Matching Capacity and Demand: Using Advanced Analytics for Improvement and Forecasting

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Analytics involves studying past *historical* data to research potential trends, to analyze the effects of certain decisions or events, or to evaluate the performance of a given tool or scenario. (businessdictionary.com)
Advanced Analytics Defined

Advanced analytics focuses on forecasting future events and behaviors, allowing businesses to conduct what-if analyses to predict the effects of potential changes (whatis.com)
Analytic Influence Model

What Happened
- Raw Data
- Standard Reports & Measures
- Trend Measurement

Why did it Happen
- Ad Hoc / Drill down Reporting

What is likely to Happen
- Descriptive Modeling
- Predictive Modeling

How to influence what Happens
- Planning Models/Tools

Value of Information
- Data
- Information
- Knowledge
- Insight
- Action

* Model adapted from initial model developed by IBM
Prediction – Model for the Future

- **Static Analytics**
  - Performing a **ONE TIME** analysis of processes with historical data in order to **PREDICT** what’s going to happen under certain circumstances.

- **Critical care Bed Modeling for Growth**

- **Real-Time Prediction**
  - Performing **ONGOING** analysis of processes with latest available data in order to continuously **PREDICT** what’s going to happen under certain circumstances.

- **RN Bedside Nurse Staffing Model**
Modeling Approach

Determine goals & objectives → Build conceptual model → Convert to computational model → Verify & validate model → Utilize the model

ORGANIZATION LEADERS

ANALYTIC PROFESSIONALS

PARTNERSHIP
An example of static prediction

CRITICAL CARE BED PLANNING
2 Types of Demand

- **SCHEDULED**: Demand that we know about ahead of time because we have scheduled it (i.e., a planned admission or a planned elective surgical case)
- **UNSCHEDULED**: Demand that we don’t know about ahead of time. This unscheduled demand is a random pattern that happens every day or year and may or may not be seasonal.

**ANALYTICS TO IMPROVE FLOW**

- Determine method to control flow
  - Can’t control UNSCHEDULED but can understand it better
- Develop plan for SCHEDULED demand

**SIMULATION MODELS**

- Determine beds needed for UNSCHEDULED
- Daily CAP for SCHEDULED procedures to utilize remaining capacity
Critical Care Bed Predictions

![Diagram of ICU bed utilization and patient wait times]

Amy M. Anneken, Division of Health Policy & Clinical Effectiveness
Flow Improvements

- Reduction in Flow Failures from ED and PACU
- More evenly dispersed resource utilization due to CAP
- Ability to respond to anticipated unscheduled demand in advance
Impact of Growth on Critical Care Bed Needs

**PICU Growth**
- Bone Marrow Transplant
- Neurosurgery
- ENT/ Airway
- Oncology
- Organ Transplants

**CICU Growth**
- Heart Transplant
- Cardiomyopathy
- Adult
- Cardiothoracic Surgery
- Non-Surgical

How many Critical Care Beds do we need to support growth and effectively utilize our facilities?

What will happen if areas exceed their targets?

When will we begin to run out of critical care beds?
Data Gathering and Analysis Steps

- Consult with clinicians to identify planned and unplanned input streams into critical care units.
- Analyze data and consult with physician leaders to identify logical and meaningful sub-groupings for model.
- Establish a template for collecting inpatient program growth from physician leaders in each program.

<table>
<thead>
<tr>
<th>Group</th>
<th>Current Volume</th>
<th>Low/Conservative</th>
<th>Mid-Range/Most Likely</th>
<th>High/Aggressive Growth</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>2 YRS 5YRS 7YRS</td>
<td>2 YRS 5YRS 7YRS</td>
<td>2 YRS 5YRS 7YRS</td>
<td>2 YRS 5YRS 7YRS</td>
</tr>
</tbody>
</table>
Data Gathering

- Apply data mining and analysis to determine:
  - Probabilistic input streams for unplanned admissions for each sub-grouping
  - Volume and frequency of planned admissions for each sub-grouping
  - Length of Stay (LOS) for each sub-grouping and stream
  - Demand and LOS not included in growth programs
  - Seasonality (by Day of Week and Time of Year)

Example: ENT LTP procedures have an arrival rate that varies by day of the week with a 5% probability that they will require a Critical Care Bed and will stay LOGN(4.6,7.4) in the PICU
Analytic Model Design

PICU Model
- Oncology
- Neurosurgery
- BMT
- Elective Surgery
- Unplanned Admits
- Transplants
- Cardiomyopathy
- General Admits
- Unit Admissions
- Length of Stay

PICU Reports

CICU Model
- Transplants
- Surgery
- Adults

CICU Reports
Data stored by replication and arrival time is sorted so that identical arrival patterns are included in the analysis.
Critical Care Bed Growth Analysis

YEAR 2-7 Forecasted PICU Bed Needs - Mid-Range/Most Likely

Bed Needs for PICU - Probability of a Full Unit
20 Replications of a 425 Period (60 Day Warmup) - Mean Probability

POPULATION: Unscheduled Medical/Surgical, BMT, ENT Airway ICU Elective Cases+ OR CAP=3
## Forecasted Bed Needs

### Advantages of Efficiency

Estimated number of beds required for given probability of the unit being full.

<table>
<thead>
<tr>
<th>Forecast Time Frame</th>
<th>Probability of Full Unit</th>
<th>PICU Beds</th>
<th>CICU Beds</th>
<th>ICU Bed Needs</th>
<th>Combined ICUs</th>
<th>Estimated Savings</th>
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<td>Year 2</td>
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<td>34</td>
<td>27</td>
<td>61</td>
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<td></td>
<td>5%</td>
<td>36</td>
<td>29</td>
<td>65</td>
<td>58</td>
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<tr>
<td></td>
<td>3%</td>
<td>38</td>
<td>30</td>
<td>68</td>
<td>59</td>
<td>9</td>
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<td>38</td>
<td>34</td>
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<td>37</td>
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<td>42</td>
<td>39</td>
<td>81</td>
<td>71</td>
<td>10</td>
</tr>
</tbody>
</table>

POPULATION: Unscheduled Medical/Surgical, BMT, ENT Airway ICU Elective Cases, Heart Institute Patients
Impact of Analytics

• Bed capacity models help to make crucial planning decisions
• Permit development of operational contingency plans *ahead of time*.
• Ability to understand when growth projections are changing
Number of admissions for Cardiomyopathy patients appears to be following the mid-range/most likely growth pattern.
An example of real-time prediction

SHORT TERM BED PREDICTION
Short Term Bed Prediction

- The ability to predict inpatient bed demand aids in determining appropriate clinical staffing and planning for overflow needs.

- The scope of this project is to predict census, admissions, and discharges on seventeen inpatient units providing a 10-day view of bed demand.

- We have “flow failures” each week.
  - Could we have predicted these failures and intervened?
  - Can we ensure that we have adequate staffing and resources available for our future demand?
Predicting Admissions

OR Elective Sleep Study EEG
Pulled from electronic medical records (EMR)

OR Add-On
Historic 90th percentile

ED
ARIMA model with seasonality*

Direct Admits
Linear exponential smoothing with seasonality*

Other Admits
Linear exponential smoothing with seasonality*

* Two seasonal indices
  1. Day of week seasonality
  2. Holiday index
Predicting Discharges

- **Electronic Medical Record**: Approximately 75% of patients have a predicted discharge date entered by nursing staff.
- **Utilize historic Length of Stay (LOS)** to predict missing values.
  - Additional analysis required to determine “best” method for selecting length of stay. Median, Average, Random distribution???
Census calculation

Tomorrow’s census =

Today’s census + Today’s admissions – Today’s discharges

Easy enough, right?

Developed more than 200 models:

17 units, 7 days a week, admissions, and discharges, multiple input and output streams
Model Outputs

Delivered electronically every morning

Automated feed into nurse scheduling tool to aid in short term staffing decisions

![Weekly Census Prediction Report](image-url)
### Model Outputs

<table>
<thead>
<tr>
<th>Wednesday</th>
<th>PICU</th>
<th>HI</th>
<th>NICU</th>
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</thead>
<tbody>
<tr>
<td>3/23/2016</td>
<td>B6CC</td>
<td>B8HI</td>
<td>A8C</td>
</tr>
<tr>
<td>Total Capacity (# of Beds on Unit)</td>
<td>36</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>Actual Midnight Census</td>
<td>26</td>
<td>21</td>
<td>17</td>
</tr>
</tbody>
</table>

**Scheduled Admits**

- OR electives: 1, 4, 4, 0
- Sleep Study: 0, 0, 0, 0
- EEG: 0, 0, 0, 0

**Predicted Admits**

- OR electives: 1, 2, 2, 0
- OR add on: 0, 0, 0, 0
- ED: 4, 0, 1, 0
- Sleep Study: 0, 0, 0, 0
- Direct Admits: 0, 1, 1, 1
- EEG: 0, 0, 0, 0
- Other: 3, 1, 4, 0

**Predicted Discharges**

- 8, 1, 4, 0

**Predicted Demand**

- 27, 24, 21, 62

**Predicted Overflow**

- 1 (BMT), 1 (A8C)

**Predicted Unit Occupancy**

- 28, 25, 17, 62

- Available bed capacity
- Midnight census
- Scheduled admissions
- Predicted admissions
- Predicted discharges
- Predicted demand (census + adm – disch)
- Predicted overflow placement
Model Outputs

Accuracy measured daily for each unit
Impact of Analytics

- Bed demand predictions facilitate staffing and overflow planning – right patient – right team
- ED admit predictions improved from 40% to 70% accuracy – resource allocation
- Encourages staff to more consistently predict and document estimated discharge date, which helps guide care – system efficiency
- Uncovers scheduling issues – efficiency and access
- One-stop source to determine where there is capacity (or lack thereof) to add services (infusions, etc.) – efficiency and utilization
An example of static prediction

MANAGING FLOW PROCESSES IN THE ED
Project Purpose & Scope

- The ability to segment populations of patients who arrive to the ED and to separate their care streams optimizes ED flow. The scope of this project is to show the power of a simulation model for examining and testing various process changes to the “fast-track” process.

- Idea: model the changes before we try them in real-life. This is especially important in health care applications since we are dealing with potentially life or death situations.

<table>
<thead>
<tr>
<th>Triage Level</th>
<th>Medical Need</th>
<th>Resource Requirements</th>
<th>“Fast-Track” Eligible?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 or 2</td>
<td>Urgent &amp; High Illness Severity</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>More than 1 Resource</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>1 Resource</td>
<td>Certain Chief Complaints</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>0</td>
<td>Yes</td>
</tr>
</tbody>
</table>
ED Flow Simulation Model
Phase I - Impact of Alternative Care Streams

ALTERNATIVE #1

Total Patient Wait Time Before ED Care Begins

Mean

7
6
2
2
4
5
6
4

Simulation Time

Mean ED Cycle Time (Hours)

Arrival Volume

3.13 1
2.63 5
2.56 6
2.50 7
2.38 4

Current Model Inputs

PRIORITY - Lowest Triage Value:
Triage Level 1 1
Triage Level 2 2
Triage Level 3 3
Triage Level 4 3
Triage Level 5 3

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What-if Scenarios for Testing

1. **Scenario 1** – All Level 5’s (L5) are sent directly to the fast track (FT) without going through triage, patient waits in lobby if FT bed is unavailable.

2. **Scenario 2** – All L5’s are sent directly to the FT without going through triage, if a FT bed is unavailable, the patient will go to the major side.

3. **Scenario 3** – All “Yellow” L4’s & All L5’s are sent directly to the FT without going through triage, patient waits in lobby if FT bed is unavailable.

4. **Scenario 4** – All “Yellow” L4’s & All L5’s are sent directly to the FT without going through triage, if a FT bed is unavailable, the patient will go to the major side.

5. **Scenario 5** – All “Yellow” & “Red” L4’s & All L5’s are sent directly to the FT without going through triage, patient waits in lobby if FT bed is unavailable.

6. **Scenario 6** – All “Yellow” & “Red” L4’s & All L5’s are sent directly to the FT without going through triage, if a FT bed is unavailable, the patient will go to the major side.

7. **Scenario 7** – Patients waiting for test results will be taken out of their ED Care room and sent to a Results Waiting Lobby to wait. After the test results, they will be brought back to a room to disposition and discharge. One FT room will be “held” to ensure a room is available for a patient to return to.

8. **Scenario 8** – Combine 5 & 7

9. **Scenario 9** – Combine 6 & 7
Simulation Results
ED Phase I Flow TOTAL CYCLE TIME* BY TRIAGE LEVEL
Simulation of 30 Replications of 24 hour Day, Peak Season Volume

* 95% Confidence Interval for Mean Cycle Time

Also looked at total wait time and resource utilization measures.
Impact of Analytics

• Presented the model to the entire ED leadership and physician group. Animation is a powerful tool.

• Scenario Results showed these process changes not only reduced cycle time for the fast-track patients, it reduced the cycle time for higher acuity patients – resource efficiency

• Gained consensus. Project was accepted for the ED to plan and test the recommended design changes – leadership buy-in
Brief history of the simulation projects completed at CCHMC related to productivity & flow

HISTORY
History and Brief Description

2009

- ICU Bed Planning – How many beds for unscheduled ICU admits?
- A7C Capacity Planning – Is A7C appropriately sized?
- BMT Model – How many beds are needed to accommodate current & future BMT demand?

2010

- ENT B5CA Bed Smoothing – Assessing unit size based on scheduled and unscheduled admits
- MRI Radiology Clinic Flow – Optimize clinic flow to reduce waiting
- ED Fast Track – How should we implement Fast Track in the ED?
- TCC Bed Model – How many beds are needed in the TCC?
- GI Clinic Flow – What scheduling and resource changes are needed to improve utilization and flow?
- Pulmonary Clinic Flow – How can we improve flow, reduce wait time and increase resource utilization?
History and Brief Description

2011

- EVS Staffing Demand – Assess staffing levels to determine if they are sufficient
- Fetal Care Center – Forecast number of beds needed for Fetal Care Center
- Perinatal Institute – How many beds do we need?
- ICU Beds Needs – How many beds do we need to meet short term and long term demand?
- Heart Institute Inpatient Construction – How many beds and other resources are needed to meet current and future demand?
- CICU Bed Needs – How many beds do we need to meet short term and long term demand?
- HI EP Clinic Scheduling – What are the most efficient clinic schedules for the EP Clinic?

2012

- Combined ICU and CICU bed analysis – What would be the benefits of combining the ICU and CICU beds?
- Revisit BMT Model as part of CBDI Flow Analysis – How many beds are needed?
- DDBP Floor Consolidation Analysis – How many rooms does DDBP need in the MOB? Could they fit on one floor?
- Sleep Study Modeling – How many sleep study beds are needed at base and Liberty?
- PPC Room Analysis – How many rooms are needed for them to relocate to MOB?
## History and Brief Description

### 2013

- **Shriners** – How many rooms and resources are needed to support multiple divisions and clinics planned to move to this new location?
- **Urgent Care Space Analysis** – Is it feasible to move the Urgent Care into one of our existing clinic spaces starting at 3:00 PM?
- **Combined EEG/Sleep Study Analysis** – How many beds are needed to support this demand in 2 locations?
- **B5CA Surgical Scheduling** – How would a suggested surgical scheduling change affect current performance?
- **Lung Transplant** – What is the environmental impact of this new program on the institution?

### 2014

- **Pulmonary CF Clinic** – How many rooms are needed and what scheduling changes would have to occur to implement improved infection control guidelines?
- **Long Term Bed Prediction** – How many beds are needed to support future growth in key programs in the long term?
History and Brief Description

2015

- Urgent Care Model – How many rooms are needed for the construction of a new Urgent Care space at base?
- Revisit MRI Flow Model – How can we improve scheduling, staffing and hours of operation?
- Continued Long Term Bed Prediction Modeling

2016

- Mental Health – How much capacity is needed to meet projected growth?
- Mental Health – How might additional capacity in the outpatient area and with Day Hospital affect inpatient demand?
- CBDI – How might we improve our schedules to improve clinic flow and reduce waiting?
- Long Term Bed Prediction Modeling – Revised and finalized analysis for presentation to board.
Thoughts on next steps for building this capability

WHERE DO I GO FROM HERE?
Keys to Success

• Leadership and Buy-in
  • Need to gather buy-in and support from recognized formal or informal leaders
  • Need leaders with control of both time and $

• Hire or contract the right resources
  • Secure resources with an understanding of capacity management, productivity/flow, and advanced analytics

• Find an area that will have an impactful win
  • Can be scoped to a workable area but must be impactful
  • Should be one that you can leverage for continued improvement

• Establish plans to monitor and sustain your results
Questions?
An example of real-time analytics

MANAGING OUTPATIENT FLOW THROUGH ANALYTICS
Outpatient Space Restriction

- 7 Satellite Facilities, 417 outpatient exam rooms
- All rooms scheduled resulting inability to place new providers in consistent clinic locations
- Divisions/Department felt like they “owned” space
- No way to measure and assess room allocations among providers
- Inconsistent clinic time allocations
- No clear process for management
Develop Measure for Space Utilization

Room Utilization = \frac{\text{Minutes Occupied}}{\text{Minutes Scheduled}}

Collection needed to be mechanized and consistent
Utilized EMR for collection after validation

Initial analysis showed rooms utilized roughly 60% of the time
Industry research indicated 70-85% utilization target
### Processes and Measurement

#### Monthly Report Link

<table>
<thead>
<tr>
<th>Divisions</th>
<th>Number Appointments</th>
<th>Appointment LOS</th>
<th>Hours of Operation</th>
<th>Existing Exam Rms</th>
<th>Existing Utilization</th>
<th>Calculations</th>
<th>Room Tmovrs</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>AM</td>
<td>PM</td>
<td>EV</td>
<td>AM</td>
<td>PM</td>
<td>EV</td>
<td>AM</td>
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<td>73.8</td>
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</table>

- Developed tool to schedule and monitor usage
- Initially targeted for monthly reporting. Moved to weekly
- Establish processes to support add/delete clinics & rooms
Managing at All Levels

**Assignment Utilization by Location**

*FY 2016 Q3 3/6 - 3/12*

<table>
<thead>
<tr>
<th>Locations</th>
<th>Location</th>
<th>Unassigned Rooms</th>
<th>Percentage of Assigned Rooms</th>
<th>Total Assigned Rooms</th>
<th>Unused Rooms</th>
<th>Percentage of Used Rooms</th>
<th>Rooms Canceled within 5 Weeks</th>
<th>Rooms Canceled 6 Weeks in Advance</th>
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</thead>
<tbody>
<tr>
<td>AND</td>
<td>Sun</td>
<td>18 18 18 18</td>
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<td>30 41 1 1</td>
<td></td>
<td>97.4% 97.6%</td>
<td>0 0 0</td>
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<td></td>
<td>Mon</td>
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<td>64 59 291</td>
<td>79.8% 81.2% 7.3%</td>
<td>225 226 26 34</td>
<td></td>
<td>88.4% 85.0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- How can we determine when we need more space?
- Utilization measures the assigned space
- Needed to measure and manage distribution all rooms
Managing Outpatient Flow

Requires assessments of all aspects of patient care:
- Access
- Resources/Space
- Scheduling
- Patient Flow
- Productivity

Changes in one area can and likely will affect results in another. Goal is to balance to produce optimal results.
Impact of Analysis

- Increased utilization by more than 12% across the institution – resource efficiency
- Additional benefits include ability to quickly identify and respond to requests for add-on clinics (Flu Clinic) – right resources – right time
- Standardized process across the institution – efficiency
- Improved sharing of exam rooms between Divisions – transparency
Green Township Office

Equivalent of adding an additional outpatient office building similar to Green Township with 30 exam rooms

417 rooms 5 days a week, 2 clinics per day, 50 weeks a year = more than TWO HUNDRED THOUSAND CLINIC ROOMS

Average Length of Stay is approx. 1 hour

Result is the ability to add approximately 100,000 more patient visits per year without adding additional capacity.