

**IDS 594: SPRING 2019**

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# AHA / HIMSS DATASET

## Research Questions



***What hospital factors are associated with having an HIE installed?***



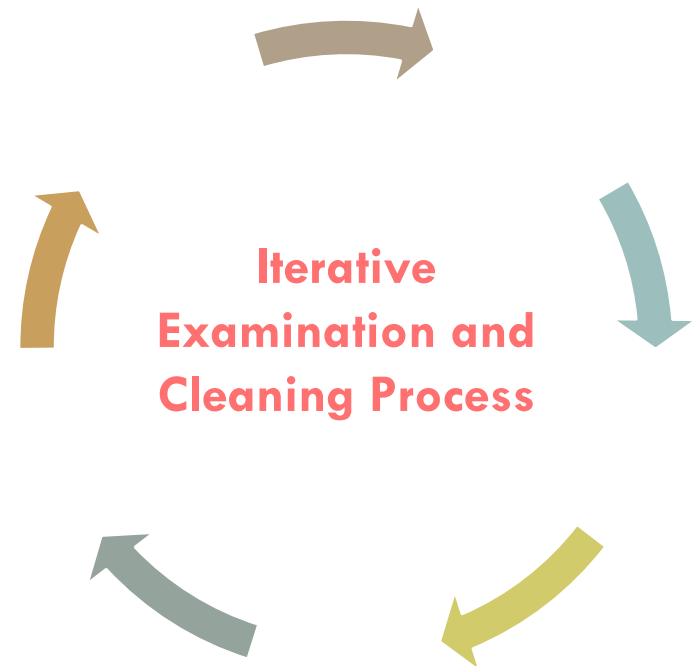
***Is having an HIE installed linked to better performance?***

# DATA PREPARATION

## RESEARCH QUESTION DEFINITION

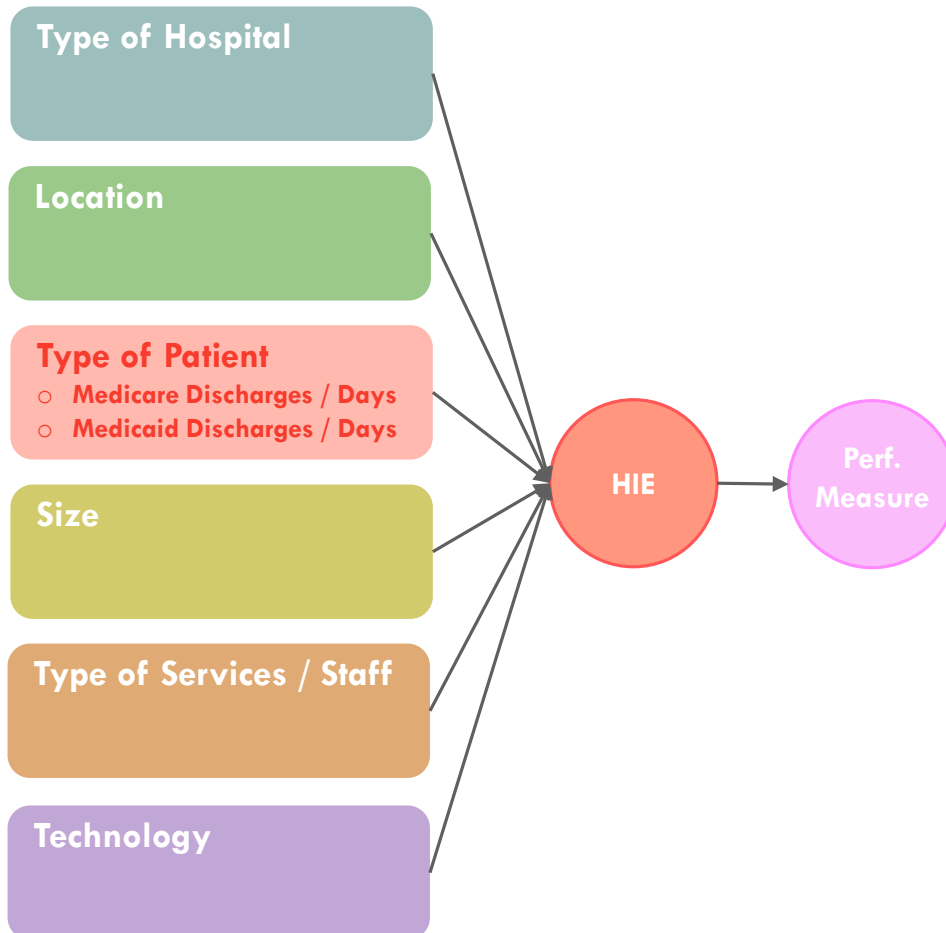
### How do we combine and edit these data sets to answer the research questions?

- AHA Data – Requested Data – 2010 - 2017  
**50,264 records – 86 Variables (Selected)**
- HIMSS Data – Demographics – 2018  
**5,494 records – 35 Variables**
- HIMSS Data – Technology – 2018  
**1,048,575 records – 19 Variables**
- HIMSS Data – HIE – 2018  
**6,491 records – 10 Variables**
- HIMSS Data – Patient Survey – 2018  
**260,361 records – 28 Variables**



# ITERATIVE PROCESS EXAMPLE

## Preliminary Block Model *(\*Specific Variables for Most Blocks Not Listed)*



*One example of the iterative process was with the block model.*

*The original conceptual model had a block for “Type of Patient” with Medicare discharges / days and Medicaid discharges / days.*

*However, after the data was pulled, these variables had missing values in all observations, so could not be used. Therefore an entire block would be eliminated.*

# DATA PREPARATION

## Steps in Preparing Initial Data Set

- **Step 1 – Select Overlapping Hospitals AHA & HIMSS Demographic Data**  
*4,160 hospitals matched using HIMSS and AHA 2017 Data*
- **Step 2 – Select a Subset of Demographic Variables from the Combined Set**  
*reduced from 121 variables to 38 variables*
- **Step 3 – Clean HIE Data Set Into 0 / 1 Data**  
*0 if not in data set or “planned” / 1 if in data set and “installed”*
- **Step 4 – Clean Technology Data to Make a Technology Score Variable**  
*only use records with matched hospitals & combine variables to make one tech score per hospital*
- **Step 5 – Clean Hospital Performance Data to Select Performance Variables**  
*only use records with matched hospitals & select one or more performance variables*
- **Step 6 – Merge All Data Files to Create One Initial Data Set**  
*4,160 hospital records – 50 Variables*

# TECHNOLOGY SCORE

## List of Technology Types after Matching the 4,106 Hospitals

*Raw Data: 94 technologies & 55 types of installed technologies*

*Matched Data: 55 types of installed technologies*

Technology Type
Barcoding
Business Intelligence - Clinical
CDSS: Clinical Decision Support System
Consulting
CPOE: Computerized Practitioner Order Entry
Device: Cardiac output monitors
Device: Cardiac Rehabilitation Devices
Device: Electrocardiographs
Device: Fetal Monitors
Device: Infant Incubators
Device: Intelligent Medical Device Hubs
Device: Interactive Infus. Pumps (smart pumps)
Device: Physiologic Monitors
Device: Robotic Surgery Devices
Device: Spirometer
Device: Telemetry Systems
Device: Ventilators
Device: Vital Sign Monitors
Dictation with Speech Recognition

Technology Type - Continued
Document Management
Electronic Forms Management
EMR
In-House Transcription
Mobile: WLAN
Obstetrical Systems (Labor and Delivery)
Outsourced Functions
Patient Portal
Pharmacy: Automated Dispensing Machines
Pharmacy: Carousels
Pharmacy: Robot Technology
Physician Documentation
Physician Portal
RCM: EDI:ElecData Interchange-ClearingHouse
RCM: Medical Necessity Checking Content
RFID
Supply: Automated Cabinet
Telemedicine
Transfusion Management System

Technology Type - Continued
PACS - Card - Cath Lab
PACS - Card - CT(Computerized Tomography)
PACS - Card - Echocardiology
PACS - Card - Intravascular Ultrasound
PACS - Card - Nuclear Cardiology
PACS - Cardiology
PACS - Rad - Angiography
PACS - Rad - CR (Computed Radiography)
PACS - Rad - CT (Computerized Tomography)
PACS - Rad - DF (Digital Fluoroscopy)
PACS - Rad - DR (Digital Radiography)
PACS - Rad - Mammography
PACS - Rad - MRI
PACS - Rad - Nuclear Medicine
PACS - Rad - Orthopedic
PACS - Rad - US (Ultrasound)
PACS - Radiology

# TECHNOLOGY SCORE

## Technology Types Listed by % of Hospitals Using

Technology Type	Installed No. Unique Orgs	%
Barcoding	4047	97%
PACS - Radiology	3666	88%
EMR	3638	87%
CPOE: Comp. Practitioner Order Entry	3552	85%
PACS - Rad - CT	3532	85%
Pharmacy: Auto Dispensing Machines	3521	85%
PACS - Rad - US (Ultrasound)	3478	84%
CSS: Clinical Decision Support System	3471	83%
PACS - Rad - CR (Comp. Radiography)	3467	83%
PACS - Rad - MRI	3334	80%
Document Management	3210	77%
Physician Documentation	3186	77%
PACS - Rad - Mammography	3112	75%
Patient Portal	3070	74%
PACS - Rad - Nuclear Medicine	3059	74%
RCM: ElecDataInterchange-ClearHouse	3029	73%
PACS - Rad - DF (Digital Fluoroscopy)	3001	72%
Electronic Forms Management	2858	69%
PACS - Rad - DR (Digital Radiography)	2779	67%
PACS - Rad - Angiography	2500	60%
Dictation with Speech Recognition	2248	54%
PACS - Rad - Orthopedic	2192	53%
RCM: Med. Necessity Checking Content	2174	52%
Physician Portal	1971	47%
PACS - Cardiology	1902	46%
Device: Physiologic Monitors	1837	44%
Device: Vital Sign Monitors	1835	44%
Telemedicine	1797	43%

Technology Type	Installed No. Unique Orgs	%
PACS - Card - Echocardiology	1726	41%
Outsourced Functions	1696	41%
Obstetrical Systems (Labor and Delivery)	1654	40%
Device: Electrocardiographs	1552	37%
Device: Ventilators	1544	37%
PACS - Card - Cath Lab	1444	35%
Device: Interactive Infus. Pumps	1343	32%
Mobile: WLAN	1338	32%
PACS - Card - Nuclear Cardiology	1314	32%
PACS - Card - CT	1219	29%
PACS - Card - Intravascular Ultrasound	1168	28%
Device: Fetal Monitors	1161	28%
Device: Infant Incubators	995	24%
Device: Cardiac output monitors	920	22%
Transfusion Management System	744	18%
Device: Robotic Surgery Devices	652	16%
In-House Transcription	629	15%
RFID	493	12%
Business Intelligence - Clinical	402	10%
Device: Telemetry Systems	362	9%
Pharmacy: Carousels	335	8%
Device: Intelligent Medical Device Hubs	332	8%
Consulting	292	7%
Pharmacy: Robot Technology	252	6%
Device: Spirometer	148	4%
Supply: Automated Cabinet	117	3%
Device: Cardiac Rehabilitation Devices	108	3%

**Technology Types Selected for Tech Score Highlighted in Yellow**

**Some Technologies Such as Barcoding Almost Universally Used (97%)**

**Others Such as RFID Rarely Used (12%)**

# TECHNOLOGY SCORE

## Creating the Technology Score

**Purpose: To Create a Broad “High Tech” Score Overarching Many Areas**

*Created “Blind” without Checking Correlation to HIE – Using Logic*

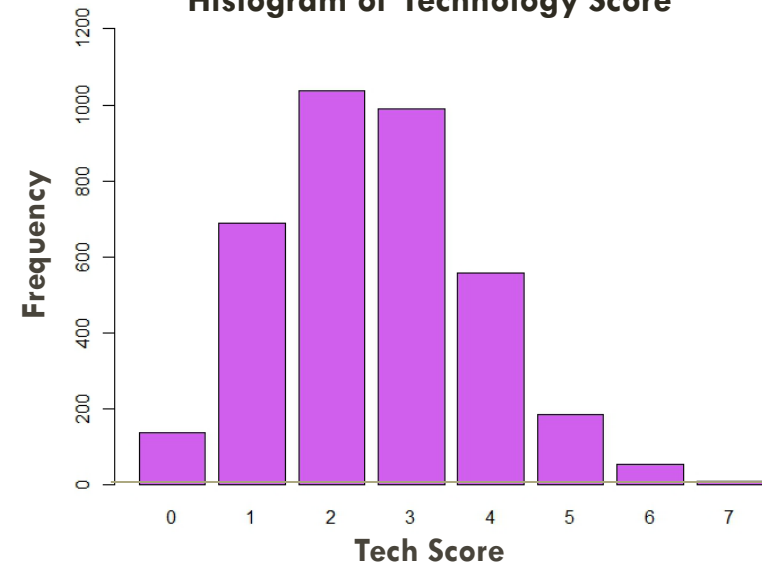
### 7 Technology Types Selected to Create Technology Score

Technology Type	Installed No. Unique Orgs	%
CDSS: Clinical Decision Support System	3471	83%
Dictation with Speech Recognition	2248	54%
Telemedicine	1797	43%
Mobile: WLAN	1338	32%
RFID	493	12%
Business Intelligence - Clinical	402	10%
Device: Intelligent Medical Device Hubs	332	8%

### Categories

- Clinical Decision Making and Intelligence
- Other Medical Technology
- Mobile & Security Technology
- Capture Streaming Data from Medical Devices

**Histogram of Technology Score**



- Scores Distributed between Low & High
- Not “Normally” Distributed but Approximate



# PERFORMANCE MEASURES

## What Performance Measure(s) Should be Selected to Evaluate the Effect of Having an HIE?

**Purpose:** Test if Having an HIE Would Increase Overall Performance Metrics, Since Implementation Can Have a Broad Impact

- **Measure 1 – Evaluate if Profitability Improves**

**Selected:** Net Patient Revenue / No. Beds Set Up and Staffed (Adjust for Hospital Size)

- **Measure 2 – Evaluate if Patients' Perspectives of Hospital Care Improves**

*Used HCAHPS (Hospital Consumer Assessment of Healthcare Providers and Systems)*

**Selected:** Overall Hospital Star Rating

*77 Performance Measures that were in the Matched Hospital List (List on Next Slide)*

*Reduced List Down to 8 Variables*

*Checked Correlation Among the 8 Variables & Selected Final Metric*

# PERFORMANCE MEASURES

## HCAHPS Performance Measures after Matching the 4,106 Hospitals

HCAHPS Measure	No. Unique Orgs
Acute Myocardial Infarction 30 Day...	2259
Care transition - linear mean score	2812
Care transition - star rating	2812
Catheter-associated urinary tract...	1737
Central line-bloodstream infect...	1518
Cleanliness - linear mean score	2812
Cleanliness - star rating	2812
Cleanliness and Quietness of Hosp...	2336
Clostridium difficile Laboratory...	2267
Comm. about Med.	2336
Comm. about med. - linear mean...	2812
Comm. about med. - star rating	2812
Comm. with Doctors	2336
Comm. with Nurses	2336
Discharge Info	2336
Discharge info - linear mean score	2812
Discharge info - star rating	2812
Doctor comm. - linear mean score	2812
Doctor comm. - star rating	2812
Heart Failure (HF) 30 Day Mortality...	2282
Medicare Spending per Beneficiary	2336
Methicillin-resist. Staphylococcus...	1406
Nurse comm. - linear mean score	2812
Nurse comm. - star rating	2812
Overall hosp. rating - linear mean...	2812
Overall hosp. - star rating	2812

HCAHPS Measure	No. Unique Orgs
Overall Rating of Hospital	2336
Pain Manage.	2336
Pain manage. - linear mean score	2812
Pain manage. - star rating	2812
Patient Safety Indicator Comp. Score	2333
Patients assessed & given influenza...	2336
Patients who... hospital a rating of 6...	3339
Patients who... hospital a rating of 7...	3339
Patients who... hospital a rating of 9...	3339
Patients who... Agree... understood...	3339
Patients who... Disagree... Strongly...	3339
Patients who... NO, they would...	3339
Patients who... NO, were not given...	3339
Patients who... staff 'Always' exp...	3339
Patients who... staff 'Sometimes' ...	3339
Patients who... staff 'Usually' exp...	3339
Patients who... area around 'Always'...	3339
Patients who... area around 'Some'...	3339
Patients who... area around 'Usually'	3339
Patients who... doctors 'Always'...	3339
Patients who... doctors 'Sometimes'...	3339
Patients who... doctors 'Usually'...	3339
Patients who... nurses 'Always'...	3339
Patients who... nurses 'Sometimes'...	3339
Patients who... nurses 'Usually'...	3339

HCAHPS Measure	No. Unique Orgs
Patients who... pain 'Always'...	3339
Patients who... pain 'Sometimes'...	3339
Patients who... pain 'Usually'...	3339
Patients who... room... 'Always' clean	3339
Patients who... room... 'Sometimes'...	3339
Patients who... room... 'Usually' clean	3339
Patients who... 'Always' rec. help...	3339
Patients who... 'Sometimes' or...	3339
Patients who... 'Usually' rec. help...	3339
Patients who... YES,... given info...	3339
Patients who... YES,... recommend...	3339
Patients who... YES,... probably...	3339
Patients who 'Strongly Agree' under...	3339
Pneumonia (PN) 30 Day Mort. Rate	2281
Quietness - linear mean score	2812
Quietness - star rating	2812
Recommend hospital - linear mean...	2812
Recommend hospital - star rating	2812
Responsiveness of Hospital Staff	2336
Staff responsiveness - linear mean...	2812
Staff responsiveness - star rating	2812
Summary star rating	2812
Surg. Site Infections Composite Score	1612
Surg. Site infect. from hysterectomy	666
Surg. Site infect. from colon surgery	1598

Top 8 for Further Review Highlighted Yellow / Example of Easily Eliminated Measures Highlighted Pink

# PERFORMANCE MEASURES

## Selecting Final HCAHPS Performance Measure

### Top 8 HCAHPS Performance Measures for Further Review

HCAHPS Measure	No. Unique Orgs
Care transition - star rating	2812
Comm. about med. - star rating	2812
Doctor comm. - star rating	2812
Nurse comm. - star rating	2812
Overall hosp. - star rating	2812
Recommend hospital - linear mean...	2812
Recommend hospital - star rating	2812
Summary star rating	2812

### Correlation of Top 8 HCAHPS Performance Measures

HCAHPS Measure	A	B	C	D	E	F	G	H
A. Summ. Star Rate	1.00	0.73	0.80	0.74	0.84	0.79	0.82	0.76
B. Rec. Hosp. Star Rate	0.73	1.00	0.84	0.56	0.69	0.58	0.76	0.95
C. Overall Hosp. Star Rate	0.80	0.84	1.00	0.64	0.74	0.66	0.76	0.87
D. Doctor Comm. Star Rate	0.74	0.56	0.64	1.00	0.66	0.64	0.63	0.59
E. Nurse Comm. Star Rate	0.84	0.69	0.74	0.66	1.00	0.72	0.75	0.71
F. Comm. Med. Star Rate	0.79	0.58	0.66	0.64	0.72	1.00	0.66	0.61
G. Care Transition Star Rate	0.82	0.76	0.76	0.63	0.75	0.66	1.00	0.79
H. Rec. Hosp. Lin. Mean Score	0.76	0.95	0.87	0.59	0.71	0.61	0.79	1.00

**-How Important is HIE to Doctor or Nurse Communications?**

**-Selected Overall Hospital Performance Metric of Overall Hospital Star Rating**

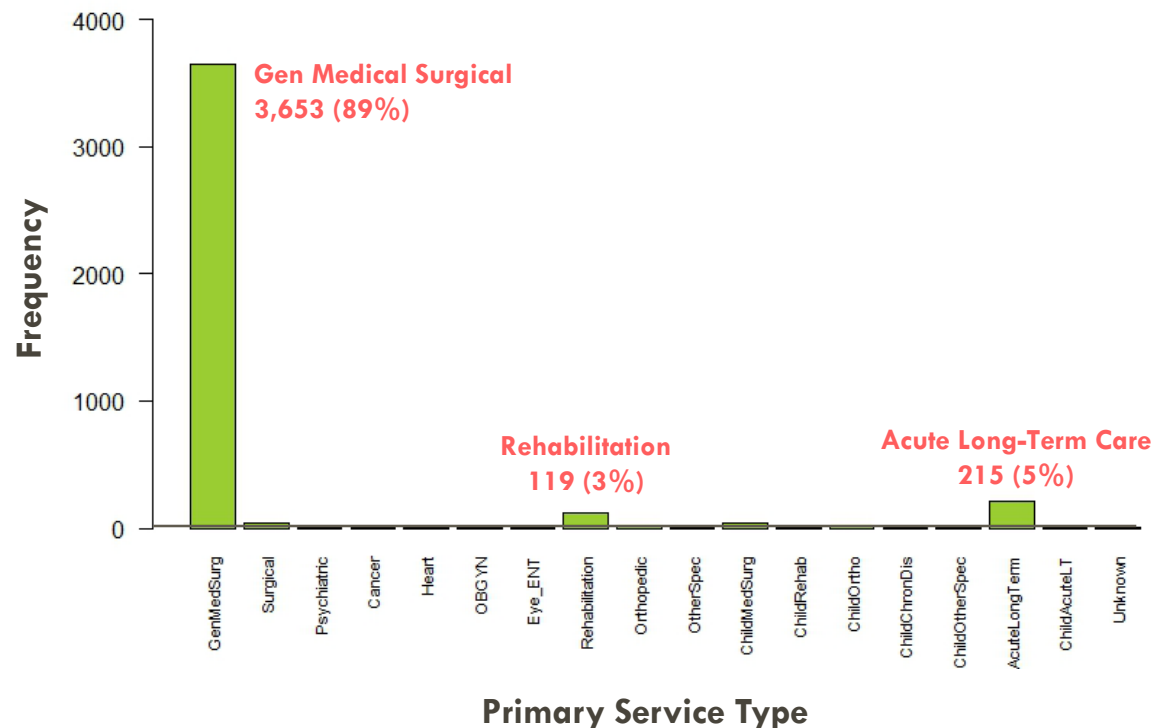
**-Most of the Top 8 HCAHPS Performance Measures Highly Correlated**

**-Communication with Doctors, Nurses, & Communication about Medicine Less Highly Correlated with Overall Hospital Performance Measures**

# DATA PREPARATION

## Filtering Data

Histogram of Hospital Primary Service Type



*Filtered By General  
Medical and Surgical  
Hospitals*

Number of Obs. = 3,653

*Base Rate ~ Same*

63.46% has HIE before  
65.43% has HIE after

# MISSING VALUES ANALYSIS

## Missing Values Table

Variable Name	Missing Values	% Total Cases
SystemType	0	0%
City	0	0%
State	0	0%
Rank100LargeCity	0	0%
CBSAType	0	0%
OrgControlType	0	0%
ControlCode	0	0%
AccredJC	0	0%
MemCOTH	0	0%
BedsLicense	0	0%
BedsStaff	0	0%
BedSizeGrp	0	0%
EMRAM_Stage	0	0%
TechScore	0	0%
<b>PatientRepServ</b>	<b>737</b>	<b>20%</b>
TotOutpatientVis	0	0%
EmergencyRoomVis	0	0%

Variable Name	Missing Values	% Total Cases
<b>EmergencyDept</b>	<b>737</b>	<b>20%</b>
<b>CertTrauma</b>	<b>737</b>	<b>20%</b>
<b>TraumaLevel</b>	<b>766</b>	<b>21%</b>
OpExpense	173	5%
TotEmployees	3	0%
FTPhysDen	0	0%
FTRegNurse	0	0%
FTVocNurse	0	0%
FTPersTot	0	0%
FTHospPersTot	0	0%
Admissions	0	0%
AdjAdmiss	0	0%
AdjPatientDays	0	0%
HIE_YN	0	0%
NetPatientRev	3	0%
TotInpatientRev	3	0%
<b>StarRate_Overall</b>	<b>917</b>	<b>25%</b>
<b>Total Cases</b>	<b>2,688</b>	<b>74%</b>

**74% of Cases have Missing Values**

**Variables with Highest Percent of Cases with Missing Values Highlighted in Pink**

**3 Main Categories of Missing Values: Patient Services, Type and Level of Emergency Care, and Hospital Overall Star Rating**

# DATA CLEANING / CODING / TRANSFORMING

## Created 0/1 Dummy Variables

### SystemType: "Single," "Multi"

- HealthSystem > 1=multi; 0=single

### ControlCode

- Church > 1=Yes (church); 0=No
- Government > 1=Yes (all gov. - state, county, city, etc.); 0=No
- ForProfit > 1=Yes (corporation, individual, partnership); 0=No
- NonProfit > 1=Yes (not-for-profit not church operated); 0=No

### Rank100LargeCity: Rank of Top 100

- Top100Cities > 1=Yes (ranked); 0=No

### CBSAType: "Metro," "Micro," "Rural"

- Metro > 1=Yes (metro); 0=No
- Micro > 1=Yes (micro); 0=No
- Rural > 1=Yes (rural); 0=No

## Recoded Variables

### AccredJC: 1=Yes 2=No

- Accred JC > 1=Yes; 0=No

### MemCOTH: 1=Yes 2=No

- Member COTH > 1=Yes; 0=No

## Missing Values

### EmergencyDept

- EmergencyDept (737 MV) >  
if EmergencyRoomVis > 0 then 1=Yes

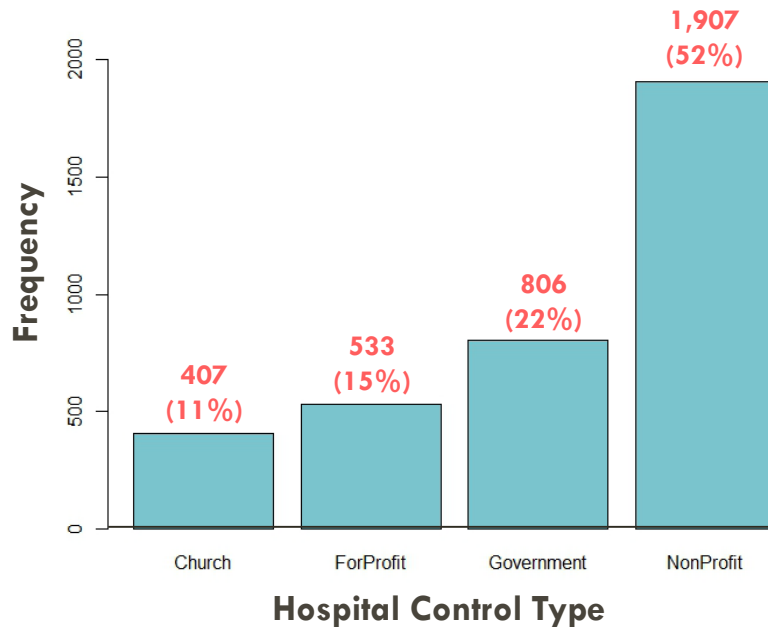
## Calculated Variables

### Org Control Type

- PercentDr > FTPhysDen / FTPersTot
- PercentNurse > FTRegNurse +  
FTVocNurse / FTPersTot
- NetPatRevSize > NetPatientRev /  
BedStaffed

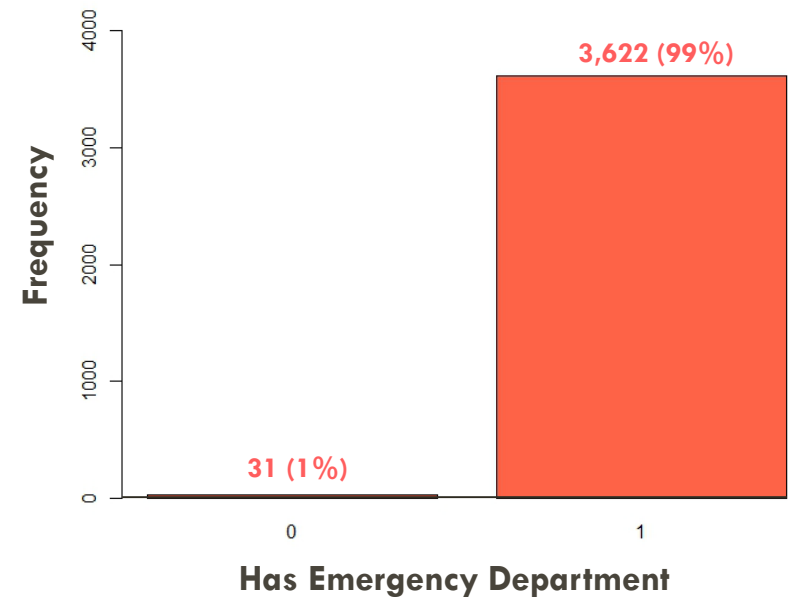
# EXPLORATORY ANALYSIS

## Histogram of Hospital Control Type



- Approximately  $\frac{1}{2}$  of Hospitals NonProfit
- Better Split of Control Types; Can Consider for Independent Variables

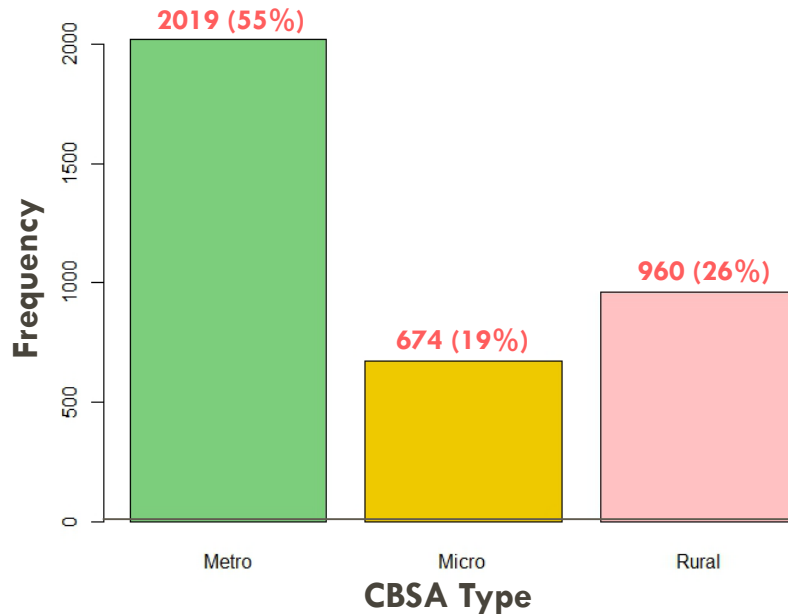
## Histogram of Emergency Department



- Not Good Candidate for an Independent Variable Since 99% Hospitals Have One
- Cannot Create Emergency Level Variable Since 766 Missing Values for Trauma Level

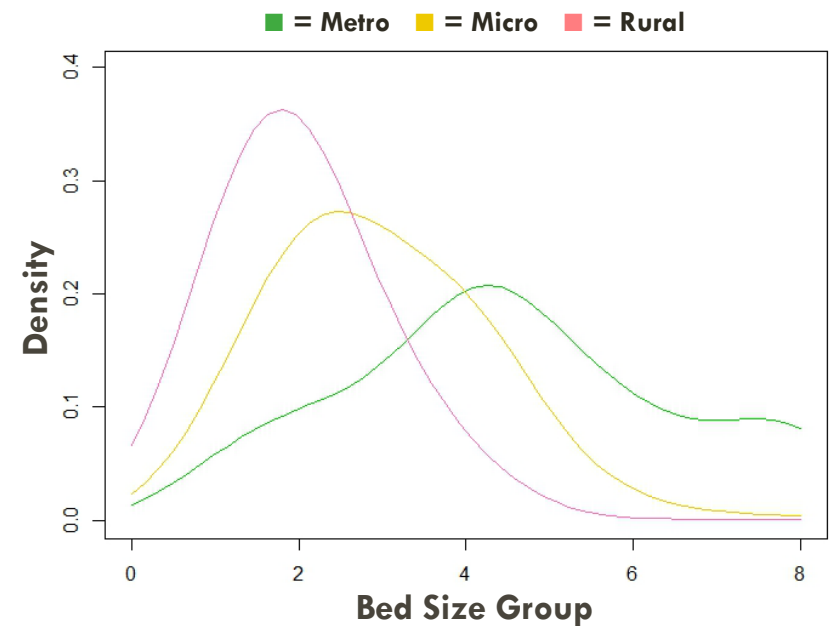
# EXPLORATORY ANALYSIS

**Histogram of CBSA Type  
Metro / Micro / Rural**



- Over ½ of Hospitals in a Metro
- 26% of Hospitals in Rural Areas

**Kernel Density Plot of Bed Size  
Group by CBSA Type**

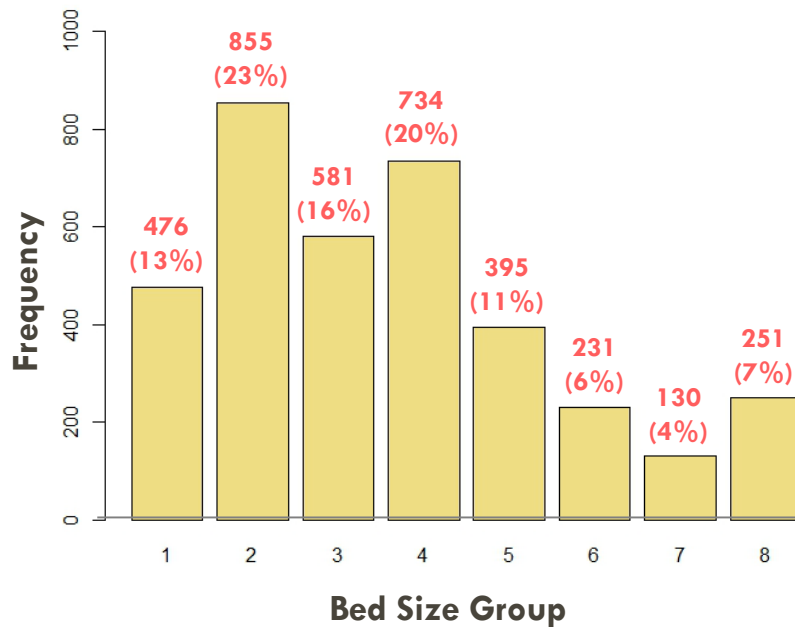


- Only Metro Hospitals Have Many Larger Hospitals (Bed Group Size 5+)
- Metro Hospitals Peak at Bed Size Group 4
- Micro & Rural Hospitals Smaller; Peak at Bed Size Group 2



# EXPLORATORY ANALYSIS

## Histogram of Bed Size Group



1: 6-25 Beds      5: 200-299 Beds  
 2: 25-49 Beds    6: 300-399 Beds  
 3: 50-99 Beds    7: 400-499 Beds  
 4: 100-199 Beds   8: 500+ Beds

## Table of Has HIE by Bed Size Group

Bed Group	HIE			
	Size	Total	0 - No	1 - Yes
1	476	210	266	56%
2	855	340	515	60%
3	581	211	370	64%
4	734	261	473	64%
5	395	124	271	69%
6	231	53	178	77%
7	130	29	101	78%
8	251	35	216	86%

- % Has HIE Steadily Increases with Bed Size
- Will Bed Size Group Mask Other Important Factors of Having an HIE?
- Should the Data be Subsetted Based on Bed Size Group?

# RESEARCH QUESTION 1

## What hospital factors are associated with having an HIE installed?

- Does the type of hospital play a role in having an HIE installed?
- Does the location of a hospital matter?
- Does being accredited matter?
- Does the size of a hospital affect whether an HIE is installed?
- Do the type of staff and services matter to whether an HIE is installed?
- What role does technology play in having an HIE installed?

# EMRAM STAGE

## HIMSS EMRAM Stage as a Technology Measure

“The **HIMSS Analytics Electronic Medical Record Adoption Model (EMRAM)** incorporates methodology and algorithms to automatically score hospitals around the world relative to their Electronic Medical Records (EMR) capabilities. This eight-stage (0-7) model measures the adoption and utilization of electronic medical record (EMR) functions.”

<https://www.himssanalytics.org/emram>

STAGE <b>7</b>	Complete EMR; External HIE; Data Analytics, Governance, Disaster Recovery, Privacy And Security	+
STAGE <b>6</b>	Technology Enabled Medication, Blood Products, And Human Milk Administration; Risk Reporting; Full CDS	+
STAGE <b>5</b>	Physician Documentation Using Structured Templates; Intrusion/Device Protection	+
STAGE <b>4</b>	CPOE With CDS; Nursing And Allied Health Documentation; Basic Business Continuity	+
STAGE <b>3</b>	Nursing And Allied Health Documentation; EMAR; Role-Based Security	+
STAGE <b>2</b>	CDR; Internal Interoperability; Basic Security	+
STAGE <b>1</b>	Ancillaries - Laboratory, Pharmacy, And Radiology/Cardiology Information Systems; PACS; Digital Non-DICOM Image Management	+
STAGE <b>0</b>	All Three Ancillaries Not Installed	+

58% of the 3,653 General Medical and Surgical Hospitals have an EMRAM Stage of 0  
41% of have an EMRAM Stage of 6 or 7; most of these 37% have a 6 Stage

# CORRELATION ANALYSIS

## Dropping Highly Correlated Independent Variables

### Variables Highly Correlated with Hospital Size (BedsStaff) Dropped

- Admissions  $r = 0.909$
- AdjAdmiss  $r = 0.880$
- FTRegNurse  $r = 0.848$
- OpExpense  $r = 0.841$
- AdjPatientDays  $r = 0.836$
- TotalEmployees  $r = 0.832$
- NetPatientRev  $r = 0.830$
- TotalInpatientRev  $r = 0.808$
- FTPersTot  $r = 0.803$
- FTHospPersTot  $r = 0.802$
- EmergencyRoomVis  $r = 0.783$

*\*Some of these variables were pulled and had been kept until this point in case they were needed for other calculated variables.*

### Variables Due to Being Similar Measures Dropped

- BedsLicense
- BedsStaff

*\*BedSizeGrp was kept instead of these two. BedsStaff was used in the performance measure calculated and discussed on slide 9 (Net Patient Revenue / Bed Staffed).*

### Variables Dropped for Consistency

- FTPhysDen
- FTVocNurse

*\*Most of the full-time staff variables were removed for being highly correlated to size. These two were dropped for consistency as well as the calculated PercentDr & PercentNurse being used instead (see slide 14).*

# CORRELATION ANALYSIS & SUBSETTING THE DATA

## Should the Data be Subsetted?

## How Should the Data be Subsetted?

### Candidate Subsets of the Data were Created Based on Bed Size Group and CBSA Type

4 Subsets were Created for Bed Size Group: Bed Size Group 1 & 2; Bed Size Group 3 & 4; Bed Size Group 5 & 6; and Bed Size Group 7 & 8

3 Subsets were Created for CBSA Type: Metro; Micro; and Rural

**Table of Observations and HIE Info Based on Subsetting by Bed Size Group and CBSA Type**

Name	All	BSG 12	BSG 34	BSG 56	BSG 78	Metro	Micro	Rural
Total No. Observations	3,653	1,331	1,315	626	381	2,019	674	960
HIE - Yes	2,390	781	843	449	317	1,422	437	531
HIE - No	1,263	550	472	177	64	597	237	429
<b>Base Rate HIE</b>	<b>65.43%</b>	<b>58.68%</b>	<b>64.11%</b>	<b>71.73%</b>	<b>83.20%</b>	<b>70.43%</b>	<b>64.84%</b>	<b>55.31%</b>

# CORRELATION ANALYSIS

Name	Type	Corr. w/HIE	All	BSG 12	BSG 34	BSG 56	BSG 78	Metro	Micro	Rural
Type of Hospital										
<b>Government</b>	<b>binary</b>	<b>r</b>	<b>-0.11</b>	<b>-0.15</b>	<b>-0.06</b>	<b>0.03</b>	<b>0.05</b>	<b>-0.03</b>	<b>-0.10</b>	<b>-0.11</b>
Church	binary	r	0.14	0.13	0.13	0.16	0.07	0.15	0.10	0.09
ForProfit	binary	r	-0.36	-0.25	-0.38	-0.51	-0.54	-0.47	-0.33	-0.21
NonProfit	binary	r	0.25	0.22	0.26	0.27	0.24	0.29	0.24	0.17
<b>HealthSystem</b>	<b>binary</b>	<b>r</b>	<b>0.16</b>	<b>0.24</b>	<b>0.08</b>	<b>-0.02</b>	<b>-0.02</b>	<b>0.12</b>	<b>-0.01</b>	<b>0.21</b>
Location										
Top 100 Cities	binary	r	0.06	-0.08	0.01	0.04	-0.01	0.04	NA	NA
Rural	binary	r	-0.13	-0.07	-0.09	-0.04	-0.16	NA	NA	NA
Metro	binary	r	0.12	0.00	0.08	0.04	0.08	NA	NA	NA
Micro	binary	r	-0.01	0.08	-0.02	-0.03	0.00	NA	NA	NA
Accreditation / Member										
Accred_JC	binary	r	0.08	0.08	-0.01	-0.07	0.01	0.02	-0.05	0.06
Member_COTH	binary	r	0.13	NA	-0.01	0.06	0.23	0.14	0.04	NA
Size										
BedSizeGroup	ordinal	r	0.16	NA	NA	NA	NA	0.17	0.00	-0.01
TotOutpatientVis	contin.	r	0.19	0.17	0.18	0.18	0.21	0.20	0.15	0.13
Type of Services / Staff										
PatientRepServ	binary	r	0.17	0.11	0.13	0.17	0.05	0.20	0.00	0.11
PercentDr	contin.	r	0.10	0.08	0.07	0.14	0.15	0.12	0.09	0.08
PercentNurse	contin.	r	-0.04	-0.05	-0.04	-0.15	-0.26	-0.10	-0.09	-0.05
Technology										
<b>TechScore</b>	<b>ordinal</b>	<b>r</b>	<b>0.35</b>	<b>0.31</b>	<b>0.34</b>	<b>0.33</b>	<b>0.28</b>	<b>0.38</b>	<b>0.26</b>	<b>0.26</b>
<b>EMRAM_Stage</b>	<b>ordinal</b>	<b>r</b>	<b>0.27</b>	<b>0.26</b>	<b>0.25</b>	<b>0.20</b>	<b>0.15</b>	<b>0.26</b>	<b>0.23</b>	<b>0.23</b>

**Correlation with HIE on All Data and Data Subsetted by Bed Size Group and CBSA Type**

*Examples of Correlations that Remain Constant with Subsetting in Bold; While Examples that Change in Red*

# CORRELATION ANALYSIS & SIGNIFICANCE TESTING

Name	Type	Test Type	All - HIE Corr.	All - HIE Sig.	BSG 12 - HIE Corr.	BSG 12 - HIE Sig.	BSG 34 - HIE Corr.	BSG 34 - HIE Sig.	BSG 56 - HIE Corr.	BSG 56 - HIE Sig.	BSG 78 - HIE Corr.	BSG 78 - HIE Sig.
Type of Hospital												
Government	binary	r	-0.11	<b>-6.44**</b>	-0.15	<b>-5.32**</b>	-0.06	<b>-2.23<sup>o</sup></b>	0.03	<b>0.65</b>	0.05	<b>1.05</b>
Church	binary	r	0.14	<b>8.22**</b>	0.13	<b>4.66**</b>	0.13	<b>4.81**</b>	0.16	<b>3.91**</b>	0.07	<b>1.32</b>
ForProfit	binary	r	-0.36	<b>-22.94**</b>	-0.25	<b>-9.28**</b>	-0.38	<b>-14.74**</b>	-0.51	<b>-14.72**</b>	-0.54	<b>-12.50**</b>
NonProfit	binary	r	0.25	<b>15.86**</b>	0.22	<b>8.08**</b>	0.26	<b>9.66**</b>	0.27	<b>6.96**</b>	0.24	<b>4.89**</b>
HealthSystem	binary	r	0.16	<b>9.69**</b>	0.24	<b>9.00**</b>	0.08	<b>2.78*</b>	-0.02	<b>-0.51</b>	-0.02	<b>-0.34</b>
Location												
Top 100 Cities	binary	r	0.06	<b>3.72**</b>	-0.08	<b>-2.89*</b>	0.01	<b>0.20</b>	0.04	<b>1.03</b>	-0.01	<b>-0.12</b>
Rural	binary	r	-0.13	<b>-7.73**</b>	-0.07	<b>2.36<sup>o</sup></b>	-0.09	<b>-3.38**</b>	-0.04	<b>-0.97●</b>	-0.16	<b>-3.19●</b>
Metro	binary	r	0.12	<b>7.12**</b>	0.00	<b>0.06</b>	0.08	<b>3.07*</b>	0.04	<b>0.91</b>	0.08	<b>1.58</b>
Micro	binary	r	-0.01	<b>-0.36</b>	0.08	<b>2.84*</b>	-0.02	<b>-0.53</b>	-0.03	<b>-0.67</b>	0.00	<b>0.01</b>
Accreditation / Member												
Accred_JC	binary	r	0.08	<b>4.64**</b>	0.08	<b>2.87*</b>	-0.01	<b>-0.48</b>	-0.07	<b>-1.82</b>	0.01	<b>0.26</b>
Member_COTH	binary	r	0.13	<b>7.69**</b>	NA	<b>NA●</b>	-0.01	<b>-0.42●</b>	0.06	<b>1.42</b>	0.23	<b>4.54**</b>
Size												
BedSizeGroup	ordinal	r	0.16	<b>9.95**</b>	NA	<b>NA</b>	NA	<b>NA</b>	NA	<b>NA</b>	NA	<b>NA</b>
TotOutpatientVis	contin.	r	0.19	<b>11.90**</b>	0.17	<b>6.24**</b>	0.18	<b>6.60**</b>	0.18	<b>4.69**</b>	0.21	<b>4.12**</b>
Type of Services / Staff												
PatientRepServ	binary	r	0.17	<b>9.43**</b>	0.11	<b>3.45**</b>	0.13	<b>4.06**</b>	0.17	<b>4.01**</b>	0.05	<b>0.99●</b>
PercentDr	contin.	r	0.10	<b>5.75**</b>	0.08	<b>3.06*</b>	0.07	<b>2.53<sup>o</sup></b>	0.14	<b>3.54**</b>	0.15	<b>2.94*</b>
PercentNurse	contin.	r	-0.04	<b>-2.60*</b>	-0.05	<b>-1.85</b>	-0.04	<b>-1.49</b>	-0.15	<b>-3.86**</b>	-0.26	<b>-5.15**</b>
Technology												
TechScore	ordinal	r	0.35	<b>22.26**</b>	0.31	<b>11.75**</b>	0.34	<b>13.23**</b>	0.33	<b>8.66**</b>	0.28	<b>5.70**</b>
EMRAM_Stage	ordinal	r	0.27	<b>16.98**</b>	0.26	<b>9.80**</b>	0.25	<b>9.23**</b>	0.20	<b>5.14**</b>	0.15	<b>2.88*</b>

**Bed Size Group Subsetting Selected; Correlation with Significance Testing**

## Notes

\*\* significant at the 0.001 level

\* significant at the 0.01 level

<sup>o</sup> significant at the 0.05 level

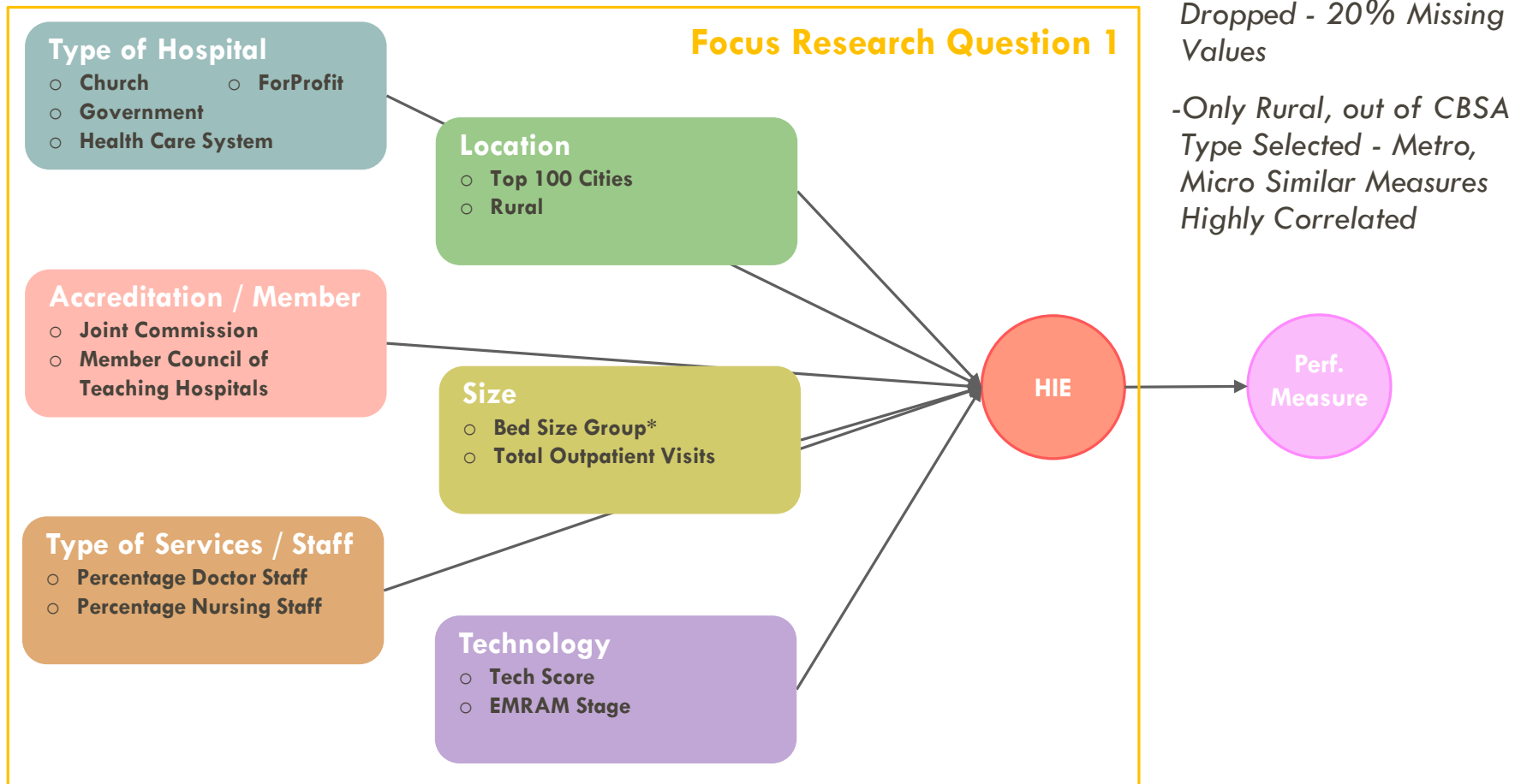
● 5 or fewer cases in a binary group

# OVERALL CONCEPTUAL BLOCK MODEL

## METHOD 1

**Method 1: Use the Same Block Model for All Variables & Each Subset Keeping Only the Significant Variables**

### All Bed Size Groups+



\*Bed Size Group [Binned 1&2=A; 3&4=B; 5&6=C; 7&8=D – Dummy Drop 1(A)] & Removed for Subsetted Models

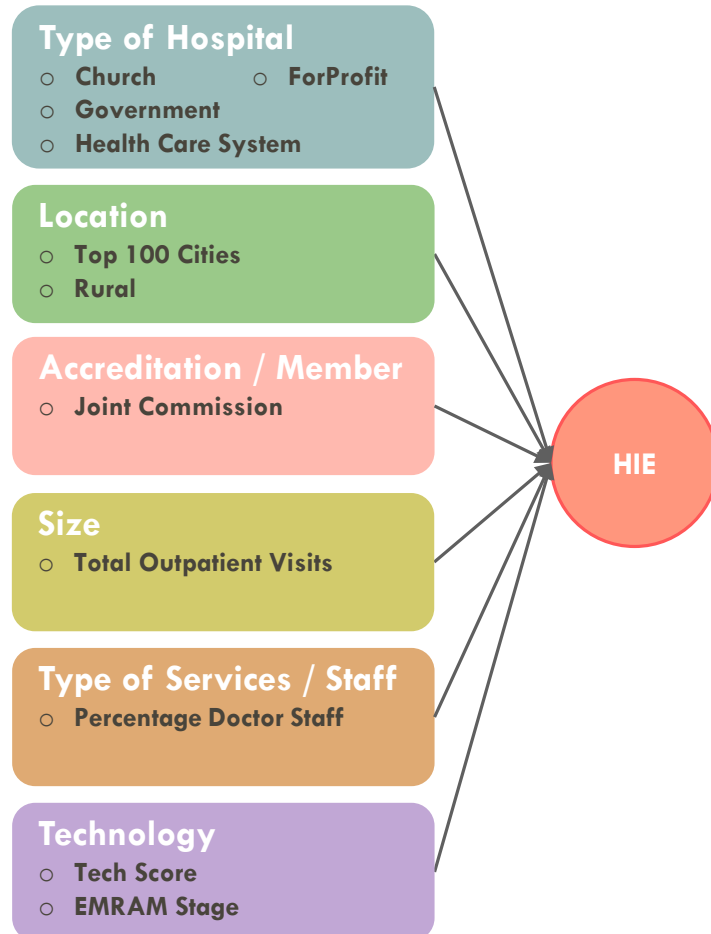


# CONCEPTUAL BLOCK MODELS PER BED SIZE GROUP

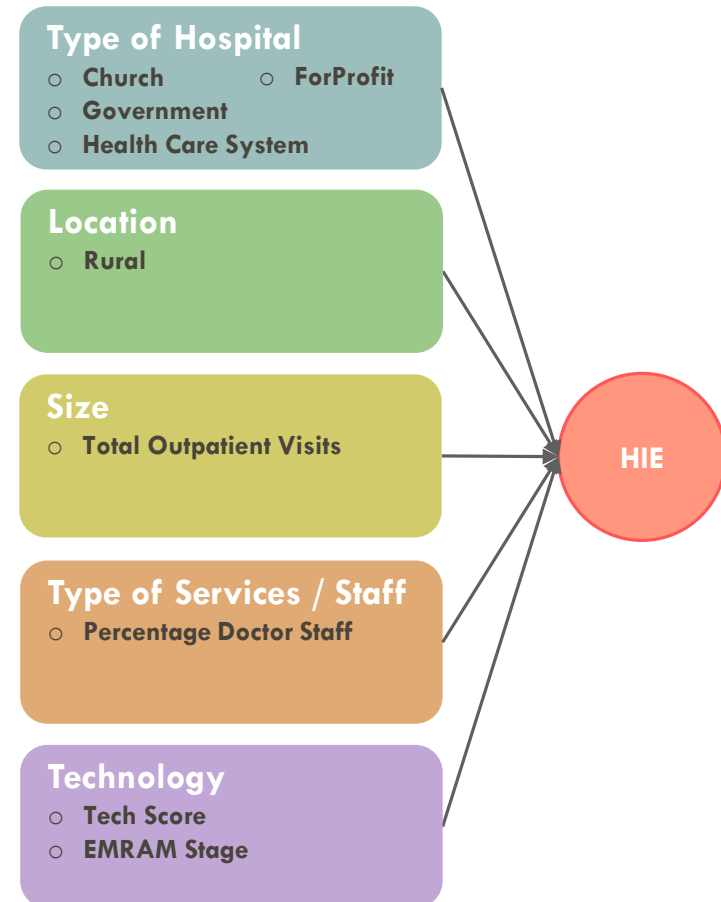
## METHOD 2

**Method 2: Use a Separate Block Model for Each Bed Size Group Based on the Correlation Analysis and Significance Testing**

### Bed Size Group 1 or 2



### Bed Size Group 3 or 4

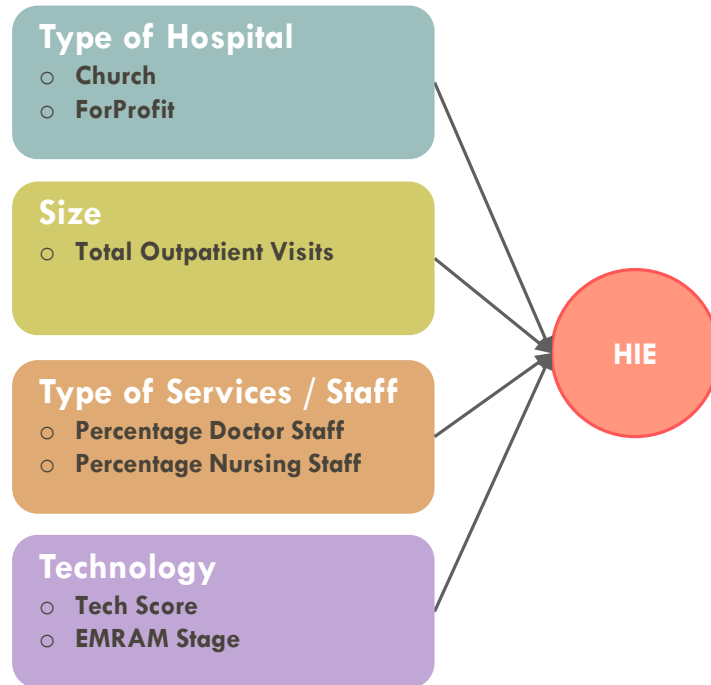


# CONCEPTUAL BLOCK MODELS PER BED SIZE GROUP

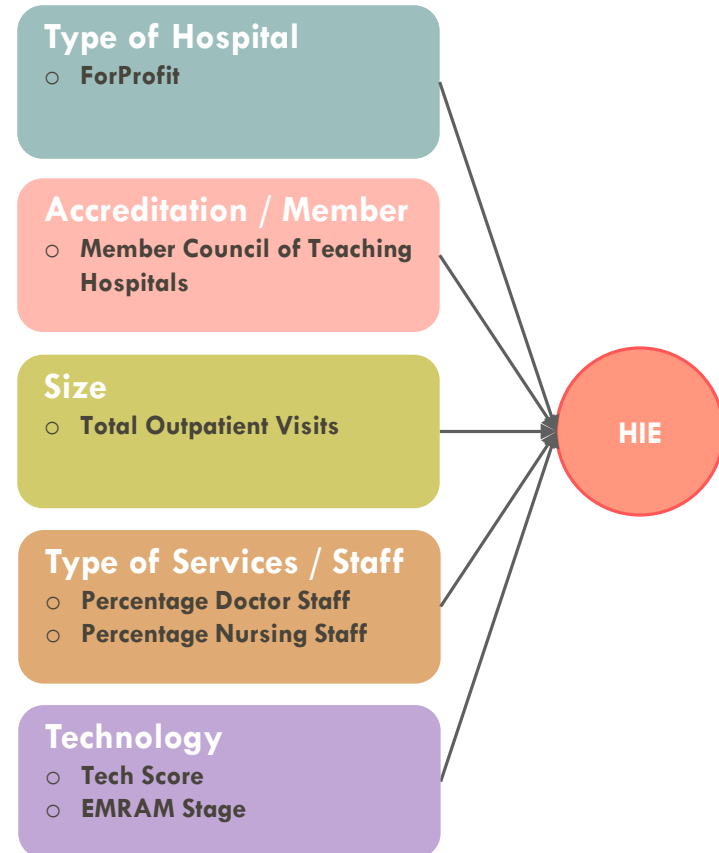
## METHOD 2

**Method 2: Use a Separate Block Model for Each Bed Size Group Based on the Correlation Analysis and Significance Testing**

### Bed Size Group 5 or 6



### Bed Size Group 7 or 8



# SELECTED MODELS — LOGISTIC REGRESSION

## METHOD 1

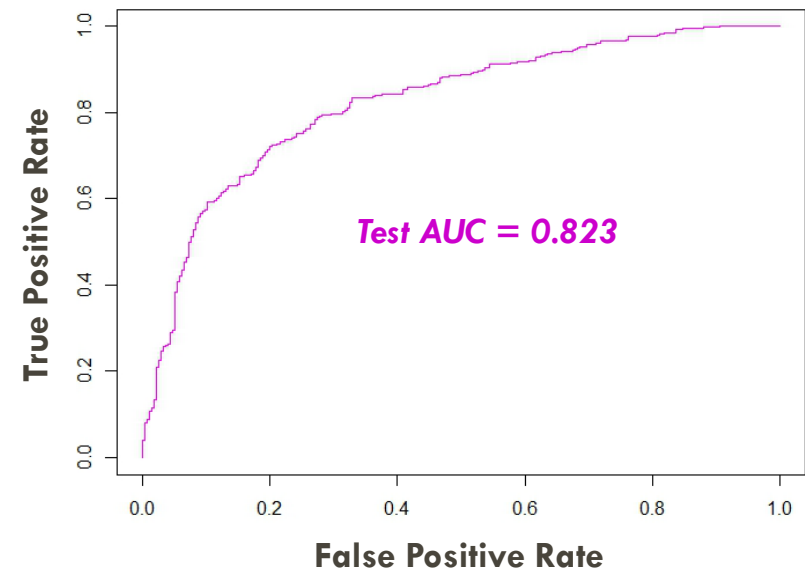
**Data Split 80% Training to 20% Test for All Models**

**Model All Bed Size Groups**

Variable	Coefficients	Odds Ratio	% INCR/DECR in Odds
Government	-0.394	0.674	-33%
ForProf	-2.073	0.126	-87%
HealthSystem	0.798	2.221	122%
Rural	-0.204	0.815	-18%
Accred_JC	-0.299	0.741	-26%
TotOutpatientVis <sup>↑</sup>	1.08E-06	1.011	1%
PercentNurse	-0.017	0.984	-2%
TechScore	0.409	1.505	50%
EMRAM_Stage	0.106	1.112	11%

<sup>↑</sup>Total Outpatient Visits Model Coefficient is per Visit While Odds Ratio and % Increase or Decrease in Odds Adjusted to Represent per 10,000 Visits

**All Bed Size Groups  
ROC Curve – Test Data**



# SELECTED MODELS — LOGISTIC REGRESSION METHOD 1

## Model Bed Size Group 1 or 2

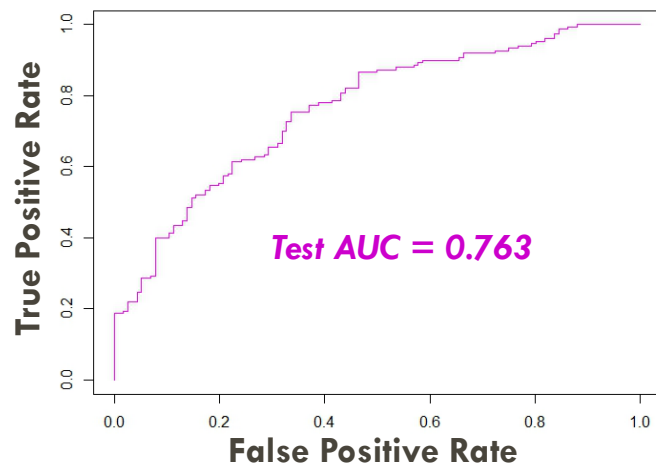
Variable	Coefficients	Odds Ratio	% INCR/DECR in Odds
ForProf	-1.770	0.170	-83%
HealthSystem	1.072	2.921	192%
TotOutpatientVis <sup>↑</sup>	3.44E-06	1.035	4%
PercentNurse	-0.023	0.977	-2%
TechScore	0.287	1.332	33%
EMRAM_Stage	0.136	1.146	15%

<sup>↑</sup>Refer to Note on Slide 25 for Both Tables on This Slide

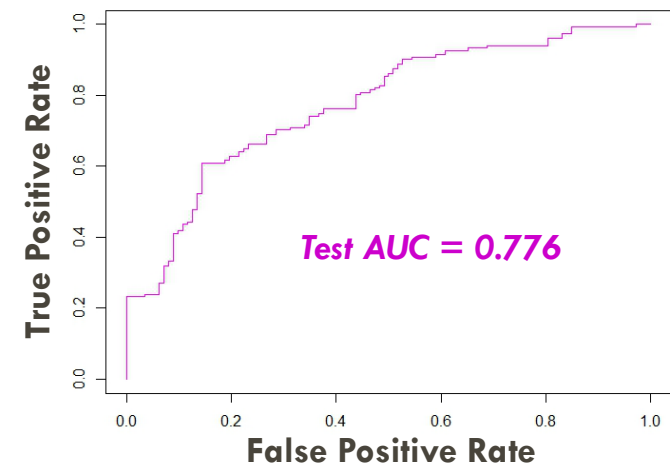
## Model Bed Size Group 3 or 4

Variable	Coefficients	Odds Ratio	% INCR/DECR in Odds
Government	-0.398	0.672	-33%
ForProf	-2.089	0.124	-88%
HealthSystem	0.752	2.120	112%
TotOutpatientVis <sup>↑</sup>	1.59E-06	1.016	2%
Accred_JC	-0.476	0.621	-38%
TechScore	0.507	1.660	66%
EMRAM_Stage	0.115	1.121	12%

## Bed Size Group 1 or 2 / ROC Curve – Test Data



## Bed Size Group 3 or 4 / ROC Curve – Test Data



# SELECTED MODELS — LOGISTIC REGRESSION METHOD 1

## Model Bed Size Group 5 or 6

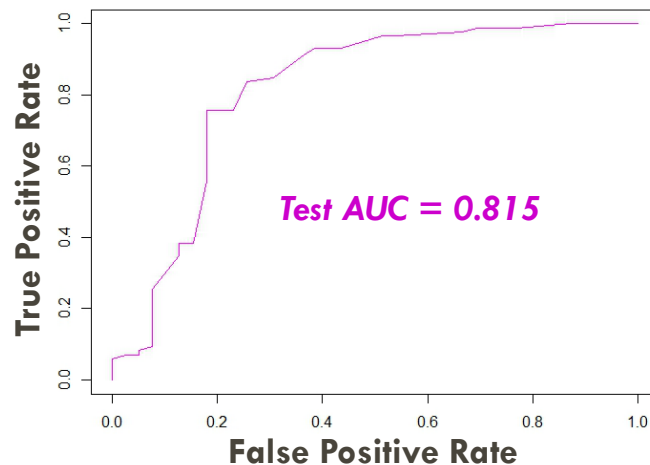
Variable	Coefficients	Odds Ratio	% INCR/DECR in Odds
ForProf	-2.414	0.089	-91%
Church	0.922	2.514	151%
TechScore	0.457	1.580	58%
EMRAM_Stage	0.119	1.127	13%

## Model Bed Size Group 7 or 8

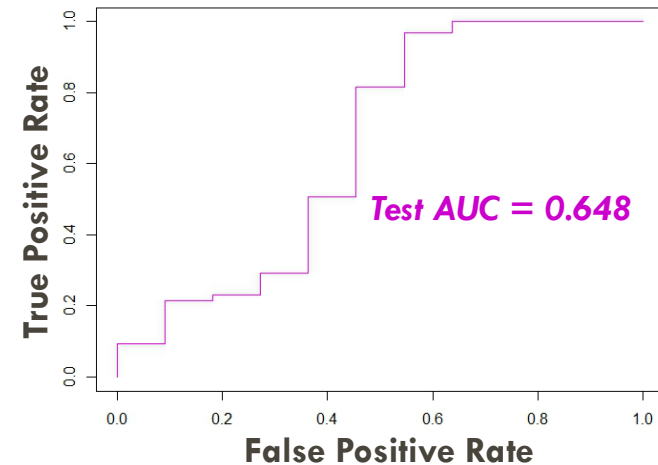
Variable	Coefficients	Odds Ratio	% INCR/DECR in Odds
ForProf	-2.523	0.080	-92%
TotOutpatientVis <sup>↑</sup>	2.05E-06	1.021	2%
TechScore	0.313	1.367	37%

<sup>↑</sup>Refer to Note on Slide 25

### Bed Size Group 5 or 6 ROC Curve – Test Data



### Bed Size Group 7 or 8 ROC Curve – Test Data



# MODEL SUMMARY

Group - Target	All - HIE		BSG 12 - HIE		BSG 34 - HIE		BSG 56 - HIE		BSG 78 - HIE	
No. of Obs.	3,653		1,331		1,315		626		381	
Test AUC	0.823		0.763		0.776		0.815		0.648	
Name	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
<b>Type of Hospital</b>										
Government	-0.39	***			-0.40	◇				
Church							0.92	*		
ForProfit	-2.07	***	-1.77	***	-2.09	***	-2.41	***	-2.52	***
HealthSystem	0.80	***	1.07	***	0.75	***				
<b>Location</b>										
Rural	-0.20	◇								
<b>Accreditation / Member</b>										
Accred_JC	-0.30	**			-0.48	*				
<b>Size</b>										
TotOutpatientVis	1.08E-06	***	3.44E-06	*	1.59E-06	*			2.05E-06	**
<b>Type of Services / Staff</b>										
PercentNurse	-0.02	*	-0.02	*						
<b>Technology</b>										
TechScore	0.41	***	0.29	***	0.51	***	0.46	***	0.31	**
EMRAM_Stage	0.11	***	0.14	***	0.11	***	0.12	**		

## 5 Model Summary of Significant Variables

### Notes

\*\*\* significant at the 0.001 level

\*\* significant at the 0.01 level

\* significant at the 0.05 level

◇ significant at the 0.1 level

# KEY FINDINGS

## Type of Hospital

- For-profit hospitals are less likely to have an HIE.
- There is an 87% decrease in the odds of for-profit hospitals to have an HIE. This decrease gradually grows as hospital size increases; ranging from 82% - 92%.
- Government hospitals have a decrease in odds of 33% of having an HIE. However, this decrease is associated with smaller hospitals (bed size group 1 & 2 or 3 & 4). This negative correlation becomes neutral in larger hospitals.
- Hospitals that are part of multi-health systems are more likely to have an HIE. Overall, the odds of having an HIE increase by 122% if a hospital is part of a health system. However, this is only significant in smaller hospitals: 192% increased odds in bed size group 1 & 2; 112% increased odds in bed size group 3 & 4.

## Location

- Overall, if a hospital is in a rural local the odds are 18% less likely that it will have an HIE.
- There are very few large rural hospitals (bed size group 5 & 6 or 7 & 8); under 5 per bin.
- Whether a hospital is located in the top 100 cities in the US is not a significant factor in any of the models, disproving a hypothesis that it would be.

# KEY FINDINGS

## Accreditation / Member

- Being a member of the Council of Teaching Hospitals (signifying an academic/teaching hospital) was included in the block model as it was hypothesized that it might be important to having an HIE. However, while having an overall positive correlation to having an HIE; it was not found to be significant in any of the models.
- Very few smaller hospitals are teaching hospitals.
- In the correlation analysis, having the Joint Commission accreditation generally has a significant positive correlation to having an HIE. Therefore, it is surprising that the overall model showed a decrease in the odds of a hospital having an HIE by 26% if they are accredited. This is mainly attributed to bed size group 3 & 4.

## Size

- While the data was subsetting by bed size group, this is a measure of size by the ability of inpatient admissions. Total outpatient visits is a slightly different size measure, recording how many outpatient visits a hospital has. This factor was significant even in most of the subsets grouped by bed size (excluding bed size group 5 & 6). Per 10,000 outpatient visits the odds of a hospital having an HIE increases by 2-4%.



# KEY FINDINGS

## Type of Services / Staff

- Patient representative services was left out of the model because it had 20% missing values. Looking at the correlation analysis, it was positively correlated to having an HIE in smaller hospitals. In the largest hospitals, most hospitals have this service, and it therefore would not be an important discriminator.
- Having a 1 unit higher percentage of nurses decreases the odds of having an HIE by 2%. This was only significant in the overall and bed size group 1 & 2 models.

## Technology

- The tech score that was created was a significant variable in every model.
- In the overall model, having a 1 unit increase in the tech score increased the odds of having an HIE by 50%. The tech score ranges from 0 – 7. So comparing a hospital with a tech score of 0 to one with a score of 7, the odds of having an HIE increase by 350%.
- Hospitals investing in various wide-ranging aspects of advanced technology measured by CDSS, dictation w/speech rec., telemedicine, mobile WLAN, RFID, business intelligence, and intelligent medical device hubs are likely to be investing in HIE as well.
- EMRAM stage was also significant in every model but bed size group 7 & 8. Overall hospitals that have a 1 unit increase in the EMRAM stage will see an 11% increase in the odds of having an HIE.

# RESEARCH QUESTION 2

Is having an HIE installed linked to better performance?

## Performance Criteria Can Refer to Different Measures

- **Profitability**

Net Patient Revenue / No. Beds Set Up and Staffed  
(Adjust for Hospital Size)

- **Patients' Perspective**

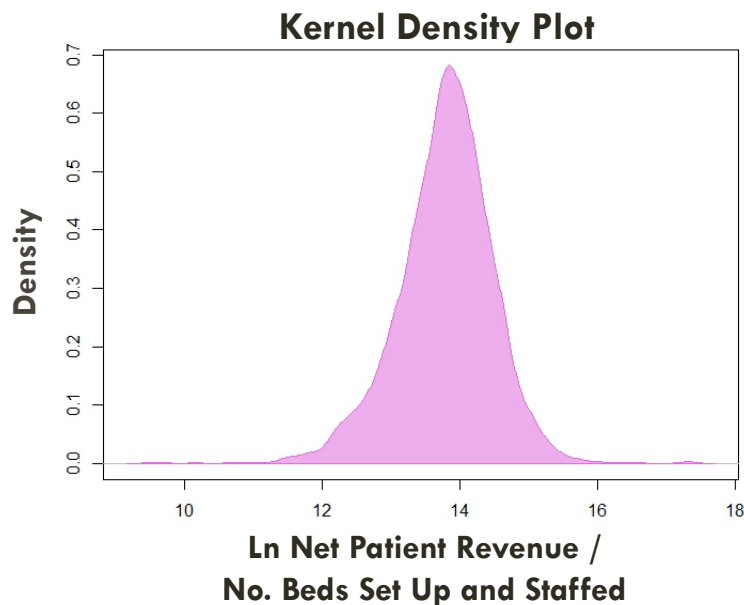
- Overall Hospital Star Rating

(HCAHPS Hospital Consumer Assessment of Healthcare Providers and Systems)

# DATA PREPARATION

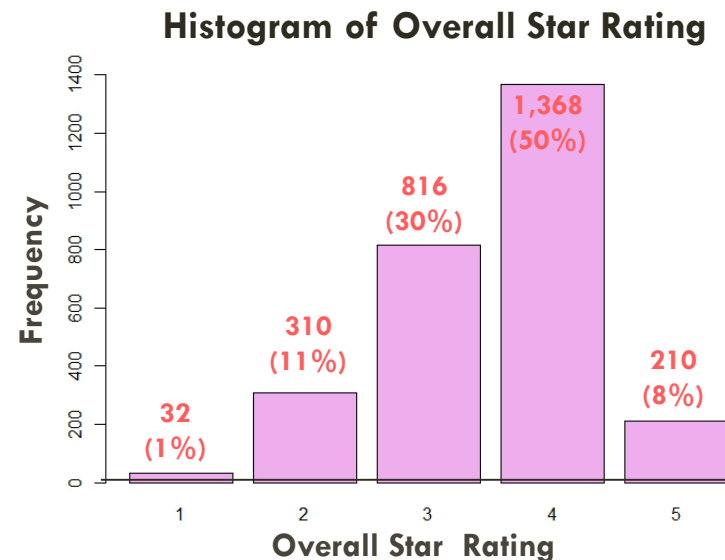
## Net Patient Revenue / No. Beds Set Up and Staffed

- Removed 3 Missing Values
- Removed 10 Outliers for Having Neg. or 0 Net Patient Revenue
- Took the Natural Log of the Target Variable so the Data would be more Normally Distributed

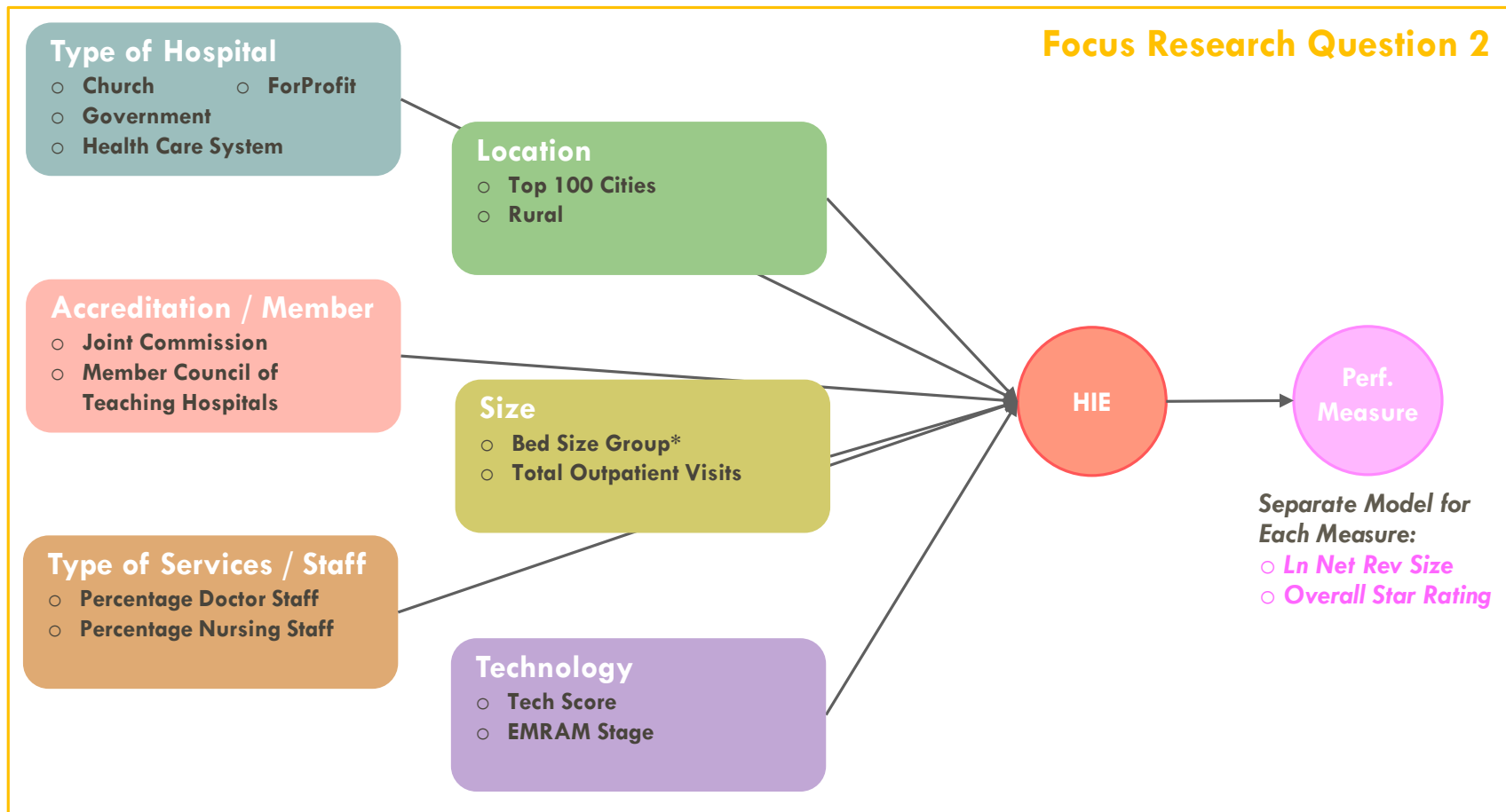


## Overall Star Rating

- Removed 917 Missing Values
- 81% of the Missing Values were from Bed Size Group 1 & 2
- 50% of Respondents Rated Hospitals as 4 Stars



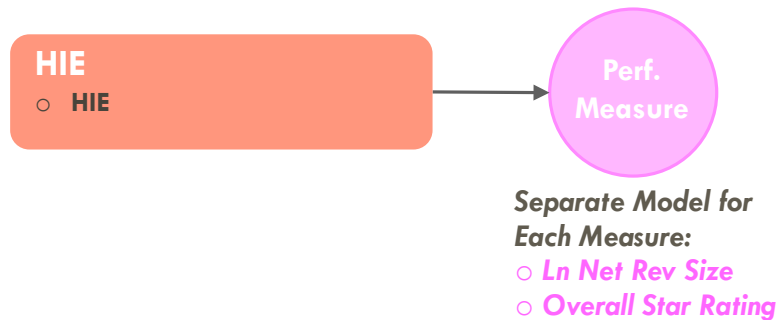
# OVERALL CONCEPTUAL BLOCK MODEL



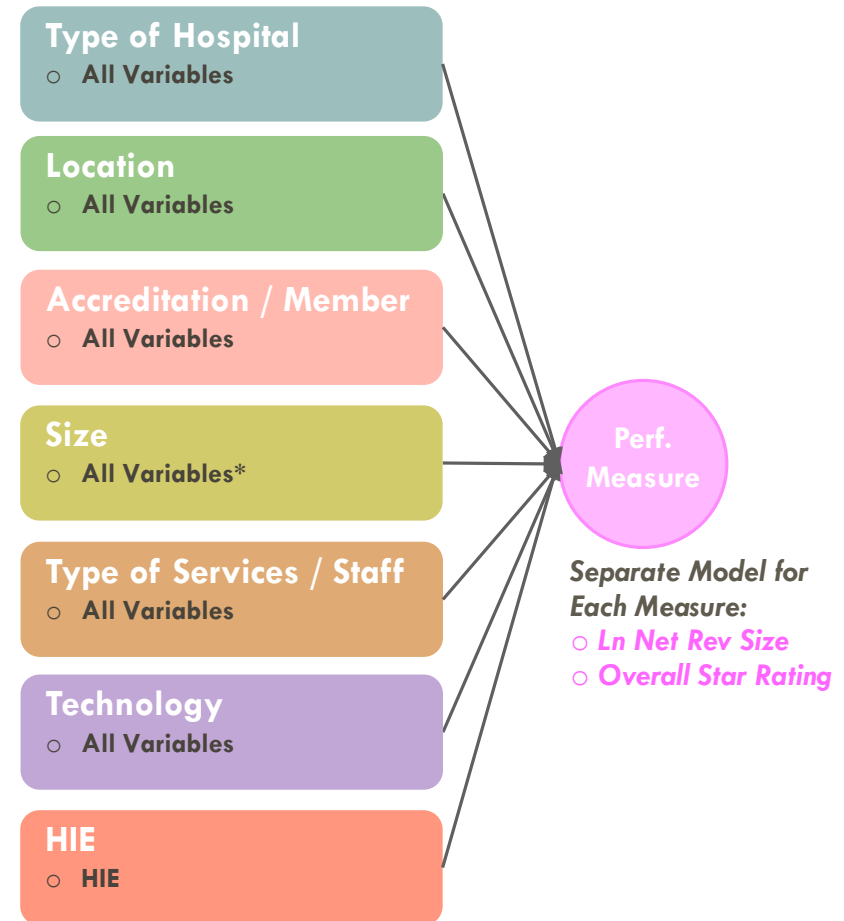
\*Bed Size Group [Binned 1&2=A; 3&4=B; 5&6=C; 7&8=D – Dummy Drop 1 (A)] & Removed for Subsetted Models

# CONCEPTUAL BLOCK MODELS

## Method 1 *Stand Alone HIE Effect*



## Method 2 *Let HIE Compete for Significance*



\*Bed Size Group Removed for Subsetted Models

# MODEL SUMMARY — LINEAR REGRESSION

## 20 Model Summary of HIE Significance by 2 Performance Measures

Group - Target	All - HIE				BSG 12 - HIE				BSG 34 - HIE				BSG 56 - HIE				BSG 78 - HIE			
No. of Obs.	3,640				1,329				1,308				623				380			
Mean Ln Net Pat Rev / Bed	13.79				13.63				13.77				13.89				14.21			
Variables	Coeff.	p-Val.	Sig.	k=10 CV Err.	Coeff.	p-Val.	Sig.	k=10 CV Err.	Coeff.	p-Val.	Sig.	k=10 CV Err.	Coeff.	p-Val.	Sig.	k=10 CV Err.	Coeff.	p-Val.	Sig.	k=10 CV Err.
<b>Ln Net Pat Rev / Bed Size</b>																				
<b>HIE Only</b>	0.37	5.4E-54	***	0.45	0.36	2.5E-15	***	0.65	0.32	6.1E-19	***	0.37	0.26	5.7E-11	***	0.19	0.21	1.4E-03	**	0.22
<b>HIE + Other Variables</b>	<b>0.13</b>	<b>2.2E-07</b>	<b>***</b>	<b>0.36</b>	<b>0.13</b>	<b>2.4E-03</b>	<b>**</b>	<b>0.50</b>	<b>0.14</b>	<b>3.3E-04</b>	<b>***</b>	<b>0.32</b>	<b>0.08</b>	<b>6.9E-02</b>	<b>◇</b>	<b>0.17</b>	<b>-0.09</b>	<b>1.8E-01</b>		<b>0.15</b>
<b>Top 3 Variables by Sig</b>	<i>Rural(-), TotOutpatientVis, TechScore</i>				<i>TotOutpatientVis, EMRAM_Stage, TechScore</i>				<i>TotOutpatientVis, TechScore, HIE</i>				<i>TotOutpatientVis, PercentDr, TechScore</i>				<i>TotOutpatientVis, HealthSystem, Member_COTH</i>			

Group - Target	All - HIE				BSG 12 - HIE				BSG 34 - HIE				BSG 56 - HIE				BSG 78 - HIE			
No. of Obs.	2,736				591				1,144				622				379			
Mean Overall Star Rating	3.52				3.96				3.40				3.34				3.47			
Variables	Coeff.	p-Val.	Sig.	k=10 CV Err.	Coeff.	p-Val.	Sig.	k=10 CV Err.	Coeff.	p-Val.	Sig.	k=10 CV Err.	Coeff.	p-Val.	Sig.	k=10 CV Err.	Coeff.	p-Val.	Sig.	k=10 CV Err.
<b>Overall Star Rating</b>																				
<b>HIE Only</b>	0.19	7.5E-08	***	0.69	0.01	8.2E-01		0.55	0.23	1.1E-05	***	0.70	0.33	3.1E-06	***	0.63	0.25	2.0E-02	*	0.60
<b>HIE + Other Variables</b>	<b>0.02</b>	<b>6.1E-01</b>		<b>0.61</b>	<b>-0.03</b>	<b>6.9E-01</b>		<b>0.55</b>	<b>0.07</b>	<b>2.6E-01</b>		<b>0.66</b>	<b>0.06</b>	<b>4.9E-01</b>		<b>0.60</b>	<b>0.08</b>	<b>5.2E-01</b>		<b>0.53</b>
<b>Top 3 Variables by Sig</b>	<i>BedSizeGrp:B,C,D(-), EMRAM_Stage, ForProf(-)</i>				<i>Top100City, TotOutpatientVis(-), ForProf(-)</i>				<i>EMRAM_Stage, Top100City(-), Rural</i>				<i>ForProf(-), EMRAM_Stage, Church</i>				<i>TotOutpatientVis, TechScore, HealthSystem</i>			

### Notes

\*\*\* significant at the 0.001 level

\*\* significant at the 0.01 level

\* significant at the 0.05 level

◇ significant at the 0.1 level

# KEY FINDINGS

## Profitability: Net Patient Revenue / No. Beds Set Up and Staffed

- Having an HIE was significant to profitability overall.
- When HIE was competing with other variables for significance, it remained significant in all but the largest hospital sizes (bed size group 7 & 8).
- While we adjusted net patient revenue for hospital size the average profitability increased as the bed size group increased.
- The other top variables affecting profitability are total outpatient visits and other technology variables such as tech score and EMRAM stage. HIE was in the top 3 significant variables in the subset for bed size group 3 & 4.
- Technology factors are positively associated to profitability. However, it is difficult to determine which is driving the other.

## Patients' Perspective: Overall Hospital Star Rating

- 25% of the data was removed due to having missing values for overall hospital star rating. 81% of the missing values were from hospitals in bed size group 1 & 2. Smaller hospitals therefore seem to have a more difficult time in obtaining patient surveys.
- HIE was not a significant factor in determining a patients' overall hospital star rating.
- Technology factors such as EMRAM stage or tech score were in the top 3 variables in 4 out of 5 models.