Team HOPE
Hospital Optimal Productivity Enterprise

March 26, 2010

Katie Johnson      John Silberholz
Daniel Kalowitz    Alex Simpson
Jay Kellegrew      Emily Sze
Ben Kubic          Ekta Taneja
Joseph Lim         Edward Tao

Team Mentor: Dr. Bruce Golden
Team Librarian: Zaida Diaz
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Project Overview

Broad Healthcare Landscape

- Health Care Reform Bill, 2010
- Americans spent $2.3 trillion on health care in 2007
- Hospitals are one of the least efficient sectors

University of Maryland Medical Center (UMMC)

UMMC
- 800 beds
- 1,182 doctors
- 742 residents

UMMC ED
- 55 beds
- 20% admission rate
- 46,000 patients/year
# UMMC Stats

<table>
<thead>
<tr>
<th></th>
<th>UMMC ED</th>
<th>Top quartile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume (patients / bed / day)</td>
<td>3.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Ambulance diversions</td>
<td>408</td>
<td>20</td>
</tr>
<tr>
<td>Ambulance diversion (hrs)</td>
<td>4,038</td>
<td>100</td>
</tr>
<tr>
<td>Length of stay (hrs)</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>LOS Admitted patients (hrs)</td>
<td>10.3</td>
<td>6.7</td>
</tr>
<tr>
<td>LOS Treated &amp; released patients (hrs)</td>
<td>9.7</td>
<td>3</td>
</tr>
<tr>
<td>Bed ready after request (min)</td>
<td>110.2</td>
<td>70.2</td>
</tr>
</tbody>
</table>

3/29/2010
Residency Model

Medical School
- Four years
- Classes, clinical rotations

Residency
- First year: Internship, general medicine
- Next 2-6 years: Specialty

Attending Physician
- Private practice or hospital
Research Objectives

Hypothesis

If a simulation modeling the flow of resources within the ED is utilized, then the overall level of efficiency will increase, thus improving patient care.
## Literature Review

### Resident Education

<table>
<thead>
<tr>
<th>Study Author</th>
<th>Description of Findings</th>
<th>Impact on Hospital</th>
<th>Simulation Used?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvey, 2008</td>
<td>Patients’ length of stay reduced when residents on strike</td>
<td>Negative</td>
<td>No</td>
</tr>
<tr>
<td>Jeanmonod, 2007</td>
<td>Productivity of inexperienced doctors decreases over the course of a shift</td>
<td>Negative</td>
<td>No</td>
</tr>
<tr>
<td>Shayne, 2009</td>
<td>Increased patient density leads to poor time management by residents</td>
<td>Negative</td>
<td>No</td>
</tr>
<tr>
<td>Dassinger, 2008</td>
<td>Multitude of 1 to 5 minute actions fragment residents’ work processes</td>
<td>Negative</td>
<td>No</td>
</tr>
<tr>
<td>Bush, 2007</td>
<td>Increased patient density leads to improved patient care</td>
<td>Positive</td>
<td>No</td>
</tr>
</tbody>
</table>
## Literature Review

### Simulation Modeling

<table>
<thead>
<tr>
<th>Study Author</th>
<th>Description of Findings</th>
<th>Research Hospital?</th>
<th>Emergency Department?</th>
<th>Live Data Collection?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Komashie, 2005</td>
<td>Adding staff/beds leads to reduced waiting times</td>
<td>Unknown</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Miller, 2004</td>
<td>Simulations are more fluid than mathematical models</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Kolb, 2008</td>
<td>Tested five different patient buffer concepts through their simulation</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Rossetti, 1999</td>
<td>Adding one attending from 10am to 6pm leads to reduced LOS</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
## Studies Comparison

<table>
<thead>
<tr>
<th></th>
<th>Research Hospital</th>
<th>Emergency Department</th>
<th>Live Data Collection</th>
<th>Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bush</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Dassinger</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Harvey</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
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<tr>
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<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Kolb</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Komashie</td>
<td>Unknown</td>
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<td>Y</td>
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<tr>
<td>Miller</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
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<td>Rossetti</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Shayne</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><strong>Team HOPE</strong></td>
<td><strong>Y</strong></td>
<td><strong>Y</strong></td>
<td><strong>Y</strong></td>
<td><strong>Y</strong></td>
</tr>
</tbody>
</table>
Methodology Overview

Data Collection

Apply for UMD IRB
Apply for UMMC IRB

Acquire Funding

Approved

Patient-specific Data Collection
Doctor-specific Data Collection

Formulation of Research Hypothesis

Formulate Conclusions

Simulation Model

Program Simulation Model

Analyze Data
Simulation Model

- Several parts to model creation
  - Collect timing, patient and availability data
    - Enables simulation model
  - Validate model
Collected Data

**Timing Data**
- Patient visit times
- Computer access times
- Transportation times
- Lab test times

**Historical Patient Data**
- Arrival time
- Demographic info
- Priority
- Lab tests needed

**Availability Data**
- Personnel schedules
- Available lab equipment
- Available beds
Simulation Process Flow

Patient Arrival
Patient Attributes
Patient Bed Selection
Patient Activity/LOS
Simulation Process Flow

Useful Statistics Regarding Patient Arrivals Must Be Collected

Poisson Coefficients (Rates) of Patient Arrivals
Organized by Day and Time

- Poisson coefficient represents rate of patient arrivals
- Coefficients were calculated for each day of the week by hour
Simulation Process Flow

Patient Arrival  \[\text{Patient Attributes}\]  Patient Bed Selection  Patient Activity/LOS
Simulation Process Flow

Apply Attributes to Each Patient in Simulation Model

- Severity Score (1 to 5)
- # of Lab Tests Conducted
- Triage Time
- Probability of Patient Admittance into Inpatient Ward
- Probability of Patient Admittance into Ambulatory Zone
Simulation Process Flow

Severity of Incoming Patients to ED Waiting Room

- Severity 1: 0.30%
- Severity 2: 12.07%
- Severity 3: 37.99%
- Severity "NA": 24.31%
- Severity 5: 5.10%
- Severity 4: 20.24%
Simulation Process Flow

Incoming Patients Sent to Ambulatory Zone

<table>
<thead>
<tr>
<th>Severity</th>
<th>Percentage Sent to Ambulatory Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severity 1</td>
<td>6.45</td>
</tr>
<tr>
<td>Severity 2</td>
<td>3.41</td>
</tr>
<tr>
<td>Severity 3</td>
<td>25.30</td>
</tr>
<tr>
<td>Severity 4</td>
<td>90.07</td>
</tr>
<tr>
<td>Severity 5</td>
<td>95.54</td>
</tr>
<tr>
<td>Severity &quot;NA&quot;</td>
<td>34.14</td>
</tr>
</tbody>
</table>

3/29/2010
Simulation Process Flow

# Lab Tests for Severity 1–3 and did not go into ward

Sample Size: 2447
Mean: 10.56804
Std Deviation: 5.785679
Skewness: -0.03029
Kernel AMISE: 0.000097
Bandwidth: 1.484219
C Value: 0.785204
Normal
Simulation Process Flow

# Lab Tests for Severity Null and went into ward

- Sample Size: 622
- Mean: 18.618
- Std Deviation: 7.692321
- Skewness: 1.013267
- Gamma Shape: 9
- Scale: 2
- Threshold: 0
Simulation Process Flow

Triage Time for Severity Null and went into ward

- Sample Size: 781
- Mean: 960.7068
- Std Deviation: 781.9343
- Skewness: 1.324655
  - Gamma Shape: 1.680497
  - Scale: 571.5801
  - Threshold: 0
Simulation Process Flow

Triage Time for Severity Null and did not go into ward

Sample Size: 642
Mean: 1037.291
Std Deviation: 816.7351
Skewness: 1.897809
Gamma Shape: 1.587685
Scale: 653.2531
Threshold: 0
Simulation Process Flow

- Patient Arrival
- Patient Attributes
- Patient Bed Selection
- Patient Activity/LOS
Simulation Process Flow

Analytic Hierarchy Process

Goal

Criterion 1
Criterion 2
Criterion 3
Criterion 4

Alternative 1
Alternative 2
Alternative 3
Simulation Process Flow

Analytic Hierarchy Process

• Pairwise Comparison is done for all patients
  • Patient Severity Level
  • # of Times Patient is Passed Over by Triage Nurse

• 16 Classes of Patients are determined
  • Probability of ED Admittance is determined for each class

• No Answer When Called (NAWC) Rate is also taken into account
Simulation Process Flow

Analytic Hierarchy Process

- Key initial findings include:
  - Patients with low severity level are often admitted before those with higher severity level
  - The longer patients wait to be admitted, the less likely they are to ever be admitted
Simulation Processes Flow

Parameters Used to Calculate Patient Length of Stay

Basic Parameters (Historical Data)
- Patient Severity Level
- # of Lab Tests Conducted
- Whether or not Residents were on duty when patient was admitted

Advanced Parameters (Live Data)
- Time spent by doctors during initial patient visit
- Time spent by doctors during typical rounds visit
- Doctor preferences based on severity level, patient condition type, lab tests taken, etc.
Simulation Processes Flow

**Parameters Used to Calculate Patient Length of Stay**

- Created distributions using SAS according to identified parameters
- Distributions are used to calculate average Length of Stay (LOS) for patients
Simulation Processes Flow

Patient not warded and with no labs;
Severity 1-3, Residents present

Sample Size 1185
Mean 11455.04
Std Deviation 5742.892

Normal Mean (Mu) 11000
Std Dev (Sigma) 5758.475

Secs

[Bar chart and distribution graph showing data points and statistical measures]
Simulation Processes Flow

• Created distributions using SAS according to identified parameters
• Distributions are used to calculate average Length of Stay (LOS) for patients
Simulation Processes Flow

**Parameters Used to Calculate Patient Length of Stay**

**Basic Parameters (Historical Data)**
- Patient Severity Level
- # of Lab Tests Conducted
- Whether or not Residents were on duty when patient was admitted

**Advanced Parameters (Live Data)**
- Time spent by doctors during initial patient visit
- Time spent by doctors during typical rounds visit
- Doctor preferences based on severity level, patient condition type, lab tests taken, etc.
Data Collection

UMD IRB: October 8, 2008

To: Dr. Bruce Golden
Ekta Taneja
Gemstone

Re: IRB Application Number: 08-0431
Project Title: "Hospital Optimal Productivity Enterprise"

Approval Date: October 08, 2008
Data Collection

UMMC IRB: December 7, 2009

New Study Approval Notification

Date: December 7, 2009

To: Jon Mark Hirshon
From: IRB Chair/Vice Chair: Lisa Dixon
RE: HP-00044061
Risk designation: Minimal Risk
Submission Date: 11/3/2009
Original Version #: N/A

Approval for this project is valid from 12/7/2009 to 12/6/2010
Data Collection

Patient-Specific Collection

- Attending Visit
- Senior Resident Visit
- Resident/Intern Visit
- Nurse Visit
- Technician Visit
- Clerk Visit
- Consulting M.D. Visit
- Patient Arrival
- Patient Departure

Doctor-Specific Collection

- Initial Visit to Patient
- Typical Rounds Visit
- Discussion with Doctor/s
- Discussion with Nurse/s
- Writing on Paper Chart
- Using Computer
- Using Phone
ED Scheduling Board

<table>
<thead>
<tr>
<th>MD'S</th>
<th>RN'S</th>
<th>A</th>
<th>P</th>
<th>PCT'S</th>
</tr>
</thead>
<tbody>
<tr>
<td>SENIOR</td>
<td>CHARGE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RED</td>
<td>TRIAGE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLUE</td>
<td>AZ 1-8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GREEN</td>
<td>AZ 9-14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORANGE</td>
<td>RES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PURPLE</td>
<td>1-4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATTENDINGS</td>
<td>5-8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N-AZ-RDU</td>
<td>9-14</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>41-44</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>34-40</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RDU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FLT</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CLERK: TRANSPORTER
### Data Sheets

#### Patient Sheet

<table>
<thead>
<tr>
<th>Action Codes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1st - attending visit (note north/south)</td>
</tr>
<tr>
<td>2</td>
<td>2nd - senior resident visit (note different people)</td>
</tr>
<tr>
<td>3</td>
<td>3rd - resident/staff visit (note different people)</td>
</tr>
<tr>
<td>4</td>
<td>4th - nurse visit (note nurse's name)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Collection Start Time</th>
<th>1/13/10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bed Number of Initial Patient</td>
<td></td>
</tr>
<tr>
<td>Local Bed Numbers Being Watched</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Start Timestamp</th>
<th>End Timestamp</th>
<th>Bed #</th>
<th>Action #</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:30 am</td>
<td>6:00 am</td>
<td>1</td>
<td>1</td>
<td>1st - attending visit</td>
</tr>
<tr>
<td>6:00 am</td>
<td>6:30 am</td>
<td>2</td>
<td>2</td>
<td>2nd - senior resident visit</td>
</tr>
<tr>
<td>6:30 am</td>
<td>7:00 am</td>
<td>3</td>
<td>3</td>
<td>3rd - resident/staff visit</td>
</tr>
<tr>
<td>7:00 am</td>
<td>7:30 am</td>
<td>4</td>
<td>4</td>
<td>4th - nurse visit</td>
</tr>
</tbody>
</table>

#### Doctor Sheet

<table>
<thead>
<tr>
<th>Action Codes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1st - initial visit to patient (if available)</td>
</tr>
<tr>
<td>2</td>
<td>2nd - writing on paper chart</td>
</tr>
<tr>
<td>3</td>
<td>3rd - using computer (note program being used)</td>
</tr>
<tr>
<td>4</td>
<td>4th - typical rounds visit to patient</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Collection Start Time</th>
<th>9:50 am</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doctor Name</td>
<td>Dr. Smith, M.D.</td>
</tr>
<tr>
<td>Doctor Type</td>
<td>Southside Attending</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Start Timestamp</th>
<th>End Timestamp</th>
<th>Bed #</th>
<th>Action #</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:50 am</td>
<td>10:00 am</td>
<td>1</td>
<td>1</td>
<td>1st - initial visit to patient</td>
</tr>
<tr>
<td>10:00 am</td>
<td>10:30 am</td>
<td>2</td>
<td>2</td>
<td>2nd - writing on paper chart</td>
</tr>
<tr>
<td>10:30 am</td>
<td>11:00 am</td>
<td>3</td>
<td>3</td>
<td>3rd - using computer (note program being used)</td>
</tr>
<tr>
<td>11:00 am</td>
<td>11:30 am</td>
<td>4</td>
<td>4</td>
<td>4th - typical rounds visit to patient</td>
</tr>
</tbody>
</table>
### Patient Sheet

<table>
<thead>
<tr>
<th>Time</th>
<th>Action</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:57</td>
<td>6:09</td>
<td>7</td>
</tr>
<tr>
<td>5:59</td>
<td>6:03</td>
<td>86</td>
</tr>
<tr>
<td>6:10</td>
<td>6:12</td>
<td>7</td>
</tr>
</tbody>
</table>

### Doctor Sheet

<table>
<thead>
<tr>
<th>Time</th>
<th>Action</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:05</td>
<td>10:13</td>
<td>9</td>
</tr>
<tr>
<td>10:13</td>
<td>10:17</td>
<td>5</td>
</tr>
<tr>
<td>10:17</td>
<td>10:18</td>
<td>5</td>
</tr>
</tbody>
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<td>10:13</td>
<td>1</td>
</tr>
<tr>
<td>10:13</td>
<td>10:17</td>
<td>5</td>
</tr>
<tr>
<td>10:17</td>
<td>10:18</td>
<td>5</td>
</tr>
</tbody>
</table>
Model Validation

- Metrics in simulation matched closely with their counterparts in the historical data

<table>
<thead>
<tr>
<th>Metric</th>
<th>Historical Value</th>
<th>Our Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients Per Bed Per Day</td>
<td>2.35</td>
<td>2.37</td>
</tr>
<tr>
<td>NAWC Rate</td>
<td>8.02%</td>
<td>8.08%</td>
</tr>
<tr>
<td>Time to First Bed</td>
<td>4819s</td>
<td>4909.77s</td>
</tr>
</tbody>
</table>
Model Validation

- The Kolmogorov-Smirnov test was used to check distributions for the total length of stay, NAWC rate, and time to first bed.

<table>
<thead>
<tr>
<th>Variable</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total LOS</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>NAWC Rate</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Time to First Bed</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
Using simulation model, we tweaked the variable “% of Patients Seen by Residents in ED”

Tested the effects of this on:
- Average Time to Discharge Patients
- Time to First Bed for Patients
Results

Total Stay Time by Percentage of Resident Care

Low Sevices of Patients

![Graph showing the relationship between Low Priority Total Time and Percentage of Care Performed by Resident. The trend line indicates a negative correlation.]
Results

Time to Bed by Percentage of Resident Care

Low Severities of Patients

Time to Bed by Percentage of Resident Care

High Severities of Patients
Conclusions

- Developed a simulation model that is provably similar to actual UMMC ED operations
  - Used quantitative methods to model ED staff’s decision making

- From simulation model output, we discovered novel information regarding the effects of residents on ED efficiency

**Residents expedite healthcare provided specifically to Low Priority Patients**
Acknowledgements

- Dr. Bruce Golden
- Zaida Diaz
- Gemstone Staff
- Jonathan Anderson
- Julie Markowitz
- Esther Yang
- UMD Volunteer Staff
- Peer Advantage Tutors
- Dr. Jon Mark Hirshon
- Mike Harrington
- Gail Brandt
- UMMC ED Staff
- Dr. Carter Price
- Will Herring
- Sean Barnes
- David Anderson
Questions?