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AHA / HIMSS RESEARCH PROJECT

Health Analytics Class

– Executive Summary –

Project Goals

The goal for this project based on the topic was to examine hospitals in regard to whether or not they had a Healthcare Information Exchange (HIE) installed. The two questions asked were, "What hospital factors are associated with having an HIE installed?" and "Is having an HIE installed linked to better performance?" In order to answer these questions, five data sets were available which will be discussed in the next section.

Data Set Used

The five data sets used were from the Healthcare Information and Management Systems Society (HIMSS) and the American Hospital Association (AHA). The HIMSS data had four sets including one each for demographics, technology, HIE, and hospital consumer assessment of healthcare providers and systems (HCAHPS). The AHA data was based on an annual survey the organization conducts, and specific variables of interest needed to be pulled. Some of these data sets were very large. For example, the technology data set had 1,048,575 records with 19 variables and the HCAHPS data set had 260,361 records with 28 variables. All of the HIMSS data was pulled last year for 2018 only. The AHA data spanned the years 2010 to 2017. The HIE data did not include information regarding date and only listed whether a hospital had an HIE installed in 2018. Therefore, this study was restricted to covering the year 2018 only. The five data sets needed to carefully be cleaned and combined to in order to establish one overall data set that could be used for the study.

Techniques and Software

The original data sets were individually cleaned using Excel and R. Then the merging of the data, cleaning, exploration, and modeling was done in R.

Once the initial data set was assembled, various exploratory data analysis was performed including reviewing summary statistics, univariate and bivariate plots, missing values analysis, and correlation and significance testing. As a result of the exploratory analysis, it was decided that the study would focus on general medical and surgical hospitals only. Additionally, the data would be analyzed first including all hospital sizes, but then also subsetted by the size of the hospital. This was important so that it could be determined if hospital factors important to having an HIE varied by hospital size.

First, an overall block model was developed for the two research questions. In order to answer research question one, logistic regression models were built with independent variables in blocks including: type of hospital; location; accreditation / member; size; type of services / staff; and technology. The dependent variable in the logistic regression model was whether or not a hospital had an HIE installed (0 – not installed / 1 – installed). For research question two, linear regression models were built using the same blocks and including HIE as an independent variable. The dependent variables used for the linear regressions to evaluate hospital performance was a profitability measure (net patient revenue / number of beds set up and staffed) and the hospital overall star rating evaluated by patients. The linear regression models were run separately for each of the two dependent variables. Additionally, as mentioned above, the models were run on the overall general medical and surgical hospitals as well as subsets divided by size, five data sets total.

Key Findings

Many important insights were gained from this study. A few of the most important ones will be highlighted here, while the full set will be presented in the body.

Research Question 1: ***What hospital factors are associated with having an HIE installed?***

One of the most interesting findings was regarding for-profit hospitals. One might assume that for-profit hospitals make more money and therefore might spend some of this on installing HIE systems. However, the study found that for-profit hospitals are less likely to have an HIE installed. Overall, there is an 87% decrease in the odds that for-profit hospitals have an HIE. This decrease gradually grows as hospital size increases; ranging from 82% – 92%. Another interesting finding was government hospitals have a decrease in odds of 33% of having an HIE. However, this decrease is associated with smaller hospitals and the negative correlation becomes neutral in larger hospitals. Location also plays a key role in whether or not a hospital has an HIE. Overall, if a hospital is in a rural locale the odds are 18% less likely that it will have an HIE.

One of the independent variables created in the technology block was a high-tech score based on seven technologies in the HIMSS technology data set. The tech score that was created was a significant variable in every model. In the overall model, having a one 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 are likely to be investing in HIE as well.

Research Question 2: ***Is having an HIE installed linked to better hospital performance?***

Using the profitability measure (natural log of net patient revenue / number of beds set up and staffed) as the dependent variable, it was found that having an HIE was significant to profitability overall. When HIE was competing with other independent variables for significance, it remained significant in all but the largest hospital sizes. It is important to note that the HIE coefficient in the linear regression model is small, only 0.13. HIE is a binary variable, 0 or 1. Therefore, having an HIE installed only increases profitability by $0.35 in revenue per bed. (The 0.13 coefficient is for the natural log of the dependent variable and has been transformed back for the $0.35 figure.)

Using the performance measure of patients' hospital overall star rating as the dependent variable, HIE was not found to be a significant factor in determining a patients' overall hospital star rating. This was true overall as well as for any hospital size. It is important to note that 25% of the data was removed due to having missing values for hospital overall 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.

– INTRODUCTION AND RESEARCH QUESTIONS –

As mentioned in the executive summary, this project focuses on examining hospitals in regards to whether or not they had a Healthcare Information Exchange (HIE) installed. A two-fold research question was developed. The first part of this study looks to answer the research question: *What hospital factors are associated with having an HIE installed?* Then the second part of this study looks to answer the research question: *Is having an HIE installed linked to better performance?*

– DATA PREPARATION –

Five data sets were used from the Healthcare Information and Management Systems Society (HIMSS) and the American Hospital Association (AHA). The executive summary provided a brief overview of the data. However, in this section data preparation and merging will be covered in more detail as it was an integral step in the project.

There were five data sets involved in this study. The four data sets in the HIMSS group were: demographic data - 5,494 records with 35 variables; technology data - 1,048,575 records with 19 variables; HIE data - 6,491 records with 10 variables; and the hospital consumer assessment of healthcare providers and systems (HCAHPS) data – 260,361 records with 29 variables. Specific data from the AHA database was requested, and Professor Chandrasekaran extracted it. There were 50,264 records with 86 variables from this data pull ranging from 2010 to 2017. The HIE data from the HIMSS data set was only from 2018, and therefore the study was restricted to this single time period.

Overall, there were six major steps in preparing this data into one initial data set that could be worked with. In step one, the AHA 2017 and HIMSS demographic data was merged by matching hospitals based on CMS Medicare Provider ID. There were 4,160 hospitals in the matched data with a combined 121 variables. In step two, the 121 combined demographic variables were examined and reduced to 38 variables. Next, in step three, the HIE data was cleaned into binary data. The hospitals were coded as 1 if they had any type of HIE installed (i.e. vendor, state level HIE, etc.) and 0 if they were only planning an HIE but did not have one installed. (Once all the data sets were merged any hospital that had a missing value for HIE would also be coded as 0, since they neither had an HIE installed, nor were planning one.) In step four, the HIMSS technology data was cleaned and used to make a technology score variable for the hospitals. (The specifics of creating the technology score will be discussed in the next paragraph.) For step five, the HCAHPS data was cleaned and reviewed in order to select performance variables. There were 76 performance measures to choose from. I narrowed this list down to eight for further review and conducted a correlation analysis. From this, it was found that most of the eight measures were highly correlated and hospital overall star rating was selected as the final metric. A list of all 76 performance measures, the top eight, and the correlation analysis can be found in the figures A1 and A3 in the appendix. The final step, six, was to merge all of the separate data files so that there would be one data set.

Because the technology store was created it is necessary to elaborate on that process. The HIMSS technology data was cleaned to obtain a list of the installed technologies in the hospitals. There were 55 technology types installed. A list of these technologies is included in figure A2 on page 19 in the appendix. Two large groups of technologies were "devices" and "PACS." It was decided not to include devices, because they were too connected to specific procedures and they did not seem relevant to having an HIE. For example, one device listed was a spirometer, which is a device that measures peak air flow. PACS stands for picture archiving and communications systems and are used to digitally transmit electronic images and reports. PACS were also not included because they were also devices, such as PACS – Card – Intravascular Ultrasound, and additionally because they were too related to HIE. Rather, I wanted to create a broad high-tech score that represented many aspects of hospital technology. From figure A2, one can see that some technologies such as barcoding are almost universally used (97%) while others such as RFID are rarely used (12%). The seven technologies that were included are listed in the table below and were from the general categories: clinical decision making and intelligence; other medical technology; mobile and security; and capturing streaming medical data.

Figure 1: 7 Technology Types Selected to Create the 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%

Each hospital was given a 1 if they had the technology installed and a 0 if they did not. The sum total number of technologies installed determined the technology score. Therefore, the score ranged from 0 to 7. The distribution of the technology score variable was checked after it was created. The scores were distributed between high and low, and while not normally distributed, was approximately so. The histogram of the technology score can be seen in figure A4 on page 20 in the appendix.

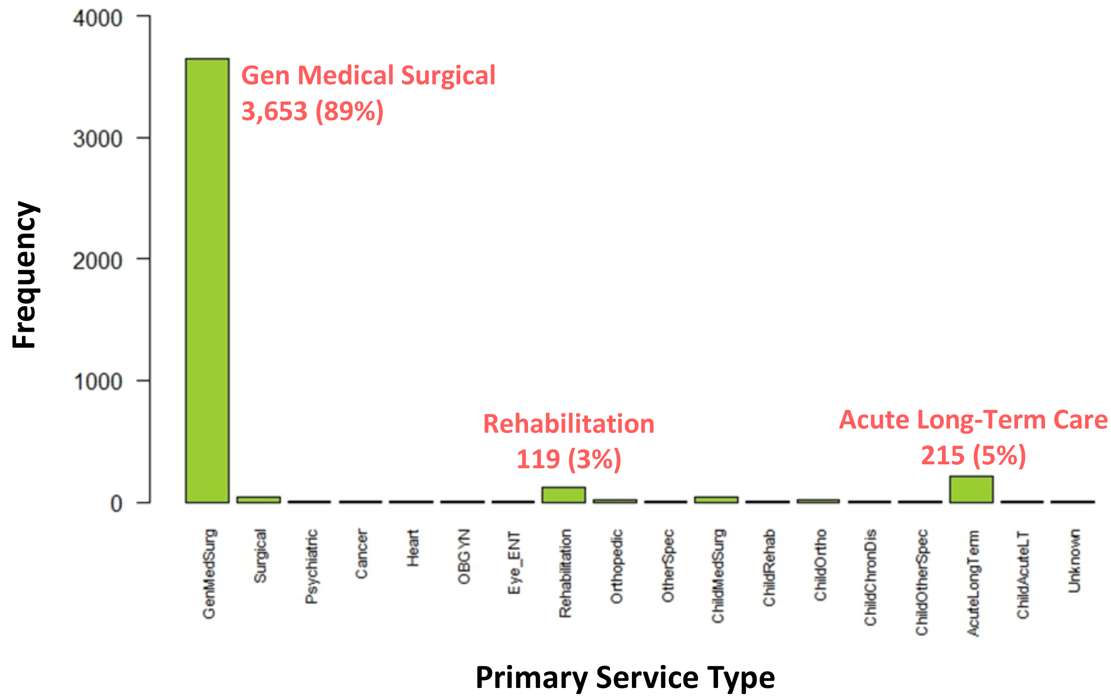
– Data Cleaning and Exploration –

After the initial data set was created, an exploratory analysis was conducted. First, the distribution of the hospital primary service was plotted, and is pictured in figure 2 on the next page. As one can see most of the hospitals are in the general medical and surgical category (89%). Since the distribution of this variable was not good and because I wanted to keep the comparison of hospitals to similar types, the hospitals were filtered to keep only general medical and surgical hospitals. The total number of general medical and surgical hospitals was 3,653. The base rate for HIE was checked before and after the filtering. It remained relatively the same, 63.46% before and 65.43% after.

Next, a missing values analysis found that 74% of the cases had missing values. This missing values table is listed in figure A5 on page 21 in the appendix. The three main categories of missing values were patient representative services (20%), type and level of emergency care (20-21%), and overall hospital star rating (25%). These missing values would be taken into account when selecting final variables for the block model.

At this point the data was further cleaned, recoded, and transformed. The variables *AccredJC* (hospitals accredited by the Joint Commission) and *MemCOTH* (hospitals that are a member of the Council of Teaching Hospitals and Health Systems signifying an academic hospital) were recoded from 1/2 (1=yes, 2=no) to 0/1 (1=yes, 0=no). The variables *HeathSystem* (hospitals part of a network) and *Top100Cities* (hospitals located in the top 100 cities) were recoded as 0/1 (1=multi, 0=single), (1=top100, 0=notTop100), respectively. The variables *ControlCode* and *CBSAType* were nominal variables and therefore were converted to dummy variables. *ControlCode* became four binary variables, *Church*, *Government*, *ForProfit*, *NonProfit*, (1= if the hospital was controlled by that type, 0= if not). *CBSAType* became three binary variables, *Metro*, *Micro*, *Rural* (1= if the hospital was of that locale, 0= if not of that

Figure 2: Histogram of Hospital Primary Service Type



locale). The missing values for the emergency department variable, *EmergencyDept*, were filled in based on the variable for the number of emergency room visits, *EmergencyRoomVis*. If a hospital had any emergency room visits, it was assumed that they had an emergency room.

Finally, three variables were calculated and transformed. Using the raw number of full-time doctors and nurses as independent variables would be affected by hospital size (i.e. larger hospitals have more full-time doctors and nurses). In order to adjust for this, the full-time doctors and nurses variable was divided by the full-time total personnel. These variables would then test how hospitals employing more doctors or nurses in comparison to total personnel would affect the dependent variables. For research question two the dependent variables for hospital performance needed to be selected. As mentioned in the "Initial Data Preparation" section, one measure selected was hospital overall star rating. I also wanted to select a variable to measure profitability. For this the net patient revenue variable was divided by the number of beds set up and staffed variable in order to adjust for hospital size. Thus, this variable would measure profitability in terms of net patient revenue per bed. Finally, we took the natural log of this variable so that it would be more normally distributed, since this would be used as a dependent variable in a linear regression model. The distribution of both these performance measure variables are pictured in figures A6 and A7 on page 22 in the appendix. Additionally, after the presentation on May 6th, Professor Chandrasekaran, asked that the *EMRAM_Stage* variable be treated as a categorical variable for a model requested by the Professor. A description of the EMRAM stage score calculated by HIMSS is listed in figure A8 on page 23 in the appendix. I examined this variable further and it was not distributed well. The table, figure 3, on the next page lists the number of observations per stage. As one can see, 58% of the 3,653 general medical and surgical hospitals have an EMRAM stage of 0; 41% have an EMRAM stage of 6 or 7 with the vast majority having a stage of 6. Stages 2, 3, and 5 had no observations. Therefore, EMRAM stage was converted into a binary variable:

stages 0, 1, and 4 were coded as 0; stages 6 and 7 were coded as 1. The binary variable could be interpreted as 0 for a low EMRAM stage and 1 as a high level.

Figure 3: Table of Original EMRAM Stage Distribution

EMRAM Stage	0	1	2	3	4	5	6	7
No. of Observations	2,129	6	0	0	1	0	1,339	178

Summary statistics comparing hospitals that had an HIE installed versus those that did not were examines to get a general grasp of the difference between groups. Many of the independent variables in this study are binary variables so cross-tabulations comparing the groups were studied in R. These were not put into the May 6th presentation, as they were mainly used to “eye-ball” the differences. For the six continuous and ordinal variables, a mean comparison chart has been added in figure A9 on page 24 in the appendix. One can see that the hospitals without an HIE have lower means for bed size group, total outpatient visits, percent Dr., tech score, and EMRAM stage (the ordinal variable before the recoding, described above, was used to get a sense of the general difference). The percent nurse mean, however, was slightly higher for the group of hospitals that did not have an HIE.

Another part of the exploratory analysis that was conducted was plotting univariate and bivariate graphs and charts comparing the groups of hospitals with and without an HIE. A few of the more interesting graphs from the exploration will be discussed. By examining distributions of independent variables, I was able to quickly identify variables that could be dropped. For example, on page 25 in the appendix figures A11 and A12, histograms for the variables *ControlType* and *EmergencyDept,* are pictured. From this, one can see *EmergencyDept* can be dropped since almost all hospitals have an emergency department, while *ControlType* was a good candidate to convert into dummy variables, as was done in this study. Examining the variables *CBSAType* and *BedSizeGrp* led to some interesting discoveries. First, I compared the percentage of hospitals that had an HIE by bed size group. This table is labeled figure A10 and is on page 24 in the appendix. The translation of the number of beds per bed size groups 1 through 8 is listed in that table as well. The percentage of hospitals who have an HIE steadily increases from 56% to 86% moving from bed size group 1 to 8. The histogram for *CBSAType* and the kernel density plot of *CBSAType* by *BedSizeGrp* are pictured in figures A13 and A14 on page 26 in the appendix. Over half of the hospitals are in a metro area. Additionally, only metro hospitals have many larger bed size groups; while micro and rural hospitals peak at a smaller bed size group of 2.

Next, a correlation and significance test analysis were performed. Any independent variables that were highly correlated at a 0.70 level or above were dropped. We dropped the following variables because they were highly correlated to hospital size: *Admissions*, *AdjAdmiss, FTRegNurse, OpExpense, AdjPatientDays, TotalEmployees , NetPatientRev, TotalnpatientRev, FTPersTot, FTHospPersTot, EmergencyRoomVis*. Some of the variables had already been dropped for logical reasons such as being too closely related to another variable or having too many missing values and therefore are not included in the table. The idea of subsetting the data by either *BedSizeGrp* or *CBSAType* was considered due to the findings mentioned in the previous paragraph. Four 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. Three subsets were created for CBSA type: metro; micro; and rural. I explored both methods of subsetting with a correlation analysis and decided that subsetting by the binned bed size group unmasked more HIE variation by subgroup. Significance testing was added to the correlations and the table pictured on the next page labeled figure 4 was produced.

Figure 4: Correlation with Significance Testing – All and Subsetted by Bed Size Group

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

Notes

** significant at the 0.001 level

* significant at the 0.01 level

° significant at the 0.05 level

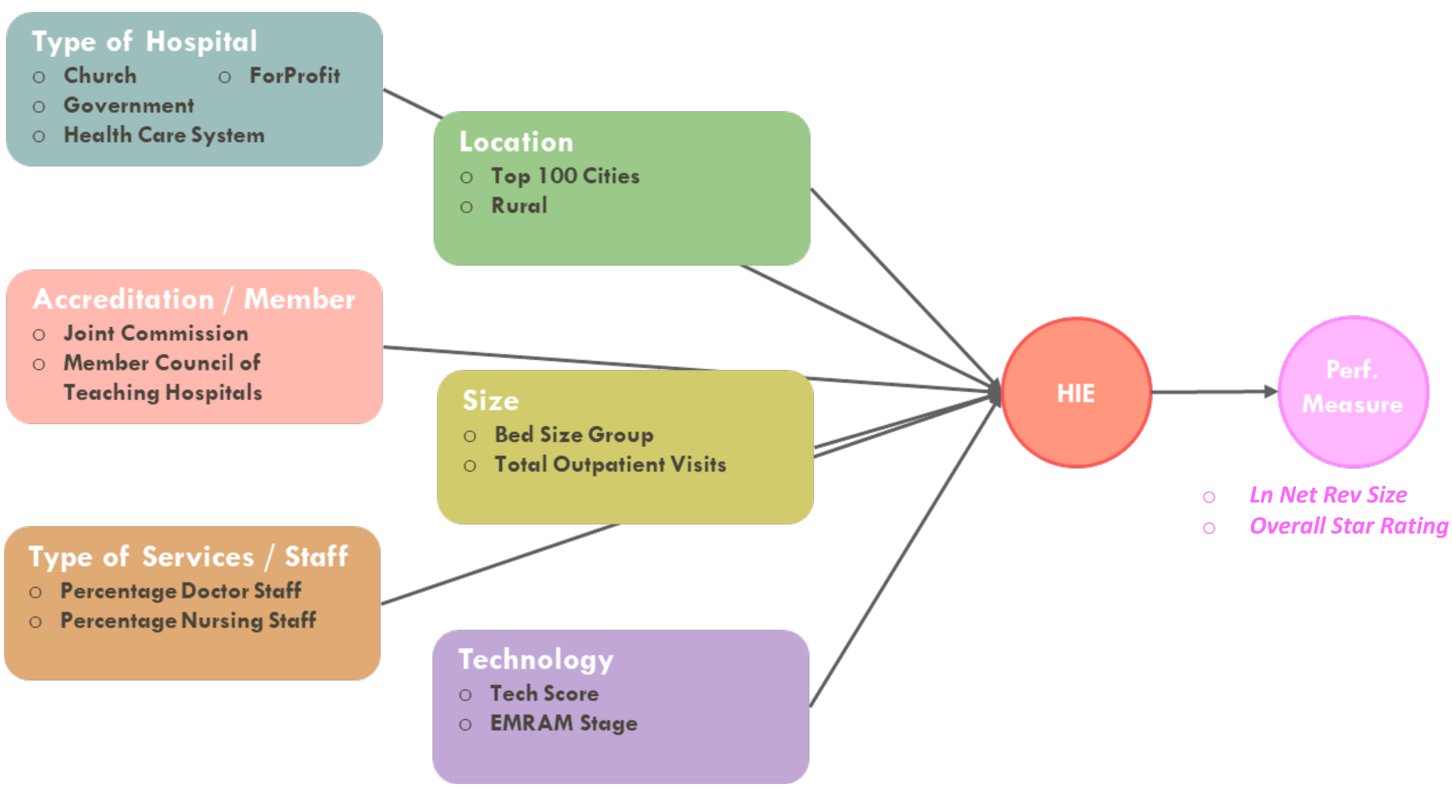
● 5 or fewer cases in a binary group

The most significant variables for the entire set, as well as each of the subsets can easily be seen from looking at it. One can clearly see examples of correlations that remain constant with subetting such as *TechScore* and *EMRAM_Stage.* However, variables such as *Government* and *HealthSystem* change across the total group and by binned bed size group. These variables are all highlighted in red in the table. Therefore, subsetting by binned bed size group is a good option. Additionally, the table shows variables that have too few cases to be included in the model in some of the subsets, such as *Rural* in subsets bed size group 5 & 6 and 7 & 8.

– Modeling Techniques and Results –

To begin, an overall block model was developed that encompassed both research questions. This is pictured in figure 5 below. Independent variables were selected under the blocks: type of hospital; location; accreditation / member; size; type of services / staff; and technology. Bed size group was treated as a categorical variable in the overall model, and binned by the same groups as the subsets (1&2= BedSizeGrpA, 3&4= BedSizeGrpB, 5&6= BedSizeGrpC, 7&8= BedSizeGrpD). In the models for each subset, this variable was dropped. Note that NonProfit and BedSizeGrpA were the base variables that were compared against (the dropped variables in the dummy drop 1 scheme).

Figure 5: Overall Conceptual Block Model



The next step was to run the block model for the overall data set as well as the four subsets. The modeling and results will be presented by research question.

Research Question 1: ***What hospital factors are associated with having an HIE installed?***

The method used to build the models was splitting the data using 80% training data and 20% test data. Having test data was very important to ensure that the model was performing well enough to use the coefficients for analysis. For example, if a model has a test AUC value of 0.5 it is no better than guessing and should not be used for interpretation. A test AUC value lower than .5 would mean the model is performing worse than randomly guessing and should be discarded. The models were first run using a logistic regression with the overall block model to see what variables were presenting as significant. Then the models were rerun using only the significant variables, dropping the insignificant variables. After all, why would one include and interpret variables that the model was showing to be insignificant. Only keeping the significant variables in the final model produced better test AUC. For these reasons, this method was used to select the final models to be interpreted for key findings. After the presentation on May 6th, Professor Chandrasekaran asked that I include one additional model on the overall data set that kept all the variables and treated EMRAM stage as a categorical variable. As discussed in the data preparation section this was converted into a binary variable due to its poor distribution. He also requested for this model that the data not be split into training and test data. The final models are pictured in figure 6 on page 11, starting with the Professor's requested model, followed by the final selected models. (Also, for the Professors requested model, a model print out including standard error and p-values is included in figure 16 on page 28 in the appendix.)

Additionally, a five model summary of the selected models were composed into one table. This is pictured in figure 7 on page 12. The table header summarizes the total number of hospitals in each group as well as the test AUC. The table portion shows the model coefficients as well as the code for their significance level. The final selected models only kept those variables presenting as significant. This table allows us to easily compare the coefficients across the subsets to compare the changes. For example, the *HealthSystem* variable was significant in the overall model, but looking at the subsets it only affected whether a hospital had an HIE in smaller hospital sizes (bed size groups 1&2, 3&4). A full interpretation of the models in answering the research question will be presented in the "Key Findings" section.

The test ROC graphs for the final selected model are in the appendix in figure A15 on page 27. The test AUC for the models were as follow: all – 0.823; bed size group 1&2 – 0.763; bed size group 3&4 – 0.776; bed size group 5&6 – 0.815; and bed size group 7&8 – 0.648. For all groups this is high, only dipping for the largest bed size groups. Therefore, we can be comfortable using these models for interpretation.

Research Question 2: ***Is having an HIE installed linked to better hospital performance?***

For research question two, in order to test if HIE was linked to better hospital performance linear regression modeling was used. There were two methods employed. First, a simple linear regression with HIE as the independent variable and the performance measures of natural log of net patient revenue / beds set up and staffed and hospital overall star rating. The second method was a linear regression with all of the independent variables used in research question one plus HIE, as the independent variables, and the performance measures as the dependent variables. As with the logistic regression models bed size group was treated as a categorical variable in the overall model, and binned by the same groups as the subsets (1&2= BedSizeGrpA, 3&4= BedSizeGrpB, 5&6= BedSizeGrpC, 7&8= BedSizeGrpD). In the models for each subset, this variable was dropped.

Figure 6: Final Models (Logistic Regression)

Model - All Bed Size Groups

all variables kept & EMRAM Stage converted to binary model requested by Professor Chandrasekaran

Variable	Coefficients	Odds Ratio	% INCR/DECR in Odds
(Intercept)	-0.32	0.73	-27%
Government	-0.36	0.70	-30%
ForProf	-2.15	0.12	-88%
Church	0.10	1.11	11%
HealthSystem	0.77	2.15	115%
Top100Cities	0.24	1.27	27%
Rural	-0.17	1.00	0%
Accred_JC	-0.24	0.78	-22%
Member_COTH	0.40	1.49	49%
BedSizeGrpB	0.01	1.01	1%
BedSizeGrpC	-0.08	0.92	-8%
BedSizeGrpD	-0.16	0.85	-15%
TotOutpatientVis↑	9.85E-07	1.00	0%
PercentDr	0.02	1.03	3%
PercentNurse	-0.01	0.99	-1%
TechScore	0.42	1.52	52%
EMRAM_Binary	0.66	1.94	94%

Model - All Bed Size Groups

Variable	Coefficients	Odds Ratio	% INCR/DECR in Odds
(Intercept)	-0.03	0.97	-3%
Government	-0.39	0.67	-33%
ForProf	-2.07	0.13	-87%
HealthSystem	0.80	2.22	122%
Rural	-0.20	0.82	-18%
Accred_JC	-0.30	0.74	-26%
TotOutpatientVis↑	1.08E-06	1.01	1%
PercentNurse	-0.02	0.98	-2%
TechScore	0.41	1.50	50%
EMRAM_Stage	0.11	1.11	11%

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

Model - Bed Size Group 1 or 2

Variable	Coefficients	Odds Ratio	%INCR/DECR in Odds
(Intercept)	-0.26	0.77	-
ForProf	-1.77	0.17	-83%
HealthSystem	1.07	2.92	192%
TotOutpatientVis↑	3.44E-06	1.04	4%
PercentNurse	-0.02	0.98	-2%
TechScore	0.29	1.33	33%
EMRAM_Stage	0.14	1.15	15%

Model - Bed Size Group 3 or 4

Variable	Coefficients	Odds Ratio	%INCR/DECR in Odds
(Intercept)	-0.67	0.51	-
Government	-0.40	0.67	-33%
ForProf	-2.09	0.12	-88%
HealthSystem	0.75	2.12	112%
TotOutpatientVis↑	1.59E-06	1.02	2%
Accred_JC	-0.48	0.62	-38%
TechScore	0.51	1.66	66%
EMRAM_Stage	0.11	1.12	12%

Model - Bed Size Group 5 or 6

Variable	Coefficients	Odds Ratio	%INCR/DECR in Odds
(Intercept)	-0.23	0.80	-
ForProf	-2.41	0.09	-91%
Church	0.92	2.51	151%
TechScore	0.46	1.58	58%
EMRAM_Stage	0.12	1.13	13%

Model - Bed Size Group 7 or 8

Variable	Coefficients	Odds Ratio	%INCR/DECR in Odds
(Intercept)	0.18	1.20	-
ForProf	-2.52	0.08	-92%
TotOutpatientVis↑	2.05E-06	1.02	2%
TechScore	0.31	1.37	37%

Figure 7: 5 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.
Type of Hospital										
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	***				
Location										
Rural	-0.20	◊								
Accreditation / Member										
Accred_JC	-0.30	**			-0.48	*				
Size										
TotOutpatientVis	1.08E-06	***	3.44E-06	*	1.59E-06	*			2.05E-06	**
Type of Services / Staff										
PercentNurse	-0.02	*	-0.02	*						
Technology										
TechScore	0.41	***	0.29	***	0.51	***	0.46	***	0.31	**
EMRAM_Stage	0.11	***	0.14	***	0.11	***	0.12	**		

Notes

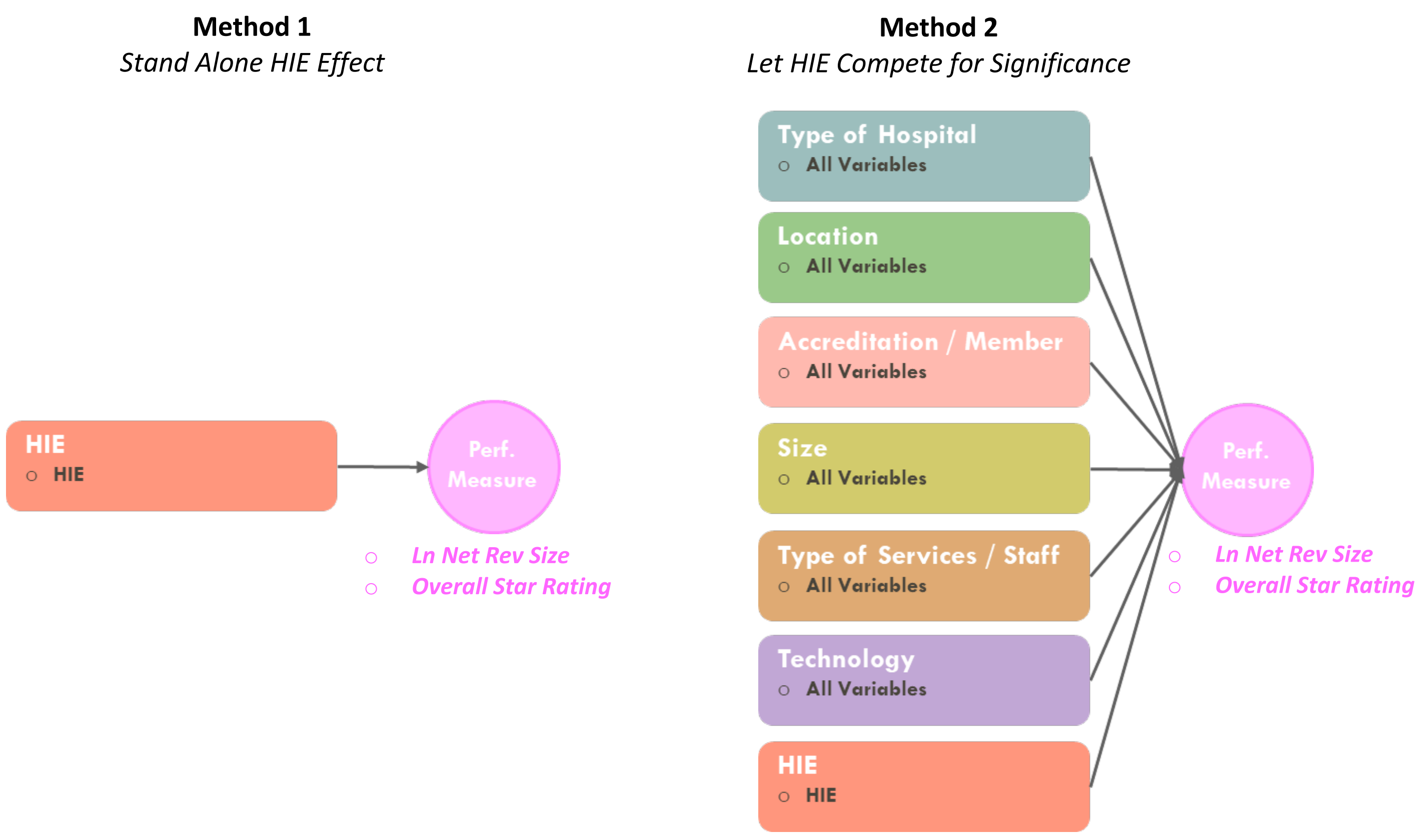
*** significant at the 0.001 level

** significant at the 0.01 level

* significant at the 0.05 level

◊ significant at the 0.1 level

Figure 8: Adapted Block Models for Method 1 and Method 2



Method two forced the HIE variable to compete for significance with the other variables. Linear regression modeling was chosen over t-tests for this reason. These two methods are visualized in the adapted block models in figure 8 above.

Since these were linear regression models, cross-validated error was used. Therefore, the data did not need to be split into train and test data. A 20 model summary table to encapsulate the models was constructed and is on page 14 in figure 9. This table allows easy comparisons of the difference in the HIE variable coefficient and significance using both methods, described above, as well as both performance metrics. In the header section of this table, the total number of hospitals as well as the mean performance metric is summarized by group. In the table portion, the model coefficients for HIE, the p-value for the significance of the coefficient, and the significance level are listed. Additionally, for the models run using method two, the top three significant independent variables in the model are listed highest significance to lowest. A (-) is listed after the variable if it was negatively correlated to the performance metric. One finding that can clearly be seen by studying the chart is that while HIE is significant in the simple linear regression with overall hospital star rating as the performance metric, it loses significance when forced to compete with the other independent variables. Therefore, having an HIE installed does not lead to increased hospital overall star ratings. A full interpretation of the models in answering the research question will be presented in the “Key Findings” section. (Also, two model print outs of the multiple regression using all bed size groups including the standard error and p-values is included in figure 16 on page 28 in the appendix as examples.)

Figure 9: 20 Model Summary HIE Significance for 2 Performance Measures

Profitability

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 CVErr.	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.
Ln Net Pat Rev / Bed Size															
HIE Only	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
HIE + Other Variables	**0.13**	**2.2E-07 *****	**0.36**	**0.13**	**2.4E-03 ****	**0.50**	**0.14**	**3.3E-04 *****	**0.32**	**0.08**	**6.9E-02 ◊**	**0.17**	**-0.09**	**1.8E-01**	**0.15**
Top 3 Variables by Sig	*Rural(-), TotOutpatientVis, TechScore*			*TotOutpatientVis, EMRAM_Stage, TechScore*			*TotOutpatientVis, TechScore, HIE*			*TotOutpatientVis, PercentDr, TechScore*			*TotOutpatientVis, HealthSystem, Member_COTH*		

Overall Star Rating

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 CVErr.	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.
Overall Star Rating															
HIE Only	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
HIE + Other Variables	**0.02**	**6.1E-01**	**0.61**	**-0.03**	**6.9E-01**	**0.55**	**0.07**	**2.6E-01**	**0.66**	**0.06**	**4.9E-01**	**0.60**	**0.08**	**5.2E-01**	**0.53**
Top 3 Variables by Sig	*BedSizeGrp:B,C,D(-), EMRAM_Stage, ForProf(-)*			*Top100City, TotOutpatientVis(-), ForProf(-)*			*EMRAM_Stage, Top100City(-), Rural*			*ForProf(-), EMRAM_Stage, Church*			*TotOutpatientVis, TechScore, HealthSystem*		

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 –

Concluding the study, in this section, the key finding are presented. The modeling results as well as the exploratory analysis were examined to produce these points. They are organized by research question. For research question one, the findings are further subdivided by the block model categories. For research question two, the findings are subdivided by the two performance measures used.

Research Question 1: *What hospital factors are associated with having an HIE installed?*

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 locale 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.

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 subsetted 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 hospitals 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%.

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 hospital performance?

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).
- The HIE coefficient is small, only 0.13. Therefore, having an HIE installed only increases profitability by $0.35 net revenue per bed.
- 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.

– APPENDIX –

Figure A1: List of HCAHPS Performance Measures

-example of easily eliminated variables highlighted in pink
-top 8 variables for further review highlighted in yellow

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
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

HCAHPS Measure	No. Unique Orgs
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
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

Figure A2: Installed Technology 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%
CDSS: 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%
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

Figure A3: Correlation of Top 8 HCAPS Performance Measures

-final selected variable highlighted in yellow

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

Figure A4: Histogram of Technology Score

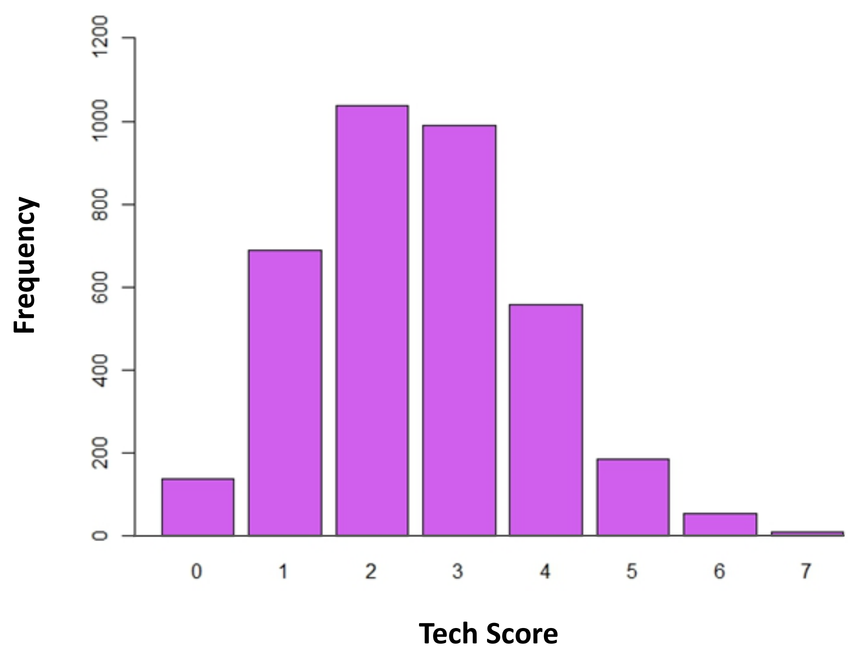


Figure A5: Missing Value Table

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%
PatientRepServ	**737**	**20%**
TotOutpatientVis	0	0%
EmergencyRoomVis	0	0%
EmergencyDept	**737**	**20%**
CertTrauma	**737**	**20%**
TraumaLevel	**766**	**21%**
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%
StarRate_Overall	**917**	**25%**
Total Cases	**2,688**	**74%**

-variables with highest percent of cases with missing values highlighted in pink

Figure A6: Kernal Density Plot of Ln (Net Patient Revenue / No. Beds Set Up and Staffed)

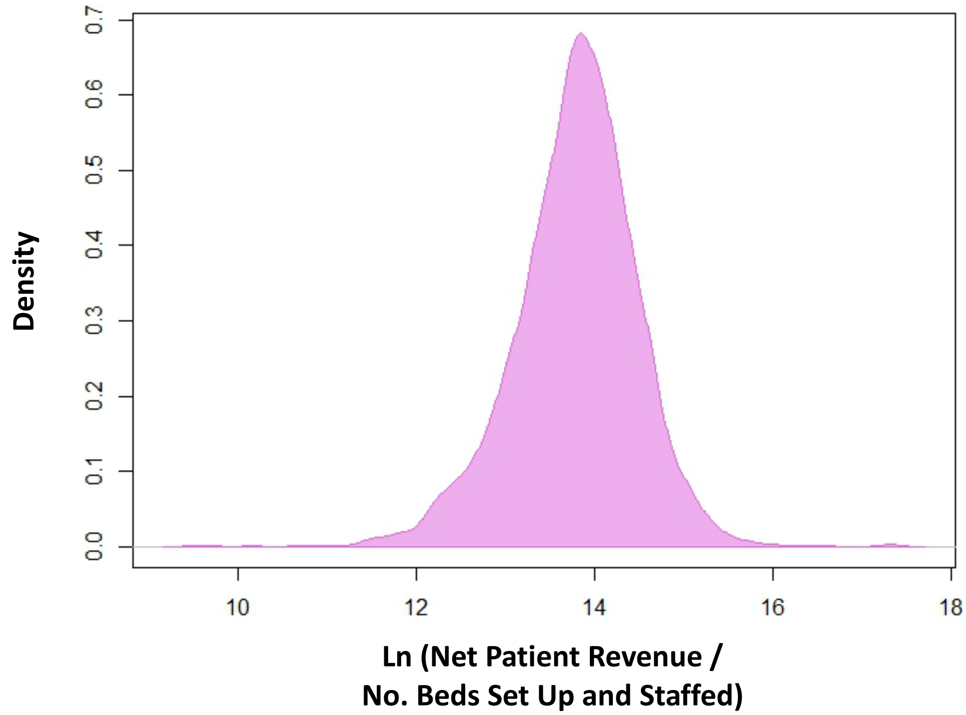


Figure A7: Histogram of Hospital Overall Star Rating

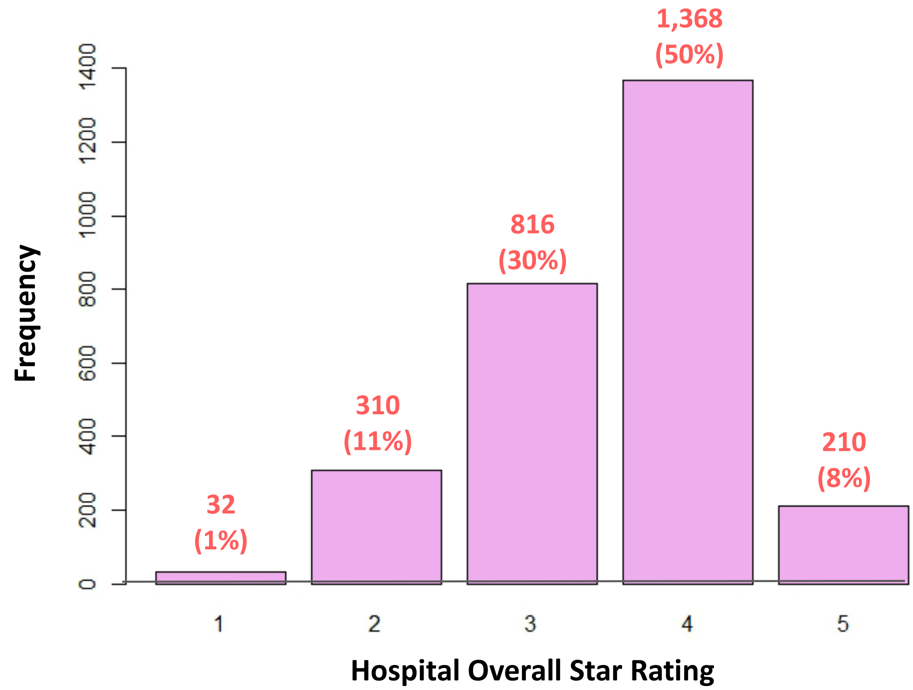


Figure A8: EMRAM Stage Description

“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.”

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

https://www.himssanalytics.org/emram

Figure A9: Mean Comparison Table for Ordinal and Continuous Variables Between Hospital with and without an HIE Installed

Name	Type	No HIE	Has HIE
		Mean	
Size			
BedSizeGroup	ordinal	3.16	3.83
TotOutpatientVis	contin.	95,965	207,808
Type of Services / Staff			
PercentDr	contin.	1.85	2.34
PercentNurse	contin.	29.68	28.96
Technology			
TechScore	ordinal	1.92	2.86
EMRAM_Stage	ordinal	1.42	3.14

**the original ordinal variable before the recoding was used to get a sense of the overall difference*

Figure A10: Table of Has HIE by Bed Size Group

Bed Group	HIE			
	No. of Hospitals			% Has 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%

Bed Size Group to # of Beds Conversion

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

Figure A11: Histogram of Hospital Control Type

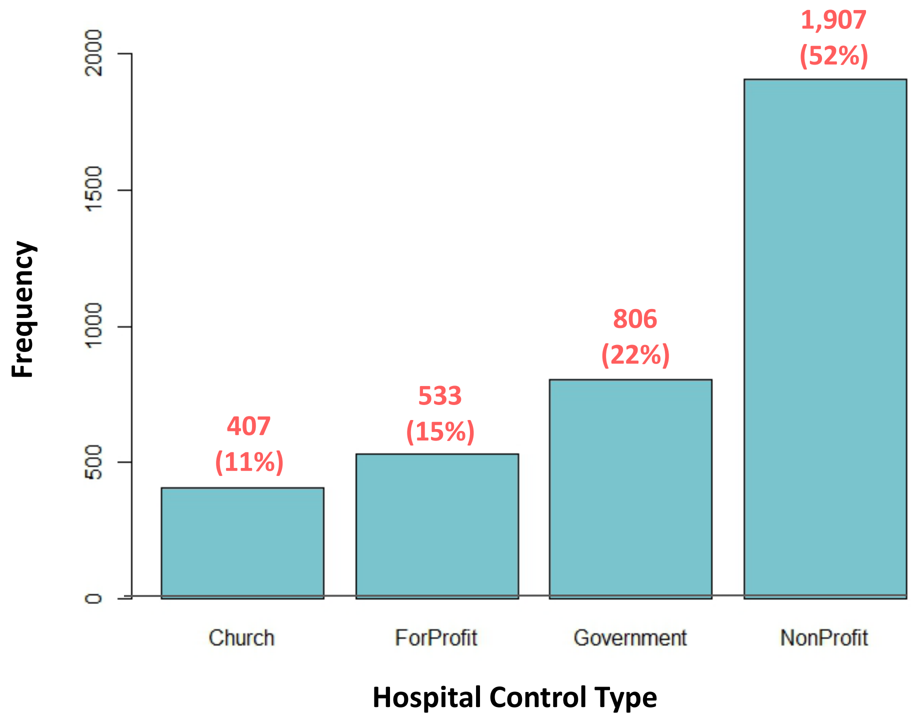


Figure A12: Histogram of Emergency Department

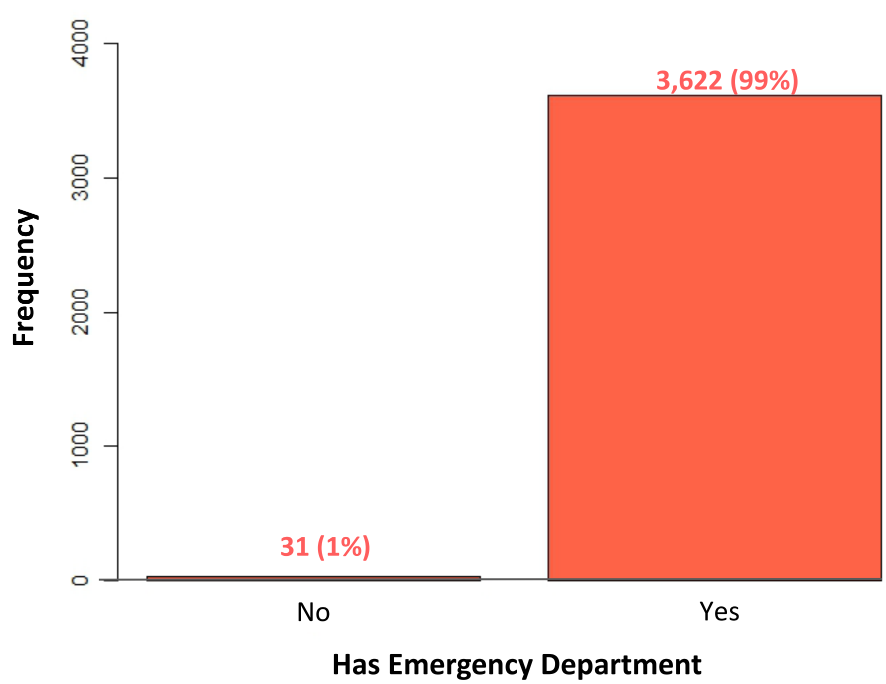


Figure A13: Histogram of CBSA Type
Metro / Micro / Rural

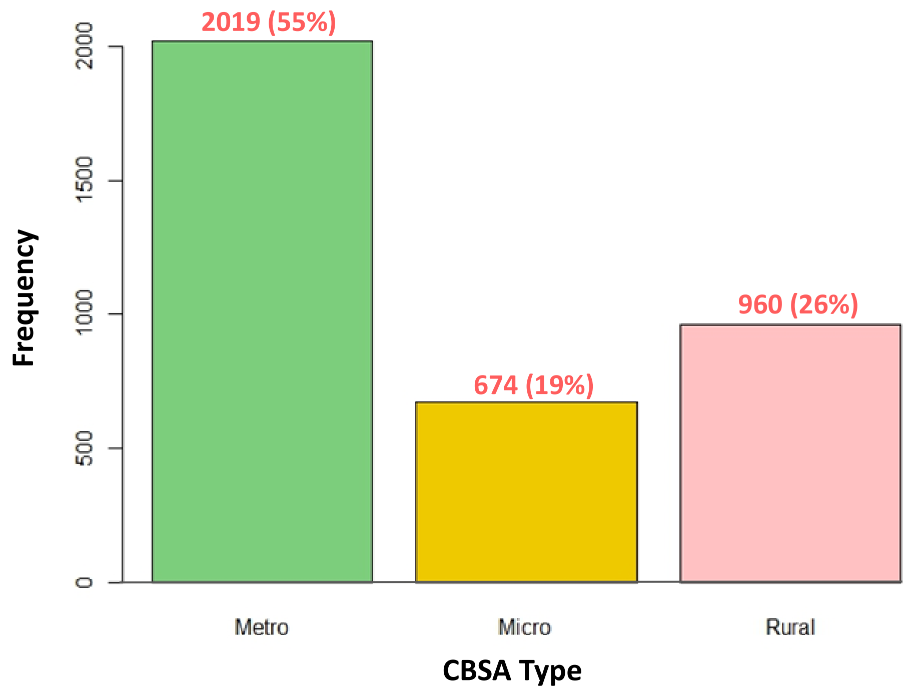


Figure A14: Kernal Density Plot of Bed Size Group by CBSA Type

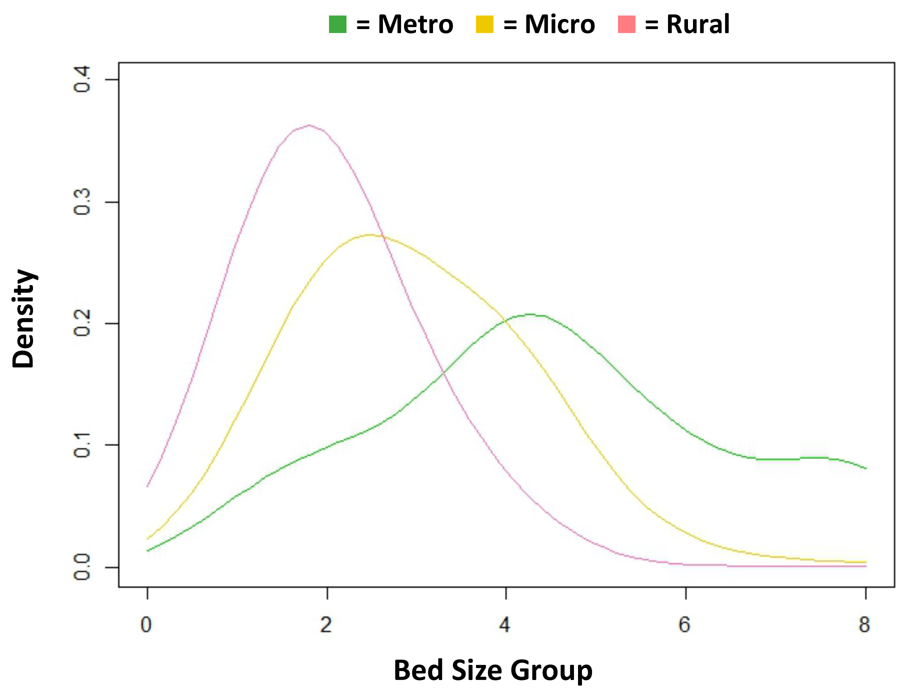


Figure A15: ROC Curves – Test Data

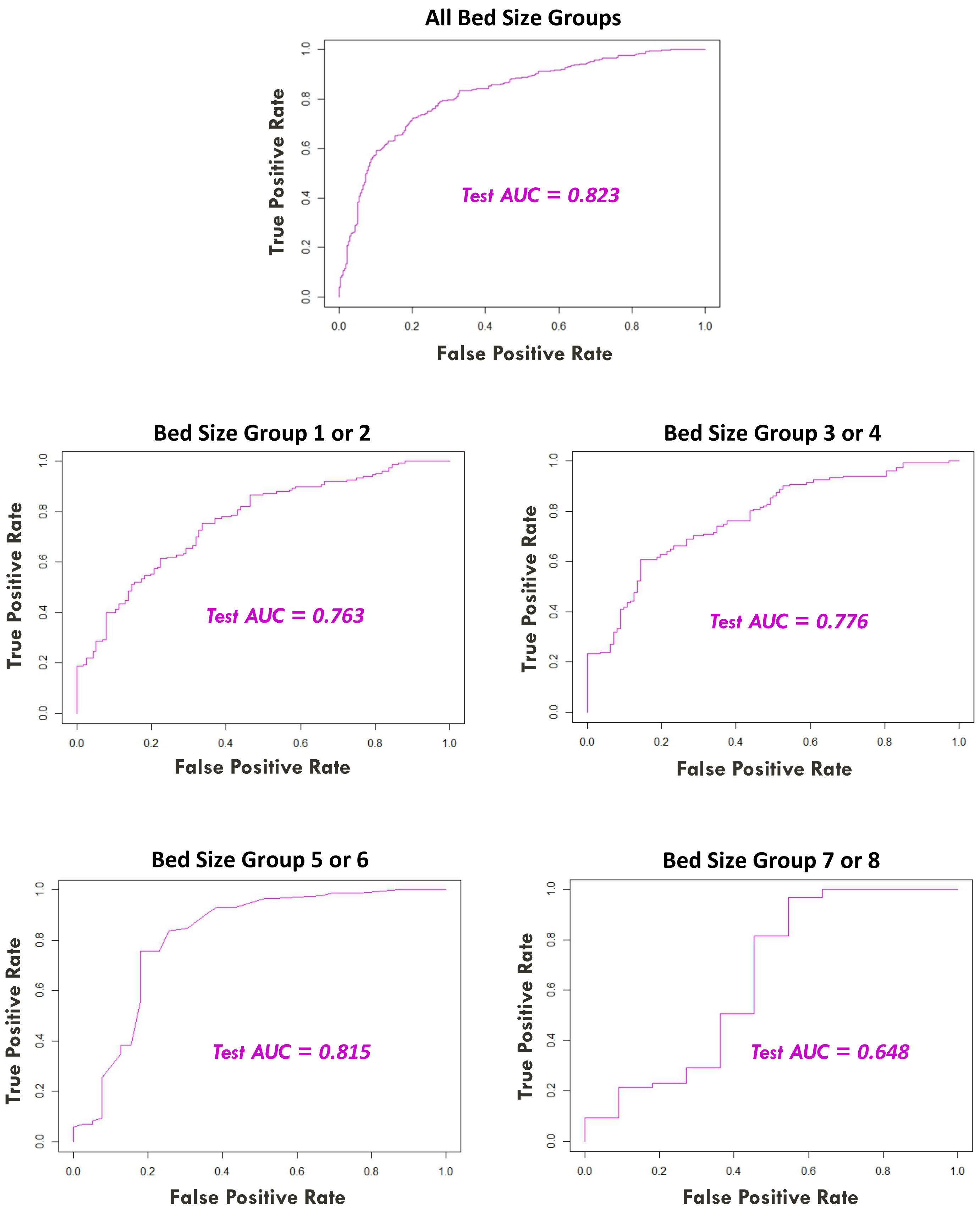


Figure A16: Example Model Print Outs

Model Print Out: Research Question 1: Logistic Regression Model Requested by Professor Chandrasekaran All Variables Kept & EMRAM Stage Converted to Binary

```
Call:
glm(formula = HIE_YN ~ Gov + Prof + Church + MultiSys + Top100City_YN +
    CBSATypeA_Rural + NewAccJC + NewMemCOTH + BGBin_B + BGBin_C +
    BGBin_D + TotOutpatientVisA + PercDr + PercNurse + TechScore +
    EMRAM_Bin, family = binomial, data = genMedD2)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.6829  -0.8519   0.4538   0.7578   2.2628

Coefficients:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)       -3.164e-01  2.306e-01  -1.372 0.169968
Gov               -3.567e-01  1.069e-01  -3.337 0.000847 ***
Prof              -2.149e+00  1.334e-01 -16.114  < 2e-16 ***
Church             1.038e-01  1.543e-01   0.673 0.501187
MultiSys           7.673e-01  1.041e-01   7.371 1.70e-13 ***
Top100City_YN      2.414e-01  1.684e-01   1.434 0.151684
CBSATypeA_Rural   -1.745e-01  1.068e-01  -1.635 0.102133
NewAccJC          -2.425e-01  1.021e-01  -2.375 0.017552 *
NewMemCOTH         3.985e-01  3.176e-01   1.255 0.209631
BGBin_B            1.343e-02  1.042e-01   0.129 0.897510
BGBin_C           -7.883e-02  1.541e-01  -0.512 0.608947
BGBin_D           -1.613e-01  2.408e-01  -0.670 0.502905
TotOutpatientVisA  9.850e-07  3.572e-07   2.757 0.005826 **
PercDr             2.479e-02  2.073e-02   1.196 0.231847
PercNurse         -1.145e-02  6.284e-03  -1.822 0.068451 .
TechScore          4.190e-01  3.798e-02  11.034  < 2e-16 ***
EMRAM_Bin          6.641e-01  9.837e-02   6.751 1.47e-11 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Model Print Out: Research Question 2: Linear Regression

Perf. Metric: Ln Net Pat Rev / Size

```
Call:
glm(formula = lnNetRevSZ ~ HIE_YN + Gov + Prof + Church + MultiSys +
    Top100City_YN + CBSATypeA_Rural + NewAccJC + NewMemCOTH +
    BGBin_B + BGBin_C + BGBin_D + TotOutpatientVisA + PercDr +
    PercNurse + TechScore + EMRAM_Stage, data = P_allMVO_LNRS2)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-4.2636  -0.3375   0.0150   0.3450   3.7905

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)        1.366e+01  5.790e-02 235.962  < 2e-16 ***
HIE_YN             1.266e-01  2.437e-02   5.193 2.19e-07 ***
Gov               -1.731e-01  2.848e-02  -6.077 1.35e-09 ***
Prof              -9.845e-02  3.447e-02  -2.856 0.004314 **
Church            -5.441e-02  3.377e-02  -1.611 0.107269
MultiSys           4.876e-03  2.658e-02   0.183 0.854465
Top100City_YN      8.107e-02  3.646e-02   2.223 0.026247 *
CBSATypeA_Rural   -2.486e-01  2.797e-02  -8.887  < 2e-16 ***
NewAccJC           7.242e-02  2.510e-02   2.885 0.003936 **
NewMemCOTH         7.316e-02  5.669e-02   1.290 0.196982
BGBin_B           -6.774e-02  2.635e-02  -2.571 0.010179 *
BGBin_C           -1.240e-01  3.541e-02  -3.503 0.000465 ***
BGBin_D           -9.356e-02  5.086e-02  -1.839 0.065929 .
TotOutpatientVisA  4.173e-07  4.965e-08   8.405  < 2e-16 ***
PercDr             2.805e-02  4.448e-03   6.308 3.18e-10 ***
PercNurse         -6.907e-03  1.528e-03  -4.521 6.34e-06 ***
TechScore          6.330e-02  8.954e-03   7.069 1.86e-12 ***
EMRAM_Stage        2.730e-02  3.868e-03   7.059 2.01e-12 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Perf. Metric: Overall Star Rating

```
Call:
glm(formula = StarRate_Overall ~ HIE_YN + Gov + Prof + Church +
    MultiSys + Top100City_YN + CBSATypeA_Rural + NewAccJC + NewMemCOTH +
    BGBin_B + BGBin_C + BGBin_D + TotOutpatientVisA + PercDr +
    PercNurse + TechScore + EMRAM_Stage, data = allStartemp2)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-2.84161  -0.48300   0.09936   0.56256   1.91611

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)        3.551e+00  9.118e-02  38.945  < 2e-16 ***
HIE_YN             1.928e-02  3.829e-02   0.503 0.614694
Gov               -1.545e-02  4.723e-02  -0.327 0.743524
Prof              -2.475e-01  4.987e-02  -4.963 7.39e-07 ***
Church             1.401e-01  4.770e-02   2.938 0.003334 **
MultiSys          -1.032e-01  4.134e-02  -2.497 0.012600 *
Top100City_YN      5.824e-04  4.776e-02   0.012 0.990272
CBSATypeA_Rural    2.121e-01  4.965e-02   4.273 2.00e-05 ***
NewAccJC          -5.573e-02  3.849e-02  -1.448 0.147801
NewMemCOTH        -1.732e-02  7.337e-02  -0.236 0.813397
BGBin_B           -5.252e-01  4.244e-02 -12.375  < 2e-16 ***
BGBin_C           -6.570e-01  5.129e-02 -12.809  < 2e-16 ***
BGBin_D           -6.662e-01  6.998e-02  -9.520  < 2e-16 ***
TotOutpatientVisA  2.345e-07  6.484e-08   3.616 0.000304 ***
PercDr             3.629e-03  6.498e-03   0.559 0.576538
PercNurse          8.205e-03  2.314e-03   3.546 0.000397 ***
TechScore          4.506e-02  1.332e-02   3.383 0.000727 ***
EMRAM_Stage        3.365e-02  5.485e-03   6.135 9.74e-10 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```