Squeezing every efficiency…. 
System Engineering in Healthcare

James Scheulen, Chief Administrative Officer  
Emergency Medicine and Capacity Management  
Johns Hopkins Medicine
Deloitte: The hospital of the future

“In the future, hospitals could have similar command centers (ATC) that equip decision makers with real time support tools to help them make quicker clinical and operational decisions.”

“ATC-like centers already exist ...Why not more broadly at hospitals?”
The future is here...
Assume you are a passenger on any of these airplanes. Would you:

a) Want someone managing flow

b) Trust the pilots to see everything

c) Assume someone is in charge

d) Close your eyes and hope for the best
### Air Traffic Control vs. Capacity Command Center

<table>
<thead>
<tr>
<th>Air Traffic Control</th>
<th>Capacity Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Fixed airspace</td>
<td>• Fixed inpatient beds</td>
</tr>
<tr>
<td>• High utilization</td>
<td>• High occupancy</td>
</tr>
<tr>
<td>• Arrival/Depart Peaks</td>
<td>• Arrival/Depart Peaks</td>
</tr>
<tr>
<td>• Types of plane</td>
<td>• Types of patients</td>
</tr>
<tr>
<td>• Pilot compliance</td>
<td>• Practice variability</td>
</tr>
<tr>
<td>• Emergencies</td>
<td>• Emergencies</td>
</tr>
<tr>
<td>• Runway capacity</td>
<td>• Hospital capacity</td>
</tr>
</tbody>
</table>

**Right plane, right place, right time**

**Right patient, right bed, right time**
Our Discussion Today

Command Center

Active Capacity Management
- Minute by minute
- System resources
- Volume planning

Systems Engineering
- Technology
- Process
- People
Set the Stage:

Hospital leaders find ourselves having to manage with **fewer resources**

Hospital leaders find ourselves having to think more critically about **efficiency**
Set the Stage:

Hospital leaders find ourselves thinking about the intersection of **quality, safety, outcomes, service and efficiency**
A New Level of Complexity: The Hospital as a System

Definition of a “System”

Inputs
Processes
Outputs

Elements that interact to produce an outcome not obtainable by the elements themselves

Hopkins Access Line – Need immediate ability to say “yes”

Variable Arrivals from Scheduled Procedures

Direct Admits from Clinics Unplanned and require rapid bed assignment
Complex System Operations

- Automotive Engineering
  - Improving Mileage
  - Autonomous Vehicles
  - HEV and Electric Vehicles
  - The Dashboard

- Aeronautical Engineering

- Power Engineering

- Air Traffic Control

- Quality
- Safety
- Service
- Outcomes
- Efficiency
How Do They Manage?

Optimize the System Using Systems Engineering & Simulation

- Requirements Review & Feasibility Analysis
- Platform Product Baseline Comparison
- Proposed System Architecture & Sub Component Specifications
- Device Modeling & System Simulation
- Test & Verification
- Pilot Production Build & Optimization

Systems Engineering Approach

Control Centers with Real-time & Predictive Analytics
We Are Here Because We Are Busy

Capacity

ED Boarding

Service

Time

Quality

Outcomes

Clinical

Patient

Access

High/Increasing Demand for Fixed Resources
Managing Fixed Resources – The Tipping Point

Queuing Theory: Matching fixed resources with unscheduled demand

Tipping Point at approximately 85% Utilization

![Graph showing the relationship between Utilization and Waiting Time (Wq) and Customers in Que (Lq)]
Address the opportunities while staying true to our goals:

- Provide the **best care** for our patients
- Place the **right patient** in the **right bed** at the **right time**
- Be **good stewards** of our resources
- Reduce the **daily heroics**

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1. ED Cases: Jan '15 – Apr '15
2. OR Holds: Jan '15 – May '15
3. Transfers: May '13 – Jun '14
Operational Occupancy

Average 24 Hour Operational Occupancy - Medicine
June 2015 - Aug 2017

Beds are fully utilized
Nurses are fully utilized
Providers are fully utilized
Operational Occupancy

**INBOUND INPATIENT TIMELINE**

<table>
<thead>
<tr>
<th></th>
<th>occ</th>
<th>occ*</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACUTE</td>
<td>94%</td>
<td>99%</td>
</tr>
<tr>
<td>Med</td>
<td>96%</td>
<td>103%</td>
</tr>
<tr>
<td>Surg</td>
<td>94%</td>
<td>97%</td>
</tr>
<tr>
<td>Neuro</td>
<td>95%</td>
<td>105%</td>
</tr>
</tbody>
</table>

OCC* includes patients boarding in ED and PACU as well as any direct admissions and HAL patients who have been pre-registered.

**CURRENT WAITING**

<table>
<thead>
<tr>
<th></th>
<th>&gt; 24 HRS</th>
<th>12 HRS</th>
<th>6 HRS</th>
<th>&lt; 6 HRS</th>
<th>TODAY</th>
<th>+1 DAY</th>
<th>+2 DAYS</th>
<th>+3 DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACUTE</td>
<td>9</td>
<td>8</td>
<td>6</td>
<td>19</td>
<td>61</td>
<td>68</td>
<td>56</td>
<td>64</td>
</tr>
<tr>
<td>Med</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surg</td>
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<td></td>
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<tr>
<td>Neuro</td>
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</tr>
</tbody>
</table>

**SCHEDULED ARRIVALS**

<p>| | | | | | | | | |</p>
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>ED</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>9</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAL</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PERIOP</td>
<td>2</td>
<td></td>
<td></td>
<td>21</td>
<td>66</td>
<td>54</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>Other Admits</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>8</td>
<td>16</td>
<td>2</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>
Drivers of Operations

Must be Balanced for Efficient Operations

Time

Volume

Space
Managing Fixed Resources – The Tipping Point

Inflection point and queuing rate:
- **Volume**: Number of patients
- **Time**: Cycle time or Dwell time
- **Space**: Available service sites

Inflection point and queuing rate:
- **Variation/Variability**
- **Variation/Variability**
- **Variation/Variability**
High Occupancy and Complexity – Drivers of Operations
System Operations – Impact of Variability

**Production Line**
- Throughput: 182,500 annually
- Stations: 8
- Cycle time: 26 minutes
- Utilization: 99%

No variation in arrivals
No variation in process
Low cycle time
Cycle time variation is minutes

**Outpatient Centers**
- Throughput: 5,840 annually
- Providers: 3
- Cycle time: 120 minutes
- Utilization: 87.5%

90% of arrivals controlled
Replicated process
Medium cycle time
Cycle time variation is hours

**Hospital**
- Throughput: 50,368 annually
- Stations: 1,059
- Cycle time: 6.2 days
- Utilization: 85%

Arrivals not fully controlled
Complexity not controlled
High cycle time
Cycle time variation is days
So What???
The Journey

• We have seen real improvement
• We have learned about our operations
• We see the further potential for command center
• We have more to do…. 
Healthcare Command Centers
Breakthrough capability for high-quality efficient patient care

Impact at JHH

- Safe sustainable utilization: from 85% → 93%
- ED patient waiting: Reduced 35%
- OR “holds” post-surgery: Reduced 70%
- “Unable to accept out-of-state patients”: Reduced 78%

Judy Reitz Command Center
The Johns Hopkins Hospital
Results: Time to bed assignment

- **Surgery**: 59% reduction
- **Neuro**: 80% reduction
- **Medicine**: 11% reduction
Results: OR Hold

OR Holds (Hours)

OR Holds
86% reduction

PACU and ICU Holds
Both number of holds and Length of hold are down

Developing predictive model

Weekly planning huddle
Results: Inpatient Boarding

ED Boarding Hours (w/o psych)

- Adult Boarding (Median Hrs)

Graph showing the median boarding hours for adults in the ED without psychological cases, with specific data points for February and March.
Results: The Queuing Curve Tipping Point

Boarding Hours vs. Occupancy (January–June 2016)

Current Tipping Point: 85%
Queuing Curve - The Tipping Point

Increasing tipping point from 86% → 94%, effectively expands capacity by 16 beds.
Queuing Curve - The Tipping Point
Applying Tools from Other Industries

Systems Engineering

Technology
Process
People
Technology – Simulation Modeling

**Inputs**

**Historic Data**
Admitted patients (ADT, ED, BedRequests, OR)

**Stakeholder Input**
Identify nuances of FH

**External Analysis**
Plans and reports

**Outputs**

**Output Data**
- Census levels
- Length of stay
- Patient routing

**Analysis**
- Occupancy levels
- Performance rates
- Outlier levels

**Future Planning**
- Emergency Department
- Periop
- IP/Bedmix

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**The Annual Budget Process**
Solution Prioritization Matrix

**Impact:** Compared outputs of various metrics from the simulation model, with high weighting on ED Boarding, OR holds and HAL wait times.

**Difficulty:** Took into consideration cost, magnitude of change, cultural transformation required and the complexity of the technical solution.

![Solution Prioritization Matrix Diagram](image)
Reaching the Capacity Goals

Requires a combination of solutions

- Adding additional 12 beds in Adult (Nelson move) and 4 in Peds
- Streamline and Empower patient placement
- Conditionally Share Beds
- Streamline ED admission process
- Discharge based on needed supply
- Fully Staffing WICU to 20 beds

- 89% patients board in ED < 4 hrs
- Capacity to see additional 8 patients in ED
- 36% reduction in OR holds (55% in WBG OR)
- 60% reduction in HAL boarding
FY17 Model vs. Actuals

**Functional Unit:**
Model Occupancy Projection's Compared to Actual

<table>
<thead>
<tr>
<th>Model Projection</th>
<th>Actuals (8/2016-1/2016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Med</td>
<td>93%</td>
</tr>
<tr>
<td>Surg</td>
<td>90%</td>
</tr>
<tr>
<td>Neuro</td>
<td>89%</td>
</tr>
<tr>
<td>Onc</td>
<td>86%</td>
</tr>
</tbody>
</table>

**Average Boarding Hours**

<table>
<thead>
<tr>
<th>Model Projected</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1 hrs</td>
<td>6.9 hrs</td>
</tr>
</tbody>
</table>
What if?

**Optimal bed complement in future scenarios?**

**Develop strategy to improve OP clinic access**

**What if we cohort ortho patients differently?**

Will growth of Cohort A cause Cohort B to be less localized which in turn increases B’s ALOS and constrains growth of Cohort C? What if we adjust Unit mix? What if we shift Cohort D to outpatient? What about ED patient waiting?
Healthcare Command Center Concept
How Does It Work?

GE Wall of Analytics
Coordinate patient-centered care now

GE Prediction & Logic Engine
Integrate, predict and prioritize

Orders System
OR System
Radiology System
ED System
Beds System
Lab System
Pharmacy System
Staffing System

Data pulled from existing source systems

Orders System
Real Time
Real Time
Real Time

PACU Hub
Units at Risk
Discharges

Oral Hygiene

Real Time
Mobile Access
In units and on-the-go

Action
Action
Action
Types of Analytics

Situational Awareness
Prescriptive
Predictive
Suite of Analytics Solving Unique Problems

Access & System Balance

Perioperative flow

Quality and Safety

Discharge and ALOS

Throughput
Transfer
Prioritize, place and route the patient to the right place
Prioritized Patient Placement Queue
Detect which patient to place in the next available bed

Description
Provides a single prioritized queue for next available bed. Prioritization schema uses machine learning to mirror organizational behavior. Client has ability to modify schema to reflect behaviour adjustments.

Impact
- Expedite patient placement
- Assimilate and adjust cultural practice
- Improve placement quality
## Sepsis Care

### Surveillance of sepsis risk and pathway compliance

**Description**
Provides caregivers a backstop in the surveillance of sepsis risk and monitoring compliance with defined sepsis bundle protocol. Alerts triggered when patients deviate from the pathway.

**Impact**
- Reduce deterioration in care quality
- Improve timeliness of sepsis care

---

### SEPSIS CARE

<table>
<thead>
<tr>
<th>SEPSIS FLAG - NO TREATMENT</th>
<th>4/72</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIME DETECTION</td>
<td>3h 50m</td>
</tr>
<tr>
<td>PATIENT</td>
<td>A.JAR</td>
</tr>
<tr>
<td>STATUS</td>
<td>CONFIRMED</td>
</tr>
<tr>
<td>FLAGS</td>
<td>MED</td>
</tr>
<tr>
<td>UNIT</td>
<td>NS04-443</td>
</tr>
<tr>
<td>BED</td>
<td></td>
</tr>
</tbody>
</table>

| TIME DETECTION            | 2h 20m |
| PATIENT                   | H.BUR |
| STATUS                    | AT RISK |
| FLAGS                     | SURG |
| UNIT                      | MBG3-005 |

| TIME DETECTION            | 6h 15m |
| PATIENT                   | B.PIN |
| STATUS                    | NEGATIVE |
| FLAGS                     | MED |
| UNIT                      | NS04-335 |

| TIME DETECTION            | 1h 15m |
| PATIENT                   | R.SUL |
| STATUS                    | NEGATIVE |
| FLAGS                     | MED |
| UNIT                      | MEY9-004 |

**BUNDLE**

<table>
<thead>
<tr>
<th>ELAPSED TIME</th>
<th>PATIENT</th>
<th>ORDERS</th>
<th>UNIT</th>
<th>BED</th>
</tr>
</thead>
<tbody>
<tr>
<td>3h</td>
<td>A.JAR</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**3-HOUR RESUSCITATION**

<table>
<thead>
<tr>
<th>ELAPSED TIME</th>
<th>PATIENT</th>
<th>ORDERS</th>
<th>UNIT</th>
<th>BED</th>
</tr>
</thead>
<tbody>
<tr>
<td>2h 20m</td>
<td>S.REN</td>
<td>Antibiotics</td>
<td>MED</td>
<td></td>
</tr>
</tbody>
</table>

**6-HOUR SEPTIC SHOCK**

<table>
<thead>
<tr>
<th>ELAPSED TIME</th>
<th>PATIENT</th>
<th>ORDERS</th>
<th>UNIT</th>
<th>BED</th>
</tr>
</thead>
<tbody>
<tr>
<td>2h 20m</td>
<td>K.JIH</td>
<td>Lactate Level</td>
<td>MED</td>
<td></td>
</tr>
</tbody>
</table>

**SOURCE CONTROL**

<table>
<thead>
<tr>
<th>PATIENT</th>
<th>INFECTION PROCEDURE</th>
<th>UNIT</th>
<th>BED</th>
</tr>
</thead>
<tbody>
<tr>
<td>T.HIR</td>
<td>Abscess</td>
<td>MEY9-006</td>
<td></td>
</tr>
</tbody>
</table>

**ELEVATED**

<table>
<thead>
<tr>
<th>PATIENT</th>
<th>STATUS</th>
<th>UNIT</th>
<th>BED</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.HAL</td>
<td>MED</td>
<td>MEY9-006</td>
<td></td>
</tr>
</tbody>
</table>

**OTHER SEPSIS**

<table>
<thead>
<tr>
<th>PATIENT</th>
<th>UNIT</th>
<th>BED</th>
</tr>
</thead>
<tbody>
<tr>
<td>J.KIN</td>
<td>GYN</td>
<td>WGH4-407</td>
</tr>
</tbody>
</table>

**F.LOG**

<table>
<thead>
<tr>
<th>PATIENT</th>
<th>UNIT</th>
<th>BED</th>
</tr>
</thead>
<tbody>
<tr>
<td>J.HIN</td>
<td>GYN</td>
<td>WGH4-411</td>
</tr>
</tbody>
</table>

**Peds**

<table>
<thead>
<tr>
<th>PATIENT</th>
<th>UNIT</th>
<th>BED</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.LEE</td>
<td>PED</td>
<td>Z0095-020</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PATIENT</th>
<th>UNIT</th>
<th>BED</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.JOH</td>
<td>PED</td>
<td>Z0095-032</td>
</tr>
</tbody>
</table>

---

### Total Sepsis Load

<table>
<thead>
<tr>
<th>Confirmed</th>
<th>At Risk</th>
<th>Elevate</th>
<th>Bundle</th>
<th>Other Sepsis</th>
<th>Peds</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>25</td>
<td>15</td>
<td>30</td>
<td>25</td>
<td>8</td>
</tr>
</tbody>
</table>
Predictive Analytics

Forecast - Occupancy

**Med**
- 98% ▼
- 251 / 242
- Census / Capacity

**Surg**
- 96%
- 216 / 224
- Census / Capacity

**Neuro**
- 95%
- 79 / 86
- Census / Capacity

**Onc**
- 96%
- 80 / 83
- Census / Capacity

Last Forecast: Mar 30 2017 06:00 Simulated at: 05:58
Recipe for success: People

- Cultural shift
- Medicine actions
- Governance
  - During process
  - Ongoing structure

Change Management
Structure: Capacity Optimization (Sustainment)

Capacity Optimization Executive Committee

Office of Capacity Management
(J. Scheulen, M. Jacobs, D. Efron, E. Kane, L. Huffman, D. Wilson, J.A. Fenstermaker)

Capacity Management Committee
(DONs, Admin, Vice Chairs)

Clinical Directors

Hospital

Oversight of patient flow and capacity optimization; Strategic capacity plans; Triage opportunities to functional level as appropriate

Functional/Departmental

Functional Units
Nursing
Care Coordination
Periop
ED
Providers
Essential Services
Command Center

Leadership
DON
Standard of Practice

OR Exec
Periop Leadership
COC
CEC
EMOG
Clinical Directors
Medical Board

Advisory Steering
Huddles
CC Ops

Cap Ops Committee partners with existing functional & multi-disciplinary teams to conduct deeper dive analysis & problem solving

*Examples of committees may not be all inclusive
Recipe for success: Process

- System design
  - Remember Southwest....
- Optimize for the system
  - Plan for the desired outcome
- Break silos
System Design vs Process Improvement

Aligned Discharges

Discharge requires more than an order
Discharge is more than a single process
Need a system design

Write order earlier in day

Some minor impact but not what we expected…..
System Design vs Process Improvement

Aligned Discharges

- ID potential for D/C: *A Predictive Analytic*
- Communication Multi-D Rounds
- Physician Rounding and Communication
- Family communication
- Patient Education
- Final required clinical studies
- ID of barriers
- Transportation home
- D/C summary
- D/C work sheet
- D/C prescriptions
- Medication reconciliation
- Write order earlier in day
# System Design vs Process Improvement

## Table: Discharge Day -3 to Discharge Day 0

<table>
<thead>
<tr>
<th>Patient</th>
<th>Discharge Day -3</th>
<th>Discharge Day - 2</th>
<th>Discharge Day - 1</th>
<th>Discharge Day 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identified as potential discharge</td>
<td>Clinical Improvement</td>
<td>First Hint</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Case Manager/Social Worker</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discuss post d/c placement</td>
<td>Discharge transportation has been discussed &amp; arranged.</td>
<td></td>
<td></td>
<td>Health care buddy involved in discharge teaching</td>
</tr>
<tr>
<td>Return to work/school letter completed</td>
<td>MOLST is available.</td>
<td></td>
<td></td>
<td>DC transportation confirmed</td>
</tr>
<tr>
<td><strong>Nursing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient has access/key to their home</td>
<td>Patient’s IV access discontinued</td>
<td></td>
<td></td>
<td>Patient has received required DC education.</td>
</tr>
<tr>
<td></td>
<td>Patient has clothes to wear upon DC</td>
<td></td>
<td></td>
<td>Return patient valuables</td>
</tr>
<tr>
<td></td>
<td>Rxs filled @ hospital outpatient pharmacy are available</td>
<td></td>
<td></td>
<td>Return meds brought</td>
</tr>
<tr>
<td><strong>Physician</strong></td>
<td></td>
<td></td>
<td></td>
<td>DC Summary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Date patient received</td>
<td>Date patient discharged</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nurse informed of AVS completion</td>
</tr>
<tr>
<td><strong>Housestaff</strong></td>
<td></td>
<td></td>
<td></td>
<td>Rest of Med Scripts Sent (i.e. different meds and/or dose)</td>
</tr>
<tr>
<td>Admissions Med Rec</td>
<td>Rx filled @ hospital outpatient pharmacy are available</td>
<td></td>
<td></td>
<td>Rxs faxed to preferred non-hospital outpatient pharmacy</td>
</tr>
<tr>
<td></td>
<td>DC med rec</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Selected Med Scripts Sent (i.e. same meds and @ same dose, and those requiring pre-auth.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Begin writing Discharge orders</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Just the Beginning
Our Vision

System Management
- HAL manage JHHS flow
- Telemedicine Connection

Clinical Care
- Sepsis Score
- Clinical Care Protocols

Care Efficiency
- Discharge Activity
  - Staffing

Productivity
- Supply tracking
  - E-Handoffs

Predictive Analytics
- LOS
- Supply & Demand
Our Approach

THINK BIG, START SMALL, ACT NOW

Azeem Alhar