Michigan Medicine Emergency Department: Space Utilization Solutions

Akul Arora
Abhishek Bhattacharya
Jeet Das
Blake Duffy
Matthew Friedland
Max Sievers
14 August 2020
Our Team

Akul Arora

Abhishek Bhattacharya

Jeet Das

Blake Duffy

Matt Friedland

Max Sievers
Agenda

- Problem Statement
- Overview of Solutions for Crowding
- Vertical Treatment Zones
- Analytical Options
- Recommendations
- Next Steps
Problem Statement

What is the optimal resource allocation for vertical treatment zones in the Michigan Medicine ED?
Agenda

• Problem Statement

• Overview of Solutions for Crowding
  • Vertical Treatment Zones
  • Analytical Options
  • Recommendations
  • Next Steps
## Solutions for Crowding

### Physician in Triage

Skilled personnel at Triage shown to increase efficiency:
- Nurse
- Physician’s Assistant
- Attending

### Fast Track

Streamlined treatment of non-urgent patients
- Recently, widely adopted
- Typically staffed by senior staff
- Selectively implemented during peak traffic

### Vertical Treatment

Waiting rooms for mid-acuity (ESI 3) patients
- Less bed utilization
- Allows for ESI escalation
Agenda

• Problem Statement
• Overview of Solutions for Crowding
• Vertical Treatment Zones
• Analytical Options
• Recommendations
• Next Steps
Patient ED journey pathway

- **Intake**
  - Ambulatory arrival
  - Waiting rooms

- **Triage**
  - Criteria (ESI)
  - Provider (nurse, APP, physician)

- **Eval/Treatment**
  - Provider (APP, physician)
  - Exam room availability

- **Discharge/Admission**
  - Time post-evaluation
  - Rerouted
Patient ED journey pathway without vertical flow

WITHOUT VERTICAL FLOW

Intake ➔ Triage ➔ Eval/Treatment ➔ Discharge/Admission
Patient ED journey pathway with vertical flow

WITH VERTICAL FLOW

Intake → Triage → Eval/Treatment → Vertical Flow Area → Discharge/Admission

ESI 1,2,4,5

ESI 3
Agenda

• Problem Statement
• Overview of Solutions for Crowding
• Vertical Treatment Zones
• Analytical Options
• Recommendations
• Next Steps
# Key Aggregate Metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of stay</td>
<td>How long do patients stay in ED?</td>
</tr>
<tr>
<td>Bed utilization rate</td>
<td>How much of our capacity is being used?</td>
</tr>
<tr>
<td>Left without being seen</td>
<td>How many patients leave prior to triage? Prior to evaluation/treatment?</td>
</tr>
<tr>
<td>Patient satisfaction</td>
<td>How satisfied are patients with their ED experience?</td>
</tr>
<tr>
<td>Billing</td>
<td>How is hospital revenue affected by inefficiencies in ED throughput?</td>
</tr>
</tbody>
</table>
# Patient Flow Modeling Options (Wiler et al. 2011)

<table>
<thead>
<tr>
<th>Modeling Type</th>
<th>Description</th>
<th>Ability to Forecast ED Crowding</th>
<th>Ability to Predict Process Improvement Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formula-Based</td>
<td>Past experiences of ED flow used to posit formulas</td>
<td>Poor</td>
<td>N/A</td>
</tr>
<tr>
<td>Regression-Based</td>
<td>Statistically predicts dependent variables based on independent variables</td>
<td>Fair</td>
<td>Poor</td>
</tr>
<tr>
<td>Time-Series Analysis</td>
<td>Statistically uses recent past performance to predict current and immediate future performance</td>
<td>Fair</td>
<td>Poor</td>
</tr>
<tr>
<td>Queuing Theory</td>
<td>Mathematical formulas derived from system principles, utilizes many underlying assumptions</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>*Discrete-Event Simulation</td>
<td>Computer-generated model used to sample inputs and generate outputs, *most frequently used in literature</td>
<td>Fair</td>
<td>Good</td>
</tr>
</tbody>
</table>
Agenda

- Problem Statement
- Overview of Solutions for Crowding
- Vertical Treatment Zones
- Analytical Options
- Recommendations
- Next Steps
Discrete Event Simulation with SimPy software

Steps of DES: mimic ED journey → tweak → evaluate outcomes
- 1. Establish baseline model that matches current ED throughput
  - Verify using Michigan ED data
- 2. Run experimental changes
  - Tweak one point in model
- 3. Evaluate effect on outcomes
- 4. Establish key recommendations

Benefits
- Free, customizable, & more control than other options (e.g. Arena, Simul8, etc.)
- Commonly used in Healthcare Discrete Event Simulations
- Can change any individual step in flow model → assess outcome changes
### Needed Data for SimPy Simulation: Normal & Vertical flow

| **Time** | Time elapsed between each step of journey  
(intake to triage, triage to evaluation, evaluation to discharge/admission, Average visit length by ESI, Average time spent with provider by ESI, Length of stay in ED by ESI) |
|---|---|
| **ESI & Outcomes** | ESI data  
(How many of each incoming?, Percentage of patients admitted vs. discharged by ESI) |
| **Dept. Setup** | Beds, Staffing, Triage  
(How many beds per area?, How many spaces in Vertical Flow area?, Staffing of each area, Staffing changes over day/week) |
| **Macro-patient data** | How many patients per day? Demographic data, most common concerns for ED by number of cases per month. |
Agenda

• Problem Statement
• Overview of Solutions for Crowding
• Vertical Treatment Zones
• Analytical Options
• Recommendations
• Next Steps
Next Steps

Data Gather

Patient Level Data
- ESI levels
- Timestamps
  - LOS
  - TTP

ED Flow Data
- Vertical treatment zone scheme

Modeling

Build
- Ensure proper inputs and outputs
- Incorporate data gathered

Validate
- Compare model outcomes with known outcomes

Presentation

Provide Final Results
- Optimal size
- Impact on time and money saved

Deeper Dive
- Potential U of M collaborations
- Student Involvement
- Professional modeling and consulting
Next Steps: Deeper Dive

- CHEP: RFID for precision data capture
- Med School Elective: Assist in the vertical treatment zones
- Formal Consulting: Arena, Flexism, other simulation companies
Bibliography


Appendix

- SimPy Screenshots
- Case Studies
- Vertical Treatment Zone Factors
SimPy Carwash Example Screenshot

```python
def setup(env, num_machines, washtime, t_inter):
    # Create a carwash, a number of initial cars and keep creating cars
    approx. every "t_inter" minutes.
    # Create the carwash
    carwash = Carwash(env, num_machines, washtime)
    # Create 4 initial cars
    for i in range(4):
        env.process(car(env, 'Car #d' % i, carwash))
    # Create more cars while the simulation is running
    while True:
        yield env.timeout(random.randint(t_inter - 2, t_inter + 2))
        i = i + 1
        env.process(car(env, 'Car #d' % i, carwash))

# Setup and start the simulation
print('Carwash')
print('Check out http://youtu.be/tKrXexP9Tv8q while simulating ... ;-)')
rng = random.Random()  # This helps reproducing the results
env = simpy.Environment(rng=rng)
env.process(setup(env, NUM_MACHINES, WASHTIME, T_INTER))

# Execute
env.run(until=SIM_TIME)
```

The simulation's output:

Carwash
Check out http://youtu.be/tKrXexP9Tv8q while simulating ... ;-)  
Car 0 arrives at the carwash at 0.00. 
Car 1 arrives at the carwash at 0.00. 
Car 2 arrives at the carwash at 0.00. 
Car 3 arrives at the carwash at 0.00. 
Car 0 enters the carwash at 0.08. 
Car 1 enters the carwash at 0.08. 
Car 2 enters the carwash at 0.08. 
Car 3 enters the carwash at 0.08. 
Carwash removed 97% of Car 0's dirt. 
Carwash removed 67% of Car 1's dirt. 
Car 2 leaves the carwash at 5.00. 
Car 1 leaves the carwash at 5.00. 
Car 2 enters the carwash at 5.00. 
Car 3 enters the carwash at 5.00. 
Car 0 arrives at the carwash at 10.00. 
Carwash removed 64% of Car 0's dirt. 
Carwash removed 58% of Car 2's dirt. 
Car 0 leaves the carwash at 10.00. 
Car 1 leaves the carwash at 10.00. 
Car 2 leaves the carwash at 10.00. 
Car 3 leaves the carwash at 10.00. 
Carwash removed 97% of Car 1's dirt. 
Carwash removed 56% of Car 2's dirt. 
Car 1 leaves the carwash at 15.00. 
Car 2 leaves the carwash at 15.00. 
Car 3 leaves the carwash at 16.00. 
Car 0 enters the carwash at 16.00. 
Car 1 leaves the carwash at 16.00. 
Car 2 leaves the carwash at 16.00. 
Car 3 leaves the carwash at 16.00.
Case Study: Vertical Flow in a Tertiary Care Center

The effect of vertical split-flow patient management on emergency department throughput and efficiency

American Journal of Emergency Medicine

Garrett, Berry, Wong, Qin, & Kline, 2018

<table>
<thead>
<tr>
<th>Vertical split-flow</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baylor University in Dallas, TX</td>
<td></td>
</tr>
</tbody>
</table>

## Hospital Characteristics
- Tertiary care center
- Level 1 trauma center
- Academic ED
- 74 beds
- Inpatient ED boarding every day
- Cohort characteristics:

## Methods

**Pre-intervention period (12 months):**
- ESI 4 and 5’s seen in a fast-track area
- ESI 1, 2, and 3’s seen in main ED

**Intervention:** Fast-track area closed (10 beds and small waiting room) and staff reassigned to vertical flow; Triage nurse used CC, pulse ox, and heart rate to assign ESI level

**Post-intervention period (12 months):**
- ESI 3, 4, and 5 who could sit were triaged to vertical flow area (VFA)
- VFA protected from ED crowding

## Outcomes
- Despite a higher patient volume in the post-intervention period, total Length of Stay (LOS) decreased by 17 minutes
- No increase in staffing or decrease in patient satisfaction
- Fewer patients using bed space because they are sitting upright in chairs (vertically)
- All exams and treatments performed in a single occupant room
- If mis-triaged, patient reassigned to "horizontal" bed
- No change in ED boarding

### Table 1
Pre- and post-cohort demographics.

<table>
<thead>
<tr>
<th></th>
<th>Pre (N = 107,217)</th>
<th>Post (N = 114,833)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in years, median (IQR)</td>
<td>41 (26-57)</td>
<td>42 (26-57)</td>
</tr>
<tr>
<td>Gender, female (%)</td>
<td>60,438 (56)</td>
<td>65,165 (57)</td>
</tr>
<tr>
<td>Pediatric (%)</td>
<td>9157 (8.5)</td>
<td>8423 (7.4)</td>
</tr>
<tr>
<td>ESI: 1, 2 (%)</td>
<td>38,552 (35.9)</td>
<td>36,849 (32.1)</td>
</tr>
<tr>
<td>Outcome (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Admit</td>
<td>21,303 (19.0)</td>
<td>21,506 (18.7)</td>
</tr>
<tr>
<td>LWBS &amp; eloped</td>
<td>3511 (33.3)</td>
<td>4004 (3.5)</td>
</tr>
<tr>
<td>Expired</td>
<td>307 (0.29)</td>
<td>307 (0.27)</td>
</tr>
<tr>
<td>Discharge</td>
<td>77,429 (72.2)</td>
<td>81,784 (73.0)</td>
</tr>
<tr>
<td>Other (transfer, left AMA)</td>
<td>4608 (4.3)</td>
<td>5232 (4.6)</td>
</tr>
</tbody>
</table>

ESI: Emergency Severity Index, LWBS: left without being seen, AMA: against medical advice.
Case study: Designing Efficient emergency departments: Discrete event simulation (DES) of internal-waiting areas and split flow sorting

Overview

Looks at nine different graded combinations of ESI, Intake Personal, and Split Flow via discrete event simulation to predict incremental increases in efficiency.


Company

[logo]

Methods:

- University of Colorado Hospital ED for DES base data
  - urban
  - tertiary care
  - primary teaching hospital
  - 101,000 Patients
- Metrics Collected: ED layout, staffing, patient data (age, sex, CC, diagnostics), Tx, LOS, ESI

Key decisions and events

1. Model Development via patient profiles
2. ARENA Input Analyzer to create probability distributions
3. Process maps created and added to ARENA
4. Model validation
5. Variable Manipulation and Data output of 3 variables:
   a. ESI
   b. Intake Personal
   c. Split Flow rooms

Results

- Endpoints observed:
  - Length of Stay
  - Bed Utilization rate over 24hr
  - Door to provider time
  - Left without being seen rate
  - Movements of Patients

- Lowest Length of stay and highest bed utilization rate seen with flow split by intake attending with two internal-waiting areas (~54 min LOS decrease)
Appendix: Intake Factors

- Ambulatory arrival
- Left without being seen
- Waiting rooms
- Length of time before triage
- Location of intake
Triage Factors

- Who performs triage
- Waiting time
- Criteria (ESI, CC, vitals)
- Options/protocols
- Location/infrastructure
- Left without being seen

Med ECG | Medical Educational Consulting Group
Evaluation/Treatment Factors

Available exam rooms

Diagnostic procedures/imaging

Provider

Location/infrastructure

Left without being seen
Disposition Factors

Reroutes

Provider

# of movements

Left without being seen

Time post-evaluation
Slide with individual copy and paste items

Header 1 – 1 line

- ✔️
- ✗
- Image graphs with Impact: High, Low

1. 2. 3. 4.

Header 2 – 2 lines

- Medical icons
- Graphs
- An image

Thought bubble point: more of these images can be found at nounproject.com

“Take home” point box
Two-panel slide with left-side graph and takeaways

Graph header

Insights/Takeaways

Point 1
• Bullet 1
• Bullet 2
  □ Sub-bullet

Point 2
• Bullet 1
• Bullet 2
  □ Sub-bullet
Two-panel slide with notes and right-side graph

Point 1
• Bullet 1
• Bullet 2
  □ Sub-bullet

Point 2
• Bullet 1
• Bullet 2
  □ Sub-bullet
Process (3 steps) with text explanation

Step 1
Point 1
• Bullet 1
• Bullet 2
  □ Sub-bullet

Point 2
• Bullet 1
• Bullet 2
  □ Sub-bullet

Step 2
Point 1
• Bullet 1
• Bullet 2
  □ Sub-bullet

Point 2
• Bullet 1
• Bullet 2
  □ Sub-bullet

Step 3
Point 1
• Bullet 1
• Bullet 2
  □ Sub-bullet

Point 2
• Bullet 1
• Bullet 2
  □ Sub-bullet
## Process (4 steps) with text explanation with dividers

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Step 2</th>
<th>Step 3</th>
<th>Step 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Point 1</strong>&lt;br&gt;• Bullet 1&lt;br&gt;• Bullet 2&lt;br&gt;  □ Sub-bullet</td>
<td><strong>Point 1</strong>&lt;br&gt;• Bullet 1&lt;br&gt;• Bullet 2&lt;br&gt;  □ Sub-bullet</td>
<td><strong>Point 1</strong>&lt;br&gt;• Bullet 1&lt;br&gt;• Bullet 2&lt;br&gt;  □ Sub-bullet</td>
<td><strong>Point 1</strong>&lt;br&gt;• Bullet 1&lt;br&gt;• Bullet 2&lt;br&gt;  □ Sub-bullet</td>
</tr>
<tr>
<td><strong>Point 2</strong>&lt;br&gt;• Bullet 1&lt;br&gt;• Bullet 2&lt;br&gt;  □ Sub-bullet</td>
<td><strong>Point 2</strong>&lt;br&gt;• Bullet 1&lt;br&gt;• Bullet 2&lt;br&gt;  □ Sub-bullet</td>
<td><strong>Point 2</strong>&lt;br&gt;• Bullet 1&lt;br&gt;• Bullet 2&lt;br&gt;  □ Sub-bullet</td>
<td><strong>Point 2</strong>&lt;br&gt;• Bullet 1&lt;br&gt;• Bullet 2&lt;br&gt;  □ Sub-bullet</td>
</tr>
</tbody>
</table>
## Table (5 row labels)

<table>
<thead>
<tr>
<th>Category</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Label 1</td>
<td>• Details</td>
</tr>
<tr>
<td>Label 2</td>
<td>• Details</td>
</tr>
<tr>
<td>Label 3</td>
<td>• Details</td>
</tr>
<tr>
<td>Label 4</td>
<td>• Details</td>
</tr>
<tr>
<td>Label 5</td>
<td>• Details</td>
</tr>
</tbody>
</table>
## Table (5 row labels x 2 columns)

<table>
<thead>
<tr>
<th>Category</th>
<th>Header 1</th>
<th>Header 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Label 1</td>
<td>• Details</td>
<td>• Details</td>
</tr>
<tr>
<td>Label 2</td>
<td>• Details</td>
<td>• Details</td>
</tr>
<tr>
<td>Label 3</td>
<td>• Details</td>
<td>• Details</td>
</tr>
<tr>
<td>Label 4</td>
<td>• Details</td>
<td>• Details</td>
</tr>
<tr>
<td>Label 5</td>
<td>• Details</td>
<td>• Details</td>
</tr>
</tbody>
</table>
Vertical process (3)

- Preparation
  - Timeline
    - Point 1
    - Point 2
    - Point 3

- Conclusion
  - Timeline
    - Point 1
    - Point 2
    - Point 3

Med ECG
Medical Educational Consulting Group
Vertical key points (2)

Key point 1

Key point description

Key point 2

Key point description
Vertical key points (3)

Key point 1

Key point description

Key point 2

Key point description

Key point 3

Key point description
Vertical key points (4)

- Key point 1
  - Key point description

- Key point 2
  - Key point description

- Key point 3
  - Key point description

- Key point 4
  - Key point description
Vertical key points (4)

- Key point 1
- Key point 2
- Key point 3
- Key point 4
Agenda

- Simple slide formats
- Advanced formats
- Copy and paste-items
Foundations (3) leading to main point

Main point

Foundation 1
• Bullet 1

Foundation 2
• Bullet 1

Foundation 3
• Bullet 1
Foundations (4) leading to main point

- Foundation 1
  - Bullet 1
- Foundation 2
  - Bullet 1
- Foundation 3
  - Bullet 1
- Foundation 4
  - Bullet 1
Interesting visual of three main points

Main point 1
Point 1 details

Main point 2
Point 2 details

Main point 3
Point 3 details
<table>
<thead>
<tr>
<th>First Name</th>
<th>Last Name</th>
<th>Role</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>picture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>picture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>picture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>picture</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Organization structure

Department/team title

Main function L1

Main function L2

L3

L3

L3

Different function L1

Different function L2
# Research paper summary template

## Research paper

**Article title**
[Author], [Year]

## Primary objectives

**Main goals of paper**

## Methods

**Methods overview (can be in steps)**

## Outcomes

**Conclusions and discussion**
Gantt chart timeline

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Date 1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Key meeting 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Key meeting 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Key meeting 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
[Name] is an [year] at the University of Michigan Medical School. In medical school, [Name] has worked on [main projects and experiences]. Prior to starting medical school, [Name] worked at [prior jobs if applicable], where he/she [main tasks and experiences]

**Education:** [Name] earned a [degree] from [School] in [Year]

**A selection of [Name]'s relevant project experience include:**
- Detailed experience/role 1
- Detailed experience/role 2

**Summary of relevant experience**
- Experience 1
- Experience 2
- Experience 3