	1762
Avg. applications no. in an hour - $\lambda_{avg}$	253.6	193	167
Peak hours in a day	11:00-12:00	10:00-11:00	9:00-10:00
Avg. applications no. in peak hours - $\lambda_{max}$	422	313	230
Avg. waiting time (secs.)	10.9	20.0	55.9
Avg. service time (secs.)	83.5	131.3	143.2
Service index	0.88	0.87	0.72
Abandonment percentage	2.7	5.6	11.2
Avg. waiting time before abandonment (secs.)	9.7	16.8	43.2
Avg. staffing level	9.7	10.3	5.2
Target waiting time	12	25	-

**JOINT COMMISSION ON ACCREDITATION OF HEALTHCARE ORGANIZATIONS**

**2006 HOSPITAL ACCREDITATION STANDARDS FOR  
Emergency Management Planning  
Emergency Management Drills  
Infection Control  
Disaster Privileges**

*(Please note that standards addressing emergency management drills and disaster privileges are undergoing additional research; revised standards for these areas are forthcoming)*

**Standard EC.4.10**

The hospital addresses emergency management.

**Rationale for EC.4.10**

An emergency<sup>1</sup> in the hospital or its community could suddenly and significantly affect the need for the hospital's services or its ability to provide those services. Therefore, a hospital needs to have an emergency management plan that comprehensively describes its approach to emergencies in the hospital or in its community.

**Elements of Performance for EC.4.10**

1. The hospital conducts a hazard vulnerability analysis<sup>2</sup> to identify potential emergencies that could affect the need for its services or its ability to provide those services.
2. The hospital establishes the following with the community:
  - Priorities among the potential emergencies identified in the hazard vulnerability analysis
  - The hospital's role in relation to a communitywide emergency management program
  - An "all-hazards" command structure within the hospital that links with the community's command structure
3. The hospital develops and maintains a written emergency management plan describing the process for disaster readiness and emergency management, and implements it when

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<sup>1</sup>**Emergency** A natural or manmade event that significantly disrupts the environment of care (for example, damage to the hospital's building(s) and grounds due to severe winds, storms, or earthquakes) that significantly disrupts care, treatment and services (for example, loss of utilities such as power, water, or telephones due to floods, civil disturbances, accidents, or emergencies within the hospital or in its community); or that results in sudden, significantly changed, or increased demands for the hospital's services (for example, bioterrorist attack, building collapse, plane crash in the organization's community). Some emergencies are called "disasters" or "potential injury creating events" (PICES).

<sup>2</sup> **Hazard vulnerability analysis:** The identification of potential emergencies and the direct and indirect effects these emergencies may have on the hospital's operations and the demand for its services.

4. The business continuity/disaster recovery plan is implemented when information systems are interrupted.

### **Standard LD.3.15**

The leaders develop and implement plans to identify and mitigate impediments to efficient patient flow throughout the hospital.

### **Rationale for LD.3.15**

Managing the flow of patients through the organization is essential to the prevention and mitigation of patient crowding, a problem that can lead to lapses in patient safety and quality of care. The Emergency Department is particularly vulnerable to experiencing negative effects of inefficiency in the management of this process. While Emergency Departments have little control over the volume and type of patient arrivals and most hospitals have lost the “surge capacity” that existed at one time to manage the elastic nature of emergency admissions, other opportunities for improvement do exist.

Overcrowding has been shown to be primarily an organization-wide “system problem” and not just a problem for which a solution resides within the emergency department. Opportunities for improvement often exist outside the emergency department.

This standard emphasizes the role of assessment and planning for effective and efficient patient flow throughout the organization. To understand the system implications of the issues, leadership should identify all of the processes critical to patient flow through the hospital system from the time the patient arrives, through admitting, patient assessment and treatment, and discharge. Supporting processes such as diagnostic, communication, and patient transportation are included if identified by leadership as impacting patient flow. Relevant indicators are selected and data is collected and analyzed to enable monitoring and improvement of processes.

A key component of the standard addresses the needs of admitted patients who are in temporary bed locations awaiting an inpatient bed. Twelve key elements of care have been identified to ensure adequate and appropriate care for admitted patients in temporary locations. These elements have implications across the organization and should be considered when planning care and services for these patients. Additional standard chapters relevant to these key elements are shown in parenthesis.

- Life Safety Code issues (for example, patients in open areas) (EC)
- Patient privacy and confidentiality (RI)
- Cross training and coordination among programs and services to ensure adequate staffing, particularly nursing staff (HR)
- Designation of a physician to manage the care of the admitted patient in a temporary location, without compromising the quality of care given to other ED patients (HR)
- Proper technology and equipment to meet patient needs (PC, LD)
- Appropriately privileged practitioners to provide patient care beyond immediate emergency services (HR)

# Patient Flow in Hospitals: Reducing Delay in Healthcare Delivery

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## Chapter 1

### MODELING PATIENT FLOWS THROUGH THE HEALTHCARE SYSTEM

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**Abstract:** The system of health care can be evaluated from four perspectives: macro, regional, center, and department. In each case, reduction of patient delay depends on improving interfaces as patients are transferred from activity to activity or department to department. This chapter presents basic tools for resolving delays at interfaces, through mapping the processes by which patients are served, and by developing and implementing measures of system performance. These tools are demonstrated through a case study of the Los Angeles County/University of Southern California Hospital.

**Key words:** Process charts, performance measurement, healthcare systems

## 1. INTRODUCTION

Health care systems have been challenged in recent years to deliver high quality care with limited resources. In the United States, large segments of the population have inadequate health insurance coverage, forcing them to rely on an under funded public health system. At the national level, the National Institutes of Health has projected a steady increase in expenditures over the next 10 years, both in absolute terms and as a percentage of the gross-domestic-product (GDP). Total expenditures in year 2000 amounted to \$1.3 trillion, or 13.2% of the GDP. While expenditures as a percentage of GDP held nearly constant between 1992 and 2000, they increased steadily from 5.2% to 13.1% in the 32-year period from 1960 to 1992. Due to aging of the population and increased costs of medical delivery, health-care costs are projected to increase to 15.9% of the GDP in 2010.



# Patient Flow in Hospitals: Macro-View

## 1. Modeling Patient Flows Through the HEALTHCARE System

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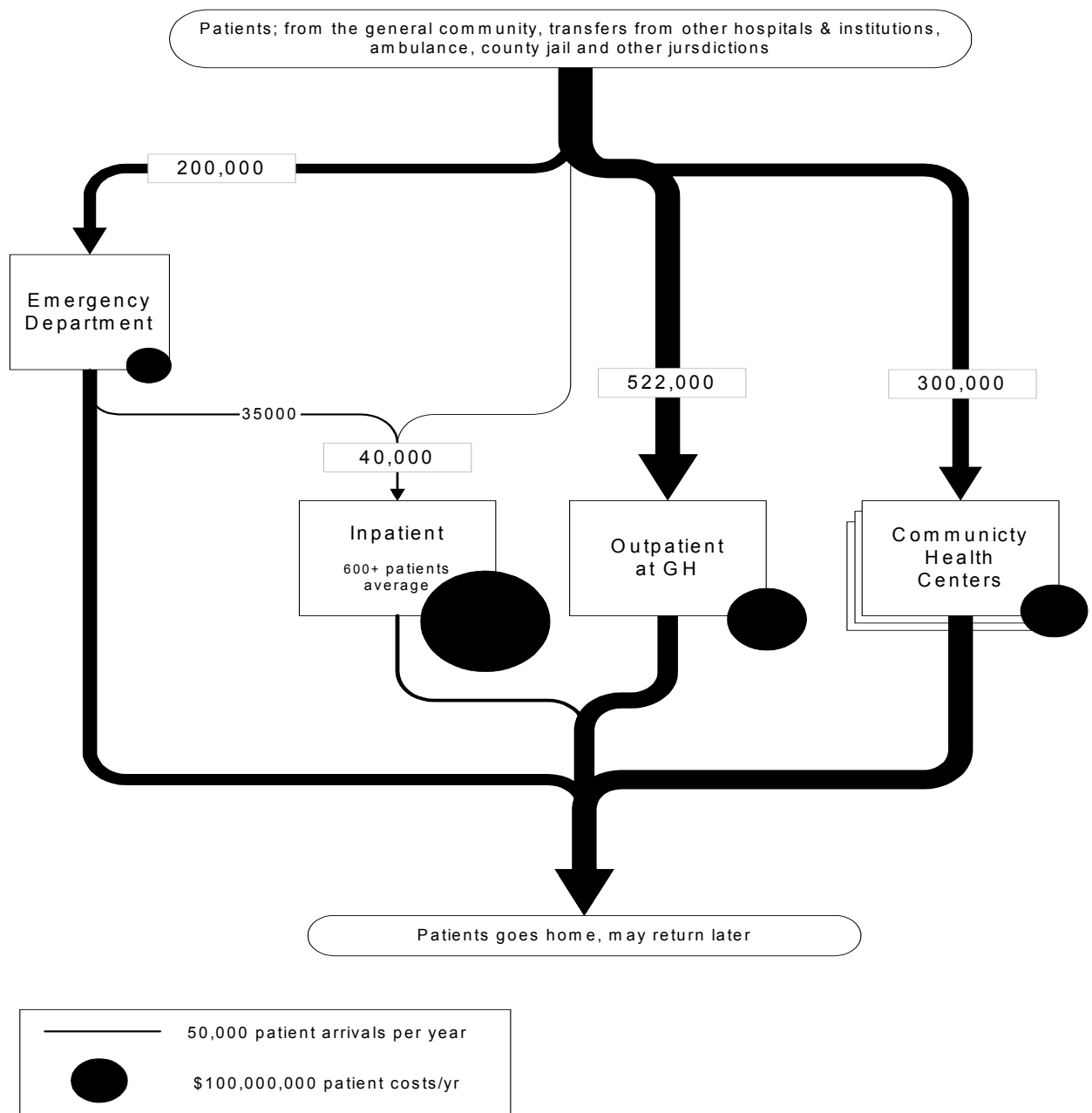


Figure 1-3. Overall Patient Flow and Costs

# Patient Flow: Inpatient Radiology 1

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Chapter 1

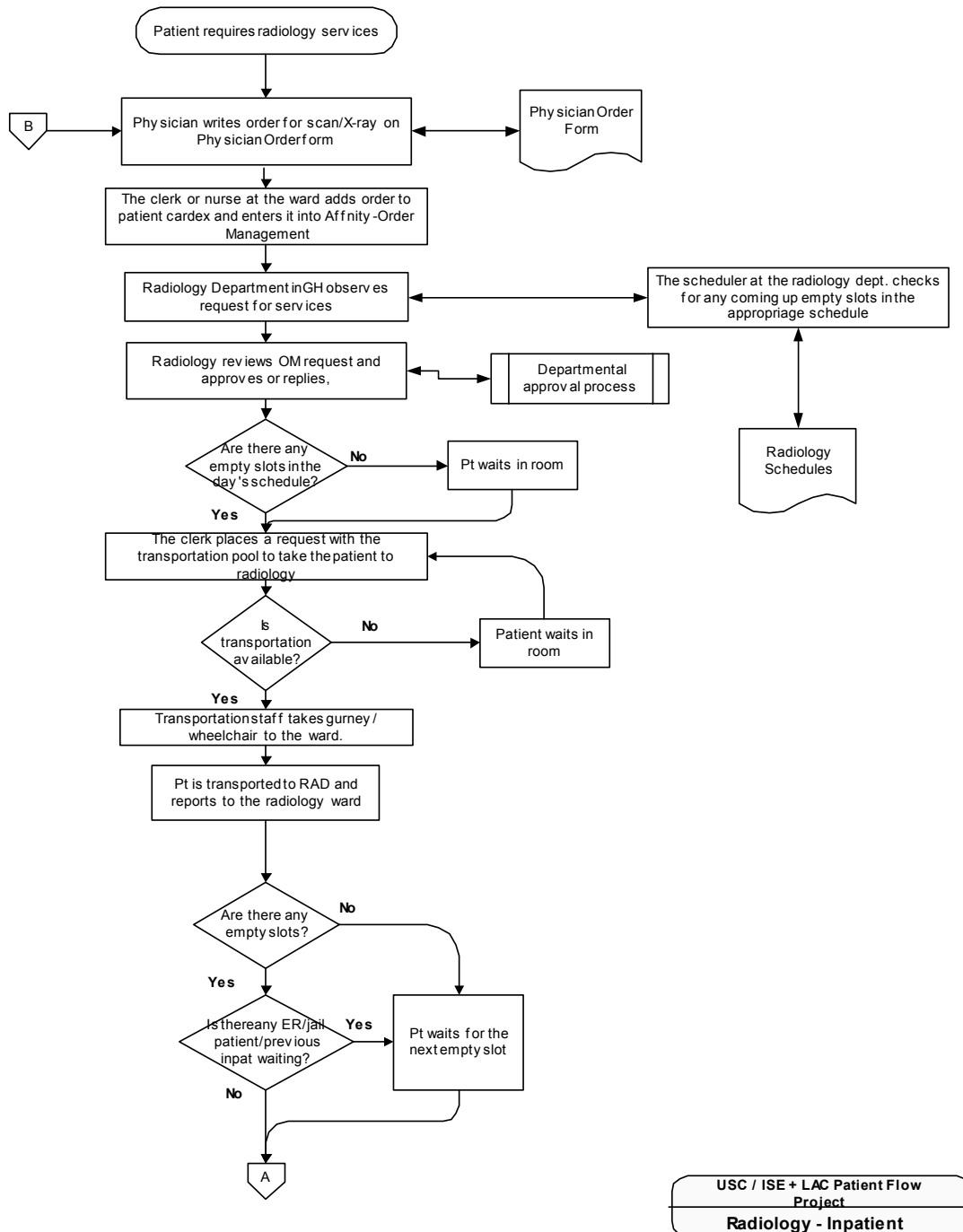


Figure 1-10a. Process Map for Inpatient Radiology, Part 1