Hospital Bed Supply Analysis

Data Understanding

Objective

A common issue faced by healthcare networks centers around sufficient bed staffing. Hospitals with sufficient bed volume for hiring more nurses are recommended in this report after analyzing:

1. Top hospitals with ICU or SICU license, census, and staffed beds
2. Top hospitals with both ICU and SICU license, census, and staffed beds

Visuals are provided to help inform a hypothetical leadership team make cost-effective, informed decisions about staffing needs for optimal patient care.

Load Data

```
bed_type_df <- read_csv("data/bed_type.csv", show_col_types = FALSE)
bed_fact_df <- read_csv("data/bed_fact.csv", show_col_types = FALSE)
business_df <- read_csv("data/business.csv", show_col_types = FALSE)
```

Data Summaries

```
summary(bed_type_df)
```

```
##      bed_id        bed_code           bed_desc
##  Min.   : 1.00   Length:20          Length:20
##  1st Qu.: 5.75   Class :character   Class :character
##  Median :10.50   Mode  :character   Mode  :character
##  Mean   :10.50
##  3rd Qu.:15.25
##  Max.   :20.00
```

```
summary(bed_fact_df)
```

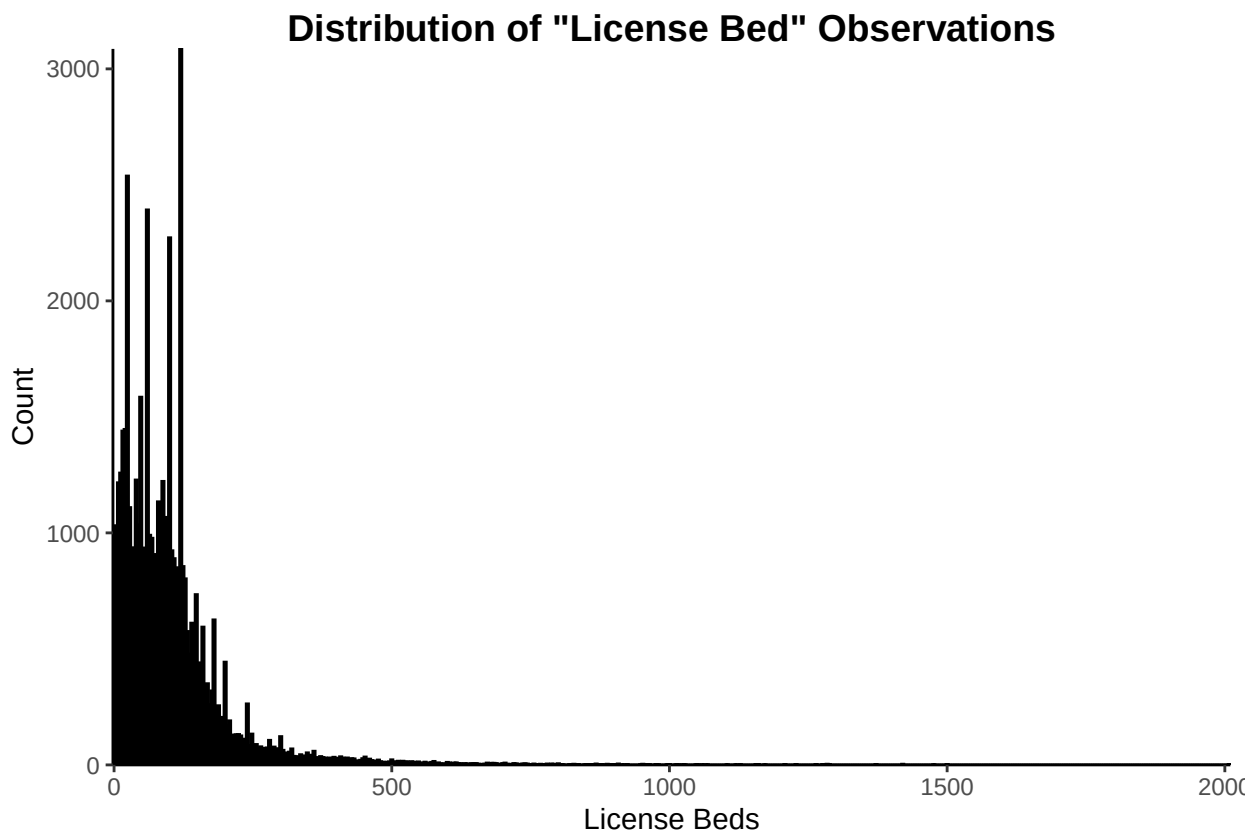
```
##   ims_org_id            bed_id       license_beds     census_beds
##  Length:51458       Min.   : 1.00   Min.   :   1.0   Min.   :   0.00
##  Class :character   1st Qu.: 8.00   1st Qu.:  41.0   1st Qu.:  29.00
##  Mode  :character   Median : 8.00   Median :  86.0   Median :  66.00
##                     Mean   :11.94   Mean   : 104.2   Mean   :  81.27
##                     3rd Qu.:18.00   3rd Qu.: 127.8   3rd Qu.: 110.00
##                     Max.   :20.00   Max.   :2007.0   Max.   :1505.00
```

```
##   staffed_beds
##  Min.   :   0.00
##  1st Qu.:  39.00
##  Median :  83.00
##  Mean   :  99.17
##  3rd Qu.: 124.00
##  Max.   :1527.00
```

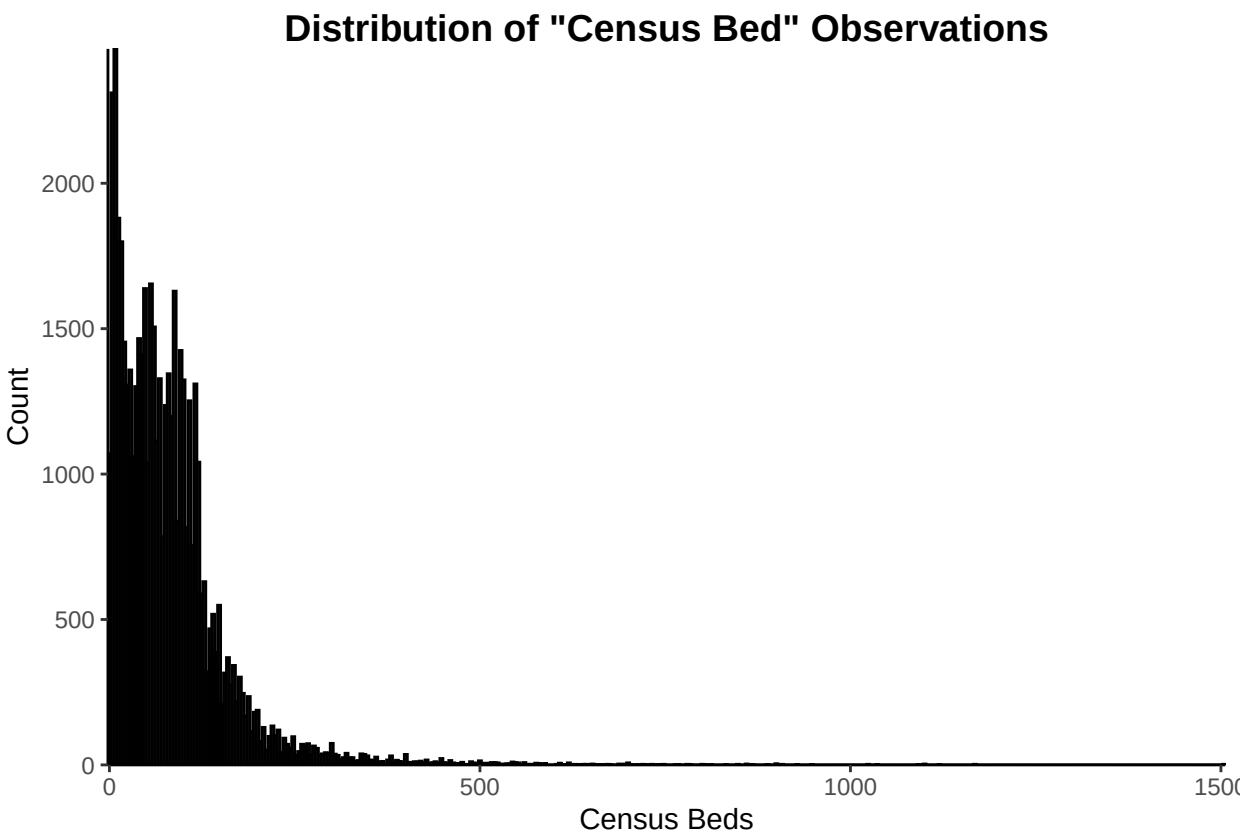
```r
summary(business_df)
```

```
##   ims_org_id        business_name      ttl_license_beds ttl_census_beds
##  Length:22202       Length:22202       Min.   :   2.0   Min.   :   0.00
##  Class :character   Class :character   1st Qu.:  59.0   1st Qu.:  44.00
##  Mode  :character   Mode  :character   Median :  99.0   Median :  80.00
##                                        Mean   : 120.8   Mean   :  94.19
##                                        3rd Qu.: 140.0   3rd Qu.: 117.00
##                                        Max.   :2007.0   Max.   :1505.00
##  ttl_staffed_beds bed_cluster_id
##  Min.   :   0.0   Min.   :1.000
##  1st Qu.:  56.0   1st Qu.:1.000
##  Median :  98.0   Median :1.000
##  Mean   : 114.9   Mean   :1.455
##  3rd Qu.: 136.0   3rd Qu.:2.000
##  Max.   :1527.0   Max.   :9.000
```

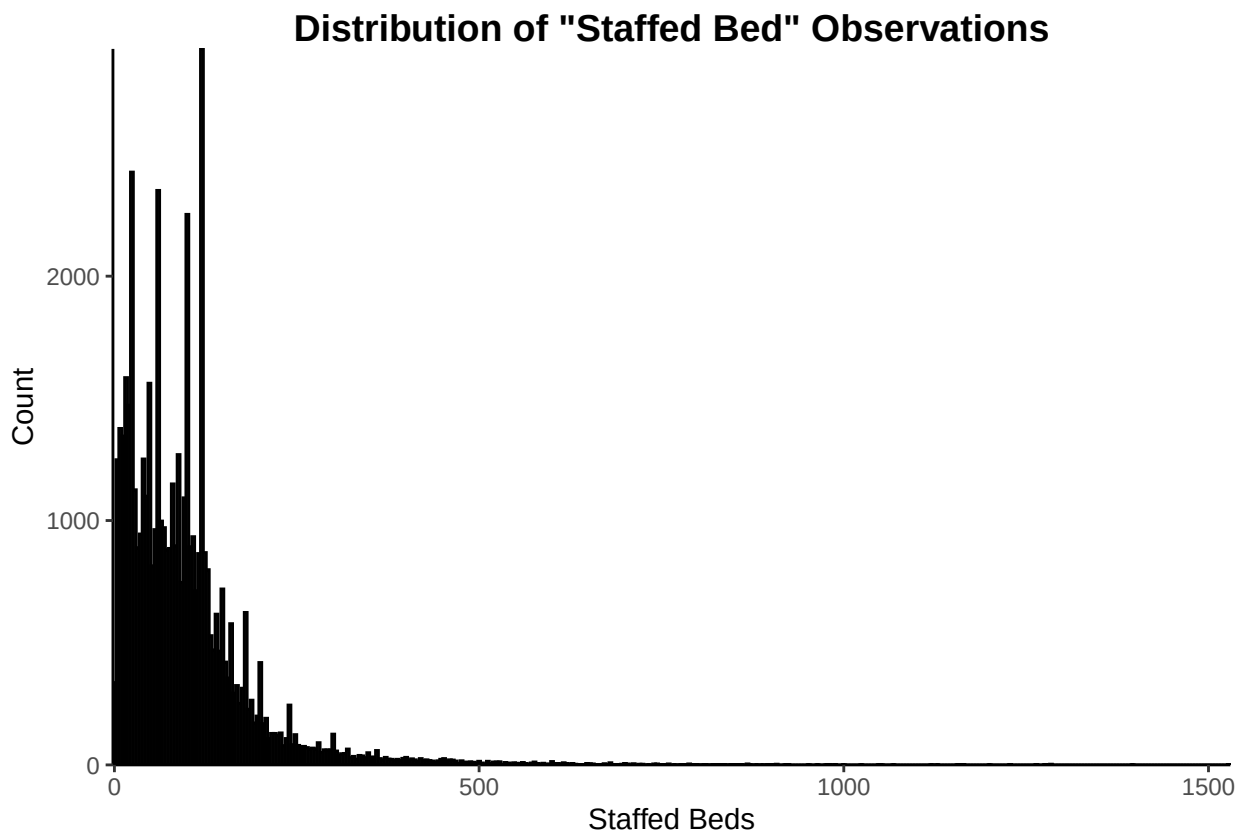
```r
# License
ggplot(bed_fact_df, aes(license_beds)) +
  geom_histogram(binwidth = 4, color = "black") +
  labs(title = "Distribution of \"License Bed\" Observations",
       x = "License Beds",
       y = "Count"
  ) +
  scale_x_continuous(expand = c(0,0)) +
  scale_y_continuous(expand = c(0,0)) +
  theme_classic() +
  theme(
    plot.title = element_text(face = "bold", size = 14, hjust = 0.5, margin = margin(t = 5))
  )
```




```
# Census
ggplot(bed_fact_df, aes(census_beds)) +
  geom_histogram(binwidth = 4, color = "black") +
  labs(title = "Distribution of \"Census Bed\" Observations",
       x = "Census Beds",
       y = "Count") +
  scale_x_continuous(expand = c(0,0)) +
  scale_y_continuous(expand = c(0,0)) +
  theme_classic() +
  theme(
    plot.title = element_text(face = "bold", size = 14, hjust = 0.5, margin = margin(t = 5))
  )
```




```r
# Staffed
ggplot(bed_fact_df, aes(staffed_beds)) +
  geom_histogram(binwidth = 4, color = "black") +
  labs(title = "Distribution of \"Staffed Bed\" Observations",
       x = "Staffed Beds",
       y = "Count") +
  scale_x_continuous(expand = c(0,0)) +
  scale_y_continuous(expand = c(0,0)) +
  theme_classic() +
  theme(
    plot.title = element_text(face = "bold", size = 14, hjust = 0.5, margin = margin(t = 5))
  )
```



Facts/Dimensions in bed_type.csv, business.csv, and bed_fact.csv

- bed_fact.csv contains four facts:
  - bed_id, license_beds, census_beds, staffed_beds are all facts since they report quantitative data
- bed_type.csv contains three dimensions that are qualitative attributes providing context for or categorizing a fact object:
  - bed_id (primary key) assigns a unique identifier for each type of bed
  - bed_code contains abbreviations for each type of bed
  - bed_desc contains descriptions of each type of bed
- business.csv contains three dimensions that are qualitative attributes providing context for or categorizing a fact object:
  - ims_org_id (primary key) assigns a unique identifier for each business
  - business_name contains the names of the organizations
  - bed_cluster_id categorizes bed clusters from 1-9
- The remaining columns in business.csv (ttl_license_beds, ttl_census_beds, and ttl_staffed_bed)s are facts due to their quantitative nature
- bed_fact.csv contains one dimension that is qualitative:
  - ims_org_id (primary key) is a dimension as it assigns a unique identifier for each business

---

Data Preparation

Database Construction

```
# Establish and open connection to existing database file
bed_connection <- dbConnect(RSQLite::SQLite(), "bed_db.sqlite")

# Function to check for an existing table
table_exists <- function(con, table_name) {
  query <- sprintf(
    "SELECT name
     FROM sqlite_master
     WHERE type = 'table' AND name = '%s';",
    table_name
  )
  result <- dbGetQuery(con, query)
  return(nrow(result) > 0)
}

# Create the bed_type_table if it does not exist
if (!table_exists(bed_connection, "bed_type_table")) {
  dbExecute(
    bed_connection,
    "
    CREATE TABLE bed_type_table (
      bed_id INTEGER PRIMARY KEY,
      bed_code TEXT,
      bed_desc TEXT
    );
    "
  )
}

# Create the bed_fact_table if it does not exist
if (!table_exists(bed_connection, "bed_fact_table")) {
  dbExecute(
    bed_connection,
    "
    CREATE TABLE bed_fact_table (
      ims_org_id TEXT,
      bed_id INTEGER,
      license_beds INTEGER,
      census_beds INTEGER,
      staffed_beds INTEGER,
      PRIMARY KEY (ims_org_id, bed_id)
    );
    "
  )
}

# Create the business_table if it does not exist
if (!table_exists(bed_connection, "business_table")) {
  dbExecute(
```

```
    bed_connection,
    "
    CREATE TABLE business_table (
      ims_org_id TEXT,
      business_name TEXT,
      ttl_license_beds INTEGER,
      ttl_census_beds INTEGER,
      ttl_staffed_beds INTEGER,
      bed_cluster_id INTEGER,
      PRIMARY KEY (ims_org_id, bed_cluster_id)
    );
    "
  )
}

# Load data into tables
dbWriteTable(bed_connection, "bed_type_table", bed_type_df, overwrite = TRUE, row.names = FALSE)
dbWriteTable(bed_connection, "bed_fact_table", bed_fact_df, overwrite = TRUE, row.names = FALSE)
dbWriteTable(bed_connection, "business_table", business_df, overwrite = TRUE, row.names = FALSE)
```

```
# Create the combined_table if it does not exist
if (!table_exists(bed_connection, "combined_table")) {
  dbExecute(
    bed_connection,
    "
    CREATE TABLE combined_table (
      ims_org_id TEXT,
      business_name TEXT,
      ttl_license_beds INTEGER,
      ttl_census_beds INTEGER,
      ttl_staffed_beds INTEGER,
      bed_cluster_id INTEGER,
      bed_id INTEGER,
      license_beds INTEGER,
      census_beds INTEGER,
      staffed_beds INTEGER,
      bed_code TEXT,
      bed_desc TEXT,
      PRIMARY KEY (ims_org_id, bed_id)
    );
    "
  )

  # Insert data from other tables into combined_table
  dbExecute(
    bed_connection,
    "
    INSERT INTO combined_table
    SELECT
      business_table.ims_org_id,
      business_table.business_name,
      business_table.ttl_license_beds,
      business_table.ttl_census_beds,
```

```
      business_table.ttl_staffed_beds,
      business_table.bed_cluster_id,
      bed_fact_table.bed_id,
      bed_fact_table.license_beds,
      bed_fact_table.census_beds,
      bed_fact_table.staffed_beds,
      bed_type_table.bed_code,
      bed_type_table.bed_desc
    FROM business_table
    JOIN bed_fact_table
      ON business_table.ims_org_id = bed_fact_table.ims_org_id
    JOIN bed_type_table
      ON bed_fact_table.bed_id = bed_type_table.bed_id;
    "
  )
}

# Retrieve data from combined_table and preview
combined_df <- dbGetQuery(bed_connection, "SELECT * FROM combined_table")
head(combined_df)
```

```
##    ims_org_id                  business_name ttl_license_beds ttl_census_beds
## 1 INS00077200 140 Prescott Street Corporation              126             122
## 2 INS00077200 140 Prescott Street Corporation              126             122
## 3 INS00000594             366th Medical Group               10               4
## 4 INS00000594             366th Medical Group               10               4
## 5 INS00039181        7 Hills Pediatric Center               83              75
## 6 INS00039181        7 Hills Pediatric Center               83              75
##   ttl_staffed_beds bed_cluster_id bed_id license_beds census_beds staffed_beds
## 1              126              2      8          126         122          126
## 2              126              2     18          126         122          126
## 3               10              1      5           10           4           10
## 4               10              1     18           10           4           10
## 5               83              1      8           83          75           83
## 6               83              1     18           83          75           83
##   bed_code         bed_desc
## 1       NF Nursing Facility
## 2       TO            Total
## 3       MS         Med/Surg
## 4       TO            Total
## 5       NF Nursing Facility
## 6       TO            Total
```

Verify Composite Primary Keys

```
# Verify composite primary keys in bed_fact_table (ims_org_id, bed_id)
duplicate_keys <- dbGetQuery(
  bed_connection,
  "
  SELECT ims_org_id, bed_id, COUNT(*)
  FROM bed_fact_table
```

```
  GROUP BY ims_org_id, bed_id
  HAVING COUNT(*) > 1;
  "
)

if (nrow(duplicate_keys) == 0) {
  print("Composite PK is unique for all combinations of ims_org_id and bed_id in bed_fact_table.")
} else {
  print("Duplicate keys found in bed_fact_table! Composite PK is not valid.")
  print(duplicate_keys)
}
```

```
## [1] "Composite PK is unique for all combinations of ims_org_id and bed_id in bed_fact_table."
```

```
# Verify composite primary keys in business_table (ims_org_id, bed_cluster_id)
duplicate_keys <- dbGetQuery(
  bed_connection,
  "
  SELECT ims_org_id, bed_cluster_id, COUNT(*)
  FROM business_table
  GROUP BY ims_org_id, bed_cluster_id
  HAVING COUNT(*) > 1;
  "
)

if (nrow(duplicate_keys) == 0) {
  print("Composite PK is unique for all combinations of ims_org_id and bed_cluster_id in business_table
} else {
  print("Duplicate keys found in business_table! Composite PK is invalid.")
  print(duplicate_keys)
}
```

```
## [1] "Composite PK is unique for all combinations of ims_org_id and bed_cluster_id in business_table.
```

Analysis

Hospital ICU or SICU Bed Volume by Bed Type

```
get_license_beds_total <- "
  SELECT business_name AS hospital_name,
         SUM(staffed_beds) AS total_icu_sicu_license_beds
  FROM combined_table
  WHERE bed_id IN (4, 15)
  GROUP BY hospital_name
  ORDER BY total_icu_sicu_license_beds DESC
  LIMIT 10;
"
```

```
license_beds_total_df <- dbGetQuery(bed_connection, get_license_beds_total)
license_beds_total_df
```

License Beds

```
##                                hospital_name total_icu_sicu_license_beds
## 1                      Vidant Medical Center                         203
## 2  Rady Childrens Hospital and Health Center                         200
## 3      University of Maryland Medical Center                         171
## 4                    Emory University Hospital                       169
## 5  Shands Hospital at the University of Florida                       167
## 6           Mercy Medical Center Saint Louis                         163
## 7                 Wesley Medical Center, LLC                         162
## 8                 Phoenix Childrens Hospital                         159
## 9                    Grady Memorial Hospital                         154
## 10              UC Health University Hospital                        151
```

```
separate_license_beds_visual <- "
  SELECT business_name AS hospital_name,
         SUM(CASE WHEN bed_desc = 'ICU' THEN license_beds ELSE 0 END) AS ICU_beds,
         SUM(CASE WHEN bed_desc = 'SICU' THEN license_beds ELSE 0 END) AS SICU_beds,
         SUM(census_beds) AS total_icu_sicu_license_beds
  FROM combined_table
  WHERE bed_desc IN ('ICU', 'SICU')
  GROUP BY hospital_name
  ORDER BY total_icu_sicu_license_beds DESC;
"

# Create a new dataframe for visualization
separate_license_beds_df <- dbGetQuery(bed_connection, separate_license_beds_visual) %>%
  as_tibble() %>%
  slice(1:10) %>%
  rename(
    ICU = ICU_beds,
    SICU = SICU_beds
  )

# Prepare for visual
pivot_license_beds_df <- separate_license_beds_df %>%
  pivot_longer(
    cols = c(ICU, SICU),
    names_to = "bed_type",
    values_to = "bed_count"
  ) %>%
  mutate(
    hospital_name = gsub(
      "Shands Hospital at the University of Florida",
      "Shands Hospital at\nthe University of Florida",
      hospital_name
    ),
    hospital_name = gsub(
      "Los Angeles County University of Southern California Healthcare Network",
      "Los Angeles County University of\nSouthern California Healthcare Network",
```

```
      hospital_name
    ),
    hospital_name = gsub(
      "University of Minnesota Medical Center Fairview",
      "University of Minnesota\nMedical Center Fairview",
      hospital_name
    ),
    hospital_name = gsub(
      "Ronald Reagan University of California Los Angeles Medical Center",
      "Ronald Reagan University of California\nLos Angeles Medical Center",
      hospital_name
    )
  )
```

```
ggplot(pivot_license_beds_df, aes(reorder(hospital_name, -bed_count), bed_count, fill = bed_type)) +
  geom_bar(stat = "identity", width = 0.7) +
  labs(
    x = "Hospital Name",
    y = "License Bed Count",
    fill = "Bed Type",
    title = "Top Hospitals with ICU or SICU License Beds",
    caption = "Figure 1: ICU and SICU license beds per hospital"
  ) +
  scale_y_continuous(expand = c(0, 0), limits = c(0, NA)) +
  scale_x_discrete() +
  theme_classic() +
  theme(
    axis.text.x = element_text(size = 9, color = "black", hjust = 0.5),
    axis.title.x = element_text(color = "black", face = "bold", margin = margin(t = 5, b = 5)),
    legend.title = element_text(face = "bold"),
    axis.text.y = element_text(color = "black"),
    axis.title.y = element_blank(),
    plot.title = element_text(hjust = 0.8, face = "bold", margin = margin(b = 10)),
    plot.margin = margin(t = 20, r = 20, l = 20, b = 10),
    plot.caption.position = "plot",
    plot.caption = element_text(face = "italic", hjust = 0.5)
  ) +
  scale_fill_paletteer_d("ggthemes::excel_Median") +
  coord_flip()
```

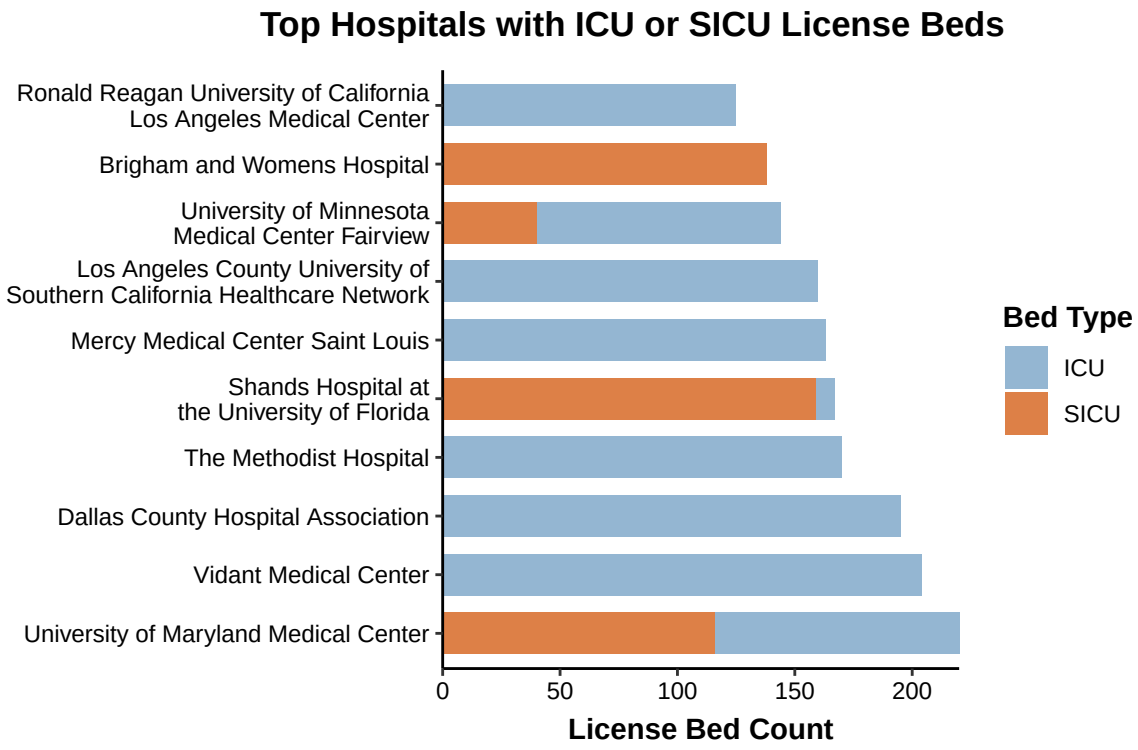


Figure 1: ICU and SICU license beds per hospital

```
get_census_beds_total <- "
SELECT
    business_name AS hospital_name,
    SUM(census_beds) AS total_icu_sicu_census_beds
FROM combined_table
WHERE bed_id IN (4, 15)
GROUP BY hospital_name
ORDER BY total_icu_sicu_census_beds DESC
LIMIT 10;
"
census_beds_total_df <- dbGetQuery(bed_connection, get_census_beds_total)
census_beds_total_df
```

Census Beds

```
##                                                                hospital_name
## 1                                Shands Hospital at the University of Florida
## 2                                          Dallas County Hospital Association
## 3                                            Mercy Medical Center Saint Louis
## 4  Los Angeles County University of Southern California Healthcare Network
## 5                                                          The Methodist Hospital
## 6                                University of Minnesota Medical Center Fairview
## 7                                          University of Maryland Medical Center
```

```
## 8                                              Brigham and Womens Hospital
## 9                                                   Vidant Medical Center
## 10       Ronald Reagan University of California Los Angeles Medical Center
##    total_icu_sicu_census_beds
## 1                         167
## 2                         145
## 3                         142
## 4                         139
## 5                         138
## 6                         129
## 7                         127
## 8                         124
## 9                         123
## 10                        122
```

```
separate_census_beds_visual <- "
SELECT
    business_name AS hospital_name,
    -- Add ICU census beds or 0 if not applicable
    SUM(CASE WHEN bed_desc = 'ICU' THEN census_beds ELSE 0 END) AS ICU_beds,
    -- Add SICU census beds or 0 if not applicable
    SUM(CASE WHEN bed_desc = 'SICU' THEN census_beds ELSE 0 END) AS SICU_beds,
    SUM(census_beds) AS total_icu_sicu_census_beds
FROM combined_table
WHERE bed_desc IN ('ICU', 'SICU')
GROUP BY hospital_name
ORDER BY total_icu_sicu_census_beds DESC;
"

separate_census_beds_df <- dbGetQuery(bed_connection, separate_census_beds_visual) %>%
    as_tibble() %>%
    slice(1:10) %>%
    rename(
        ICU = ICU_beds,
        SICU = SICU_beds
    )

separate_census_beds_df
```

```
## # A tibble: 10 x 4
##    hospital_name                                ICU  SICU total_icu_sicu_censu~1
##    <chr>                                      <int> <int>                   <int>
##  1 Shands Hospital at the University of Flor~     8   159                     167
##  2 Dallas County Hospital Association           145     0                     145
##  3 Mercy Medical Center Saint Louis             142     0                     142
##  4 Los Angeles County University of Southern~   139     0                     139
##  5 The Methodist Hospital                       138     0                     138
##  6 University of Minnesota Medical Center Fa~    93    36                     129
##  7 University of Maryland Medical Center         60    67                     127
##  8 Brigham and Womens Hospital                    0   124                     124
##  9 Vidant Medical Center                        123     0                     123
## 10 Ronald Reagan University of California Lo~   122     0                     122
## # i abbreviated name: 1: total_icu_sicu_census_beds
```

```r
# Pivot data for visualization
pivot_census_beds_df <- separate_census_beds_df %>%
    pivot_longer(cols = c(ICU, SICU), names_to = "bed_type", values_to = "bed_count") %>%
    mutate(
        hospital_name = gsub("Shands Hospital at the University of Florida",
                             "Shands Hospital at\nthe University of Florida", hospital_name),
        hospital_name = gsub("Los Angeles County University of Southern California Healthcare Network",
                             "Los Angeles County University of\nSouthern California Healthcare Network"
        hospital_name = gsub("University of Minnesota Medical Center Fairview",
                             "University of Minnesota\nMedical Center Fairview", hospital_name),
        hospital_name = gsub("Ronald Reagan University of California Los Angeles Medical Center",
                             "Ronald Reagan University of California\nLos Angeles Medical Center", hospi
    )
```

```r
# Stacked bar chart for ICU and SICU census beds for the top 10 hospitals
ggplot(pivot_census_beds_df, aes(reorder(hospital_name, -bed_count), bed_count, fill = bed_type)) +
    geom_bar(stat = "identity", width = 0.7) +
    labs(
        x = "Hospital Name",
        y = "Census Bed Count",
        fill = "Bed Type",
        title = "Top Hospitals with ICU or SICU Census Beds",
        caption = "Figure 2: ICU and SICU census beds per hospital"
    ) +
    scale_y_continuous(expand = c(0, 0), limits = c(0, NA)) +
    scale_x_discrete() +
    theme_classic() +
    theme(
        axis.text.x = element_text(size = 9, color = "black", hjust = 0.5),
        axis.title.x = element_text(color = "black", face = "bold", margin = margin(t = 5, b = 5)),
        legend.title = element_text(face = "bold"),
        axis.text.y = element_text(color = "black"),
        axis.title.y = element_blank(),
        plot.title = element_text(hjust = 0.8, face = "bold", margin = margin(b = 10)),
        plot.margin = margin(t = 20, r = 20, l = 20, b = 10),
        plot.caption.position = "plot",
        plot.caption = element_text(face = "italic", hjust = 0.5)
    ) +
    scale_fill_paletteer_d("ggthemes::excel_Median") +
    coord_flip()
```

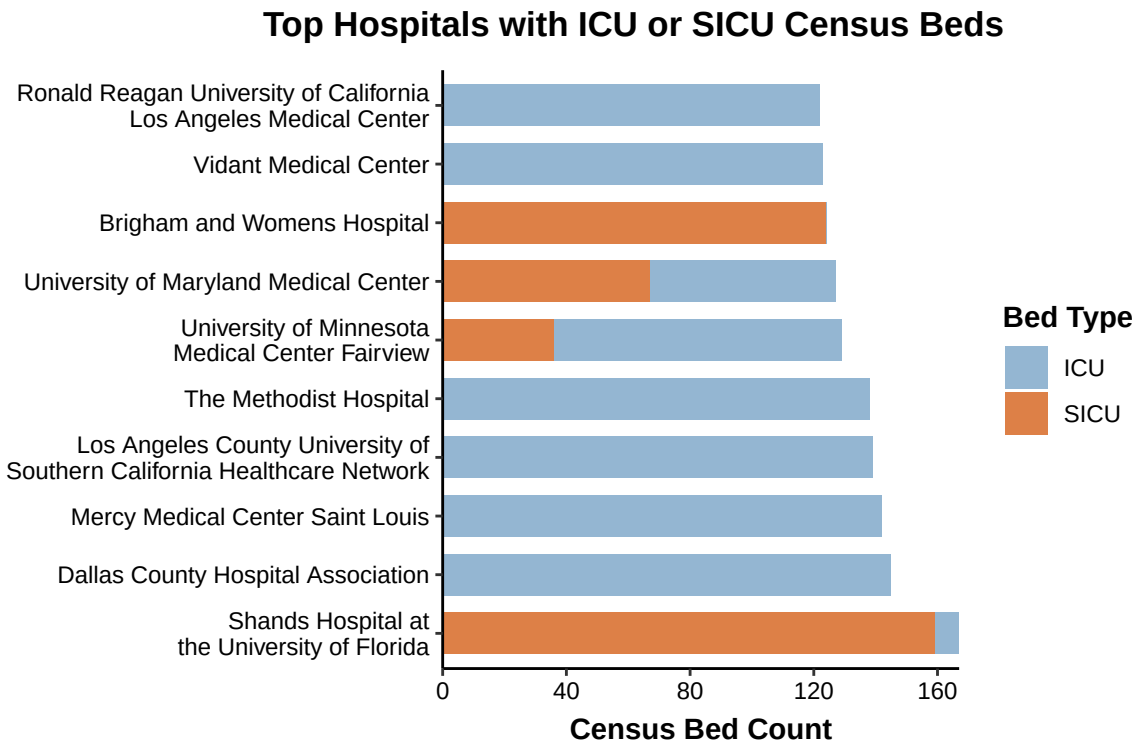


Figure 2: ICU and SICU census beds per hospital

```
# Query to get total staffed ICU and SICU beds for the top 10 hospitals
get_staffed_beds_total <- "
SELECT
    business_name AS hospital_name,
    -- Take the sum of the staffed beds in a new column total_icu_sicu_staffed_beds
    SUM(staffed_beds) AS total_icu_sicu_staffed_beds
FROM combined_table
-- Only include rows where bed_id is 4 (ICU) or 15 (SICU)
WHERE bed_id IN (4, 15)
-- Group by hospital_name
GROUP BY hospital_name
-- Arrange in descending order
ORDER BY total_icu_sicu_staffed_beds DESC
-- Only include top 10 hospitals
LIMIT 10;
"

total_staffed_beds <- dbGetQuery(bed_connection, get_staffed_beds_total) %>%
  as_tibble() %>%
  mutate(
    total_icu_sicu_staffed_beds = as.numeric(total_icu_sicu_staffed_beds)
  )
total_staffed_beds
```

Staffed Beds

```
## # A tibble: 10 x 2
##    hospital_name                                total_icu_sicu_staffed_beds
##    <chr>                                                              <dbl>
##  1 Vidant Medical Center                                                203
##  2 Rady Childrens Hospital and Health Center                            200
##  3 University of Maryland Medical Center                                171
##  4 Emory University Hospital                                            169
##  5 Shands Hospital at the University of Florida                         167
##  6 Mercy Medical Center Saint Louis                                     163
##  7 Wesley Medical Center, LLC                                           162
##  8 Phoenix Childrens Hospital                                           159
##  9 Grady Memorial Hospital                                              154
## 10 UC Health University Hospital                                        151
```

```
# Query to separate ICU and SICU staffed beds for visualization
staffed_beds_separate_visual <- "
SELECT
    business_name AS hospital_name,
    -- When bed_desc is ICU, the value is added to the total, else 0 is added
    SUM(CASE WHEN bed_desc = 'ICU' THEN staffed_beds ELSE 0 END) AS ICU_beds,
    -- When bed_desc is SICU, the value is added to the total, else 0 is added
    SUM(CASE WHEN bed_desc = 'SICU' THEN staffed_beds ELSE 0 END) AS SICU_beds,
    SUM(staffed_beds) AS total_icu_sicu_staffed_beds
FROM combined_table
-- Only include rows where bed_desc is ICU or SICU
WHERE bed_desc IN ('ICU', 'SICU')
GROUP BY hospital_name
-- Arrange in descending order
ORDER BY total_icu_sicu_staffed_beds DESC;
"

separate_staffed_beds_df <- dbGetQuery(bed_connection, staffed_beds_separate_visual) %>%
  as_tibble() %>%
  slice(1:10) %>%
  rename(
    ICU = ICU_beds,
    SICU = SICU_beds
  )

separate_staffed_beds_df
```

```
## # A tibble: 10 x 4
##    hospital_name                                ICU  SICU total_icu_sicu_staff~1
##    <chr>                                      <int> <int>                  <int>
##  1 Vidant Medical Center                        203     0                    203
##  2 Rady Childrens Hospital and Health Center    200     0                    200
##  3 University of Maryland Medical Center         81    90                    171
##  4 Emory University Hospital                    169     0                    169
##  5 Shands Hospital at the University of Flor~     8   159                    167
##  6 Mercy Medical Center Saint Louis             163     0                    163
##  7 Wesley Medical Center, LLC                   162     0                    162
##  8 Phoenix Childrens Hospital                   159     0                    159
```

```
##  9 Grady Memorial Hospital                          98    56                    154
## 10 UC Health University Hospital                   112    39                    151
## # i abbreviated name: 1: total_icu_sicu_staffed_beds
```

```r
# Pivot data for visualization
pivot_staffed_beds_df <- separate_staffed_beds_df %>%
  pivot_longer(cols = c(ICU, SICU), names_to = "bed_type", values_to = "bed_count") %>%
  mutate(
    hospital_name = gsub("Shands Hospital at the University of Florida",
                         "Shands Hospital at\nthe University of Florida", hospital_name),
    hospital_name = gsub("Los Angeles County University of Southern California Healthcare Network",
                         "Los Angeles County University of\nSouthern California Healthcare Network", hos
    hospital_name = gsub("University of Minnesota Medical Center Fairview",
                         "University of Minnesota\nMedical Center Fairview", hospital_name),
    hospital_name = gsub("Ronald Reagan University of California Los Angeles Medical Center",
                         "Ronald Reagan University of California\nLos Angeles Medical Center", hospital_
  )
```

```r
# Stacked bar chart for ICU and SICU staffed beds for the top 10 hospitals
ggplot(pivot_staffed_beds_df, aes(reorder(hospital_name, -bed_count), bed_count, fill = bed_type)) +
  geom_bar(stat = "identity", width = 0.7) +
  labs(
    x = "Hospital Name",
    y = "Staffed Bed Count",
    fill = "Bed",
    title = "Top Hospitals with ICU or SICU Staffed Beds",
    caption = "Figure 3: ICU and SICU staffed beds per hospital"
  ) +
  scale_y_continuous(expand = c(0, 0), limits = c(0, NA)) +
  scale_x_discrete() +
  theme_classic() +
  theme(
    axis.text.x = element_text(size = 9, color = "black", hjust = 0.5),
    axis.title.x = element_text(color = "black", face = "bold", margin = margin(t = 5, b = 5)),
    legend.title = element_text(face = "bold"),
    axis.text.y = element_text(color = "black"),
    axis.title.y = element_blank(),
    plot.title = element_text(hjust = 0.8, face = "bold", margin = margin(b = 10)),
    plot.margin = margin(t = 20, r = 20, l = 20, b = 10),
    plot.caption.position = "plot",
    plot.caption = element_text(face = "italic", hjust = 0.5)
  ) +
  scale_fill_paletteer_d("ggthemes::excel_Median") +
  coord_flip()
```

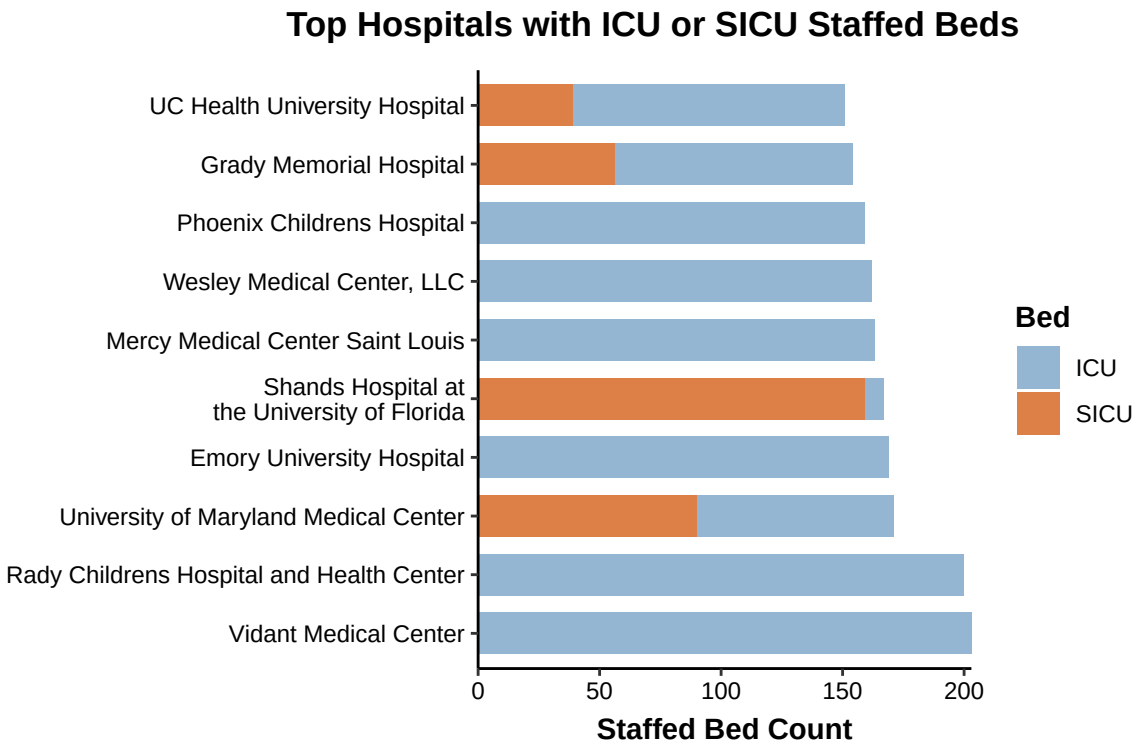


Figure 3: ICU and SICU staffed beds per hospital

Hospital ICU and SICU (≥ 1) Bed Volume by Bed Type

```
get_license_beds_min1 <- "
  SELECT business_name AS hospital_name,
         SUM(license_beds) AS total_license_beds_min1
  FROM combined_table
  WHERE (bed_id = 4 OR bed_id = 15)
  GROUP BY hospital_name
  HAVING COUNT(DISTINCT CASE WHEN bed_id = 4 THEN 1 END) > 0
         AND COUNT(DISTINCT CASE WHEN bed_id = 15 THEN 1 END) > 0
  ORDER BY total_license_beds_min1 DESC
  LIMIT 10;
"

license_beds_min1_df <- dbGetQuery(bed_connection, get_license_beds_min1) %>%
  as_tibble()

license_beds_min1_df
```

License Beds

```
## # A tibble: 10 x 2
##    hospital_name                                total_license_beds_min1
##    <chr>                                                         <int>
##  1 University of Maryland Medical Center                           220
##  2 UC Health University Hospital                                   218
##  3 Shands Hospital at the University of Florida                    167
##  4 MCGHealth, Inc                                                  155
##  5 Grady Memorial Hospital                                         154
##  6 Jackson Memorial Hospital                                       151
##  7 University of Minnesota Medical Center Fairview                 144
##  8 University Hospital in Bexar County                             144
##  9 Carolinas Medical Center                                        137
## 10 Yale New Haven Hospital                                         136
```

```
license_beds_min1_visual <- "
  SELECT business_name AS hospital_name,
         --- When bed_id is 4, the value is added to the total, else 0 is added ---
         SUM(CASE WHEN bed_id = 4 THEN license_beds ELSE 0 END) AS ICU_beds,
         --- When bed_id is 15, the value is added to the total, else 0 is added ---
         SUM(CASE WHEN bed_id = 15 THEN license_beds ELSE 0 END) AS SICU_beds,
         SUM(license_beds) AS total_icu_sicu_beds
  FROM combined_table
  --- Include ICU and SICU ---
  WHERE (bed_id = 4 OR bed_id = 15)
  GROUP BY hospital_name
  --- Ensures at least 1 bed is counted in SICU and ICU ---
  HAVING COUNT(DISTINCT CASE WHEN bed_id = 4 THEN 1 END) > 0
         AND COUNT(DISTINCT CASE WHEN bed_id = 15 THEN 1 END) > 0
  ORDER BY total_icu_sicu_beds DESC;
"

license_beds_min1_visual_df <- dbGetQuery(bed_connection, license_beds_min1_visual) %>%
  as_tibble %>%
  slice(1:10) %>%
  rename(
    ICU = ICU_beds,
    SICU = SICU_beds
  )

license_beds_min1_visual_df
```

```
## # A tibble: 10 x 4
##    hospital_name                                 ICU  SICU total_icu_sicu_beds
##    <chr>                                       <int> <int>               <int>
##  1 University of Maryland Medical Center         104   116                 220
##  2 UC Health University Hospital                 162    56                 218
##  3 Shands Hospital at the University of Florida    8   159                 167
##  4 MCGHealth, Inc                                139    16                 155
##  5 Grady Memorial Hospital                        98    56                 154
##  6 Jackson Memorial Hospital                      84    67                 151
##  7 University of Minnesota Medical Center Fairv~  104    40                 144
##  8 University Hospital in Bexar County            48    96                 144
##  9 Carolinas Medical Center                       39    98                 137
## 10 Yale New Haven Hospital                       111    25                 136
```

```r
pivot_min1_license_beds_visual_df <- license_beds_min1_visual_df %>%
  pivot_longer(cols = c(ICU, SICU), names_to = "bed_type", values_to = "bed_count")
```

```r
# Stacked bar for better visualization of ICU and SICU beds for top 10 hospitals
ggplot(pivot_min1_license_beds_visual_df, aes(reorder(hospital_name, -bed_count), bed_count, fill = bed
  geom_bar(stat = "identity") +
  labs(
    x = "Hospital Name",
    y = "License Bed Count",
    fill = "Bed Type",
    title = TeX(r"(\textbf{Top Hospitals with ICU and SICU (\textbf{$\geq 1$} License Beds)})"),
    caption = "Figure 4: ICU and SICU license beds, minimum 1 of each per hospital"
  ) +
  scale_y_continuous(expand = c(0, 0), limits = c(0, NA)) +
  scale_x_discrete() +
  theme_classic() +
  theme(
    axis.text.x = element_text(size = 9, color = "black", hjust = 0.5),
    axis.title.x = element_text(color = "black", face = "bold", margin = margin(t = 5, b = 5)),
    legend.title = element_text(face = "bold"),
    axis.text.y = element_text(color = "black"),
    axis.title.y = element_blank(),
    plot.title = element_text(hjust = 0.8, face = "bold", margin = margin(b = 10)),
    plot.margin = margin(t = 20, r = 20, l = 20, b = 10),
    plot.caption.position = "plot",
    plot.caption = element_text(face = "italic", hjust = 0.5)
  ) +
  scale_fill_paletteer_d("ggthemes::excel_Median") +
  coord_flip()
```

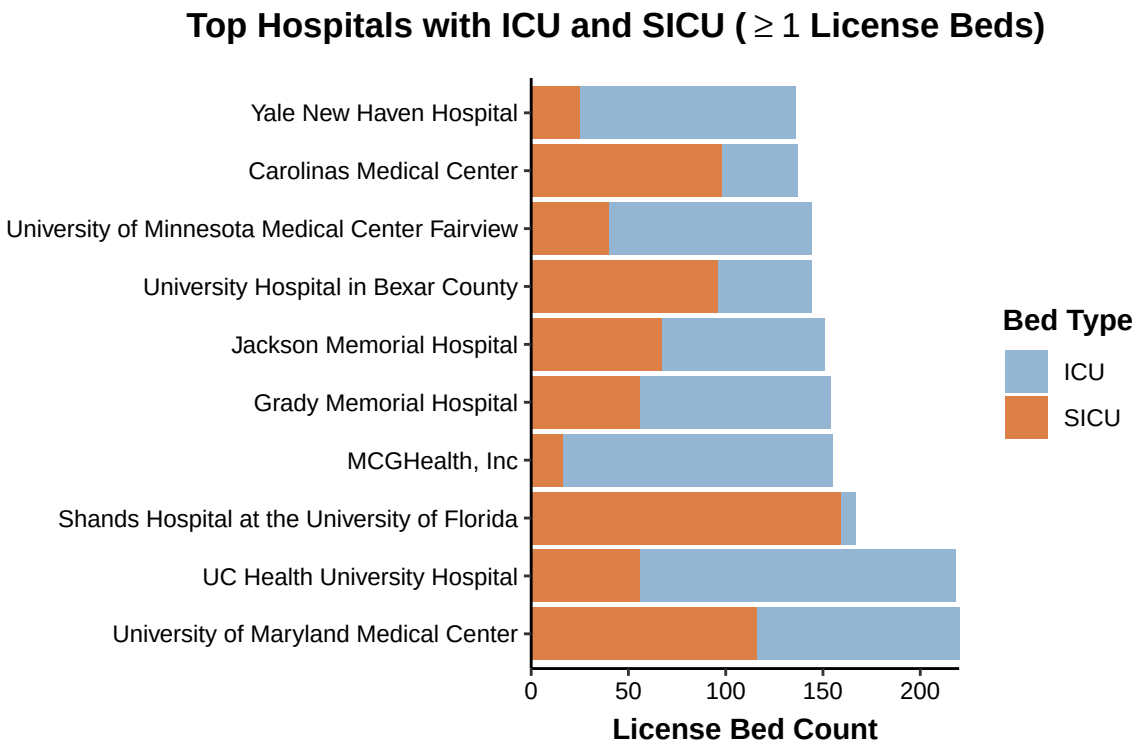


Figure 4: ICU and SICU license beds, minimum 1 of each per hospital

```
census_beds_min1 <- "
  SELECT business_name AS hospital_name,
         SUM(census_beds) AS total_census_beds_min1
  FROM combined_table
  WHERE (bed_id = 4 OR bed_id = 15)
  GROUP BY hospital_name
  HAVING COUNT(DISTINCT CASE WHEN bed_id = 4 THEN 1 END) > 0
         AND COUNT(DISTINCT CASE WHEN bed_id = 15 THEN 1 END) > 0
  ORDER BY total_census_beds_min1 DESC
  LIMIT 10;
"

census_beds_min1_df <- dbGetQuery(bed_connection, census_beds_min1)

census_beds_min1_df
```

Census Beds

```
##                                    hospital_name total_census_beds_min1
## 1     Shands Hospital at the University of Florida                    167
## 2  University of Minnesota Medical Center Fairview                    129
## 3            University of Maryland Medical Center                    127
## 4                        Jackson Memorial Hospital                    117
```

```
## 5                    UC Health University Hospital                    110
## 6                         Carolinas Medical Center                    106
## 7                       Cedars Sinai Health System                     92
## 8                University Hospital in Bexar County                     91
## 9                      Duke University Health System                     91
## 10                  The Cleveland Clinic Foundation                     88
```

```
census_beds_min1_visual <- "
  SELECT business_name AS hospital_name,
         --- When bed_id is 4, the value is added to the total, else 0 is added ---
         SUM(CASE WHEN bed_id = 4 THEN census_beds ELSE 0 END) AS ICU_beds,
         --- When bed_id is 15, the value is added to the total, else 0 is added ---
         SUM(CASE WHEN bed_id = 15 THEN census_beds ELSE 0 END) AS SICU_beds,
         SUM(census_beds) AS total_icu_sicu_beds
  FROM combined_table
  WHERE (bed_id = 4 OR bed_id = 15)
  GROUP BY hospital_name
  HAVING COUNT(DISTINCT CASE WHEN bed_id = 4 THEN 1 END) > 0
         AND COUNT(DISTINCT CASE WHEN bed_id = 15 THEN 1 END) > 0
  ORDER BY total_icu_sicu_beds DESC
  LIMIT 10;
"

census_beds_min1_visual_df <- dbGetQuery(bed_connection, census_beds_min1_visual) %>%
  as_tibble %>%
  slice(1:10) %>%
  rename(
    ICU = ICU_beds,
    SICU = SICU_beds
  )

census_beds_min1_visual_df
```

```
## # A tibble: 10 x 4
##    hospital_name                                  ICU  SICU total_icu_sicu_beds
##    <chr>                                        <int> <int>               <int>
##  1 Shands Hospital at the University of Florida     8   159                 167
##  2 University of Minnesota Medical Center Fairv~    93    36                 129
##  3 University of Maryland Medical Center            60    67                 127
##  4 Jackson Memorial Hospital                        65    52                 117
##  5 UC Health University Hospital                    82    28                 110
##  6 Carolinas Medical Center                         30    76                 106
##  7 Cedars Sinai Health System                       46    46                  92
##  8 University Hospital in Bexar County              30    61                  91
##  9 Duke University Health System                    15    76                  91
## 10 The Cleveland Clinic Foundation                  31    57                  88
```

```
pivot_min1_census_beds_visual_df <- census_beds_min1_visual_df %>%
  pivot_longer(cols = c(ICU, SICU), names_to = "bed_type", values_to = "bed_count")
```

```
# Stacked bar for better visualization of ICU and SICU beds for top 10 hospitals
ggplot(pivot_min1_census_beds_visual_df, aes(reorder(hospital_name, -bed_count), bed_count, fill = bed_
  geom_bar(stat = "identity") +
```

```
  labs(
    x = "Hospital Name",
    y = "Census Bed Count",
    fill = "Bed Type",
    title = TeX(r"(\textbf{Top Hospitals with ICU and SICU (\textbf{$\geq 1$} Census Beds)})"),
    caption = "Figure 5: ICU and SICU census beds, minimum 1 of each per hospital"
  ) +
  scale_y_continuous(expand = c(0, 0), limits = c(0, NA)) +
  theme_classic() +
  theme(
    axis.text.x = element_text(size = 9, color = "black"),
    axis.title.x = element_text(color = "black", face = "bold", margin = margin(t = 5, b = 5)),
    legend.title = element_text(face = "bold"),
    axis.text.y = element_text(color = "black"),
    axis.title.y = element_blank(),
    plot.title = element_text(hjust = 0.8, face = "bold", margin = margin(b = 10)),
    plot.margin = margin(t = 20, r = 20, l = 20, b = 10),
    plot.caption.position = "plot",
    plot.caption = element_text(face = "italic", hjust = 0.5)
  ) +
  scale_fill_paletteer_d("ggthemes::excel_Median") +
  coord_flip()
```

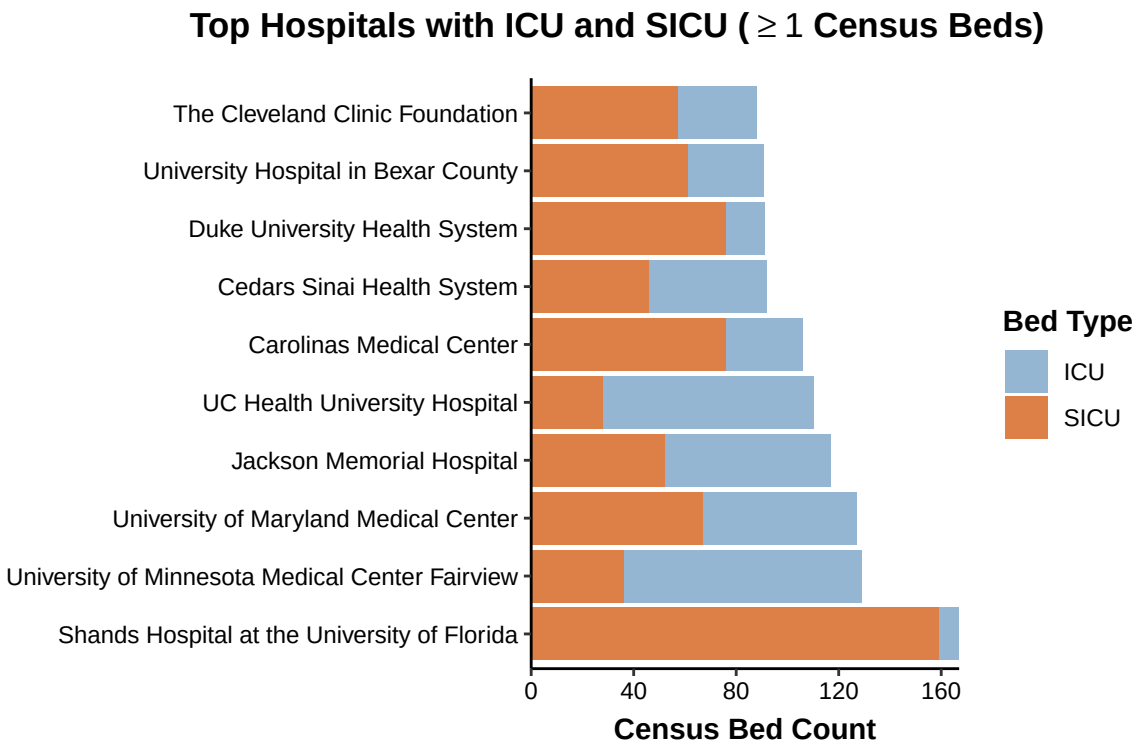


Figure 5: ICU and SICU census beds, minimum 1 of each per hospital

```
staffed_beds_min1 <- "
  SELECT business_name AS hospital_name,
         SUM(census_beds) AS total_staffed_beds_min1
  FROM combined_table
  WHERE (bed_id = 4 OR bed_id = 15)
  GROUP BY hospital_name
  HAVING COUNT(DISTINCT CASE WHEN bed_id = 4 THEN 1 END) > 0
         AND COUNT(DISTINCT CASE WHEN bed_id = 15 THEN 1 END) > 0
  ORDER BY total_staffed_beds_min1 DESC
  LIMIT 10;
"

staffed_beds_min1_df <- dbGetQuery(bed_connection, staffed_beds_min1)

staffed_beds_min1_df
```

Staffed Beds

```
##                                     hospital_name total_staffed_beds_min1
## 1     Shands Hospital at the University of Florida                     167
## 2  University of Minnesota Medical Center Fairview                     129
## 3            University of Maryland Medical Center                     127
## 4                        Jackson Memorial Hospital                     117
## 5                    UC Health University Hospital                     110
## 6                         Carolinas Medical Center                     106
## 7                       Cedars Sinai Health System                      92
## 8              University Hospital in Bexar County                      91
## 9                    Duke University Health System                      91
## 10                The Cleveland Clinic Foundation                      88
```

```
staffed_beds_min1_visual <- "
  SELECT business_name AS hospital_name,
         --- When bed_id is 4, the value is added to the total, else 0 is added ---
         SUM(CASE WHEN bed_id = 4 THEN staffed_beds ELSE 0 END) AS ICU_beds,
         --- When bed_id is 15, the value is added to the total, else 0 is added ---
         SUM(CASE WHEN bed_id = 15 THEN staffed_beds ELSE 0 END) AS SICU_beds,
         SUM(staffed_beds) AS total_icu_sicu_beds
  FROM combined_table
  --- Include ICU and SICU ---
  WHERE (bed_id = 4 OR bed_id = 15)
  GROUP BY hospital_name
  --- Ensures at least 1 bed is counted in SICU and ICU ---
  HAVING COUNT(DISTINCT CASE WHEN bed_id = 4 THEN 1 END) > 0
         AND COUNT(DISTINCT CASE WHEN bed_id = 15 THEN 1 END) > 0
  ORDER BY total_icu_sicu_beds DESC;
"

staffed_beds_min1_visual_df <- dbGetQuery(bed_connection, staffed_beds_min1_visual) %>%
  as_tibble %>%
  slice(1:10) %>%
  rename(ICU = ICU_beds,
         SICU = SICU_beds)
```

```
staffed_beds_min1_visual_df
```

```
## # A tibble: 10 x 4
##    hospital_name                                  ICU  SICU total_icu_sicu_beds
##    <chr>                                        <int> <int>               <int>
##  1 University of Maryland Medical Center           81    90                 171
##  2 Shands Hospital at the University of Florida     8   159                 167
##  3 Grady Memorial Hospital                         98    56                 154
##  4 UC Health University Hospital                  112    39                 151
##  5 University of Minnesota Medical Center Fairv~  104    40                 144
##  6 Carolinas Medical Center                        39    98                 137
##  7 Saint Josephs Hospital and Medical Center       38    96                 134
##  8 Chattanooga Hamilton County Hospital Authori~  104    30                 134
##  9 Jackson Memorial Hospital                       71    57                 128
## 10 Sunrise Hospital and Medical Center, LLC       113    12                 125
```

```
pivot_min1_staffed_beds_visual_df <- staffed_beds_min1_visual_df %>%
  pivot_longer(cols = c(ICU, SICU), names_to = "bed_type", values_to = "bed_count")
```

```
# Stacked bar for better visualization of ICU and SICU beds for top 10 hospitals
ggplot(pivot_min1_staffed_beds_visual_df, aes(reorder(hospital_name, -bed_count), bed_count, fill = bed
  geom_bar(stat = "identity") +
  labs(
    x = "Hospital Name",
    y = "Staffed Bed Count",
    fill = "Bed",
    title = TeX(r"(\textbf{Top Hospitals with ICU and SICU (\textbf{$\geq 1$} Staffed Beds)})"),
    caption = "Figure 6: ICU and SICU staffed beds, minimum 1 of each per hospital"
  ) +
  scale_y_continuous(expand = c(0, 0), limits = c(0, NA)) +
  theme_classic() +
  theme(
    axis.text.x = element_text(size = 9, color = "black"),
    axis.title.x = element_text(color = "black", face = "bold", margin = margin(t = 5, b = 5)),
    legend.title = element_text(face = "bold"),
    axis.text.y = element_text(color = "black"),
    axis.title.y = element_blank(),
    plot.title = element_text(hjust = 0.8, face = "bold", margin = margin(b = 10)),
    plot.margin = margin(t = 20, r = 20, l = 20, b = 10),
    plot.caption.position = "plot",
    plot.caption = element_text(face = "italic", hjust = 0.5)
  ) +
  scale_fill_paletteer_d("ggthemes::excel_Median") +
  coord_flip()
```

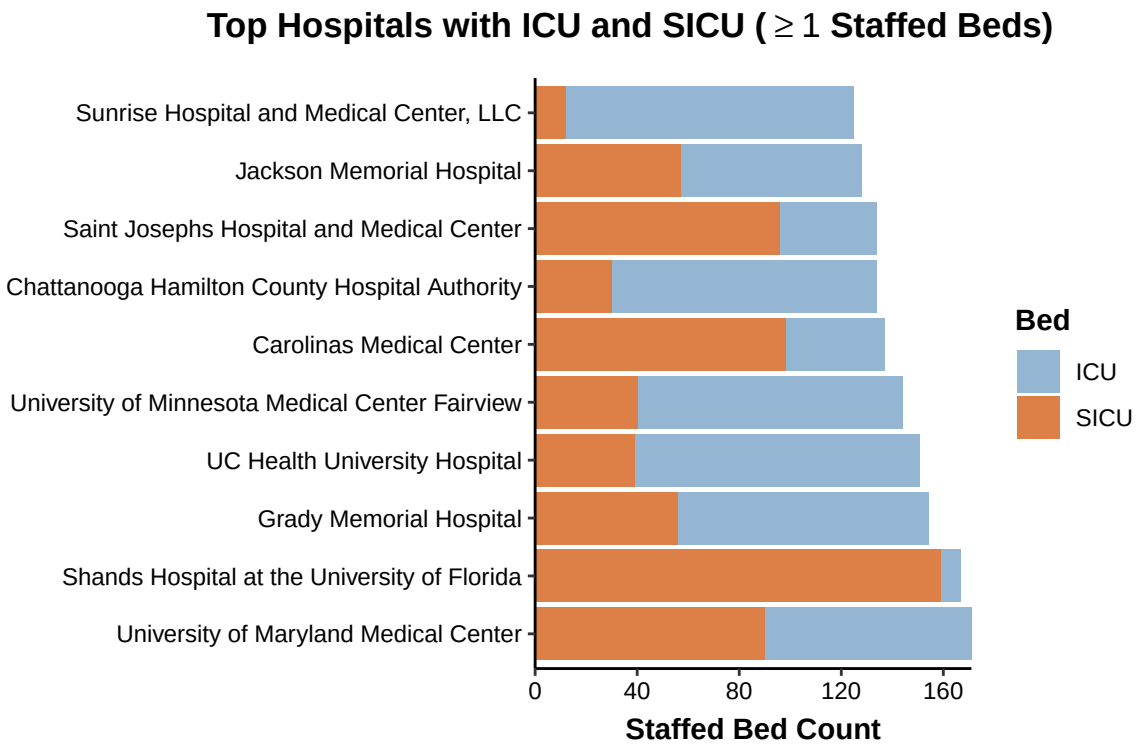


Figure 6: ICU and SICU staffed beds, minimum 1 of each per hospital

---

Final Recommendation

```
all_beds_combined_visual <- "
  SELECT business_name AS hospital_name,
         --- When bed_id is 4, the value is added to the total, else 0 is added (for each bed type, resp
         SUM(CASE WHEN bed_id = 4 THEN license_beds ELSE 0 END) AS ICU_license_beds,
         --- When bed_id is 15, the value is added to the total, else 0 is added (for each bed type, res
         SUM(CASE WHEN bed_id = 15 THEN license_beds ELSE 0 END) AS SICU_license_beds,
         SUM(license_beds) AS total_license_icu_sicu_beds,
         SUM(CASE WHEN bed_id = 4 THEN census_beds ELSE 0 END) AS ICU_census_beds,
         SUM(CASE WHEN bed_id = 15 THEN census_beds ELSE 0 END) AS SICU_census_beds,
         SUM(census_beds) AS total_census_icu_sicu_beds,
         SUM(CASE WHEN bed_id = 4 THEN staffed_beds ELSE 0 END) AS ICU_staffed_beds,
         SUM(CASE WHEN bed_id = 15 THEN staffed_beds ELSE 0 END) AS SICU_staffed_beds,
         SUM(staffed_beds) AS total_staffed_icu_sicu_beds
  FROM combined_table
  --- Include ICU and SICU ---
  WHERE (bed_id = 4 OR bed_id = 15)
  GROUP BY hospital_name
  --- Ensures at least 1 bed is counted in SICU and ICU ---
  HAVING COUNT(DISTINCT CASE WHEN bed_id = 4 THEN 1 END) > 0
         AND COUNT(DISTINCT CASE WHEN bed_id = 15 THEN 1 END) > 0
```

```
  ORDER BY total_license_icu_sicu_beds + total_census_icu_sicu_beds + total_staffed_icu_sicu_beds DESC;
"

all_beds_combined_visual_df <- dbGetQuery(bed_connection, all_beds_combined_visual) %>%
  as_tibble %>%
  slice(1:10) %>%
  rename(
    "Census ICU" = ICU_census_beds,
    "Census SICU" = SICU_census_beds,
    "License ICU" = ICU_license_beds,
    "License SICU" = SICU_license_beds,
    "Staffed ICU" = ICU_staffed_beds,
    "Staffed SICU" = SICU_staffed_beds
  )

all_beds_combined_visual_df
```

```
## # A tibble: 10 x 10
##    hospital_name             `License ICU` `License SICU` total_license_icu_si~1
##    <chr>                             <int>          <int>                  <int>
##  1 University of Maryland M~           104            116                    220
##  2 Shands Hospital at the U~             8            159                    167
##  3 UC Health University Hos~           162             56                    218
##  4 University of Minnesota ~           104             40                    144
##  5 Jackson Memorial Hospital            84             67                    151
##  6 Grady Memorial Hospital              98             56                    154
##  7 Carolinas Medical Center             39             98                    137
##  8 University Hospital in B~            48             96                    144
##  9 Saint Josephs Hospital a~            38             96                    134
## 10 Chattanooga Hamilton Cou~           104             30                    134
## # i abbreviated name: 1: total_license_icu_sicu_beds
## # i 6 more variables: `Census ICU` <int>, `Census SICU` <int>,
## #   total_census_icu_sicu_beds <int>, `Staffed ICU` <int>,
## #   `Staffed SICU` <int>, total_staffed_icu_sicu_beds <int>
```

```
pivot_all_beds_visual_df <- all_beds_combined_visual_df %>%
  pivot_longer(
    # Pivot License, Census, and Staffed ICU and SICU columns
    cols = starts_with("License") | starts_with("Census") | starts_with("Staffed"),
    names_to = c("bed_type", "icu_sicu"),
    names_sep = " ",
    values_to = "bed_count"
  ) %>%
  # Factor levels for stacked bar
  mutate(
    bed_type = factor(bed_type, levels = c("License", "Census", "Staffed")),
    icu_sicu = factor(icu_sicu, levels = c("ICU", "SICU"))
  )
```

```
ggplot(pivot_all_beds_visual_df, aes(reorder(hospital_name, -bed_count), bed_count, fill = bed_type)) +
  geom_bar(stat = "identity", position = "stack", width = 0.8) +
  facet_wrap(~ icu_sicu, ncol = 1, scales = "fixed") +
  labs(
```

```
    x = NULL,
    y = "Bed Count",
    fill = "Bed Type",
    title = "Top Hospitals Bed Type Count for ICU and SICU Beds",
    caption = "Figure 7: ICU and SICU bed type counts for top hospitals"
  ) +
  theme_classic() +
  theme(
    axis.text = element_text(color = "black"),
    axis.title.y = element_text(face = "bold", margin = margin(r = 10)),
    axis.title.x = element_text(face = "bold", margin = margin(t = 10)),
    legend.title = element_text(face = "bold"),
    legend.position = "right",
    plot.title = element_text(hjust = 0.7, face = "bold", margin = margin(b = 10)),
    plot.margin = margin(t = 20, r = 20, l = 20, b = 10),
    plot.caption.position = "plot",
    plot.caption = element_text(face = "italic", hjust = 0.5)
  ) +
  scale_y_continuous(expand = c(0, 0), limits = c(0, NA)) +
  scale_fill_paletteer_d("ltc::sylvie") +
  coord_flip()
```

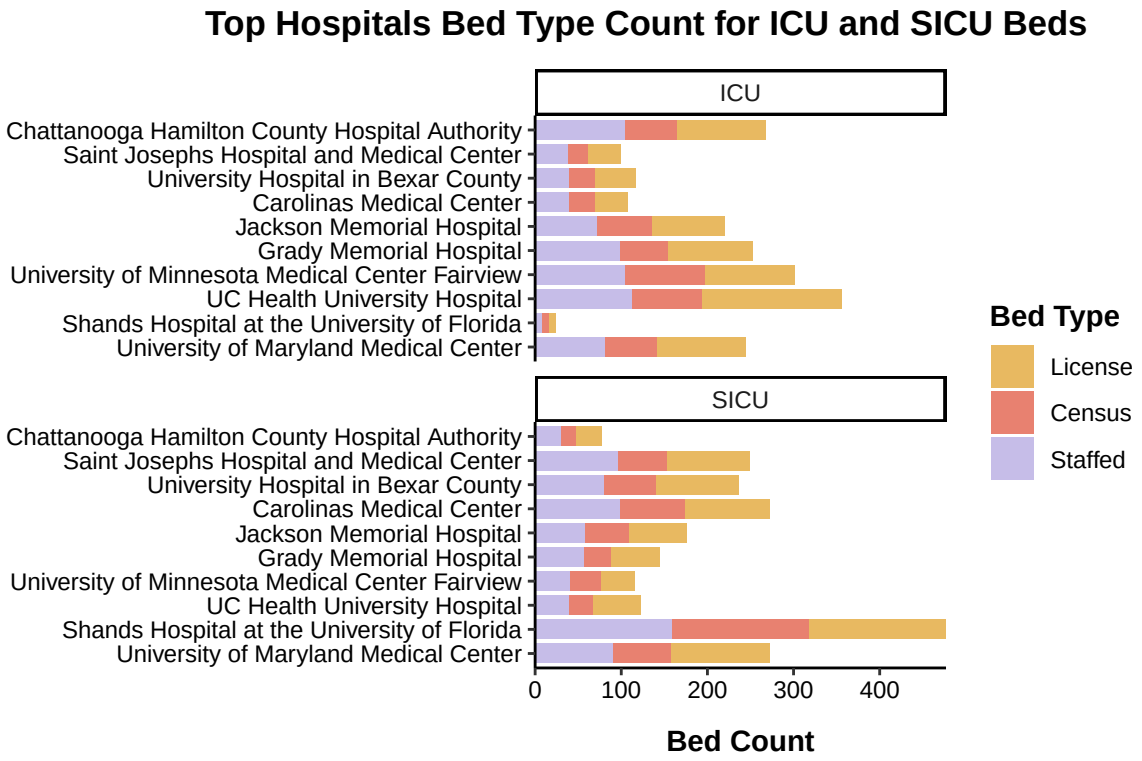


Figure 7: ICU and SICU bed type counts for top hospitals

Figure 7 shows the distribution of ICU and SICU bed counts using stacked bar charts for license, census, and staffed beds. Prime staffing locations should have similar SICU and ICU counts with a relatively equal distribution of the three bed types. Hospitals with high total bed counts are not necessarily better candidates if they only have more of one bed type. For example, the total bed count at Shands Hospital

at The University of Florida shows a majority SICU beds and small portion of ICU beds. This hospital is insufficient due to ICU bed shortages.

The two hospitals that best meet all criteria are The University of Maryland Medical Center and Jackson Memorial Hospital. The data suggests both offer a balanced distribution of all bed types for ICU and SICU beds while maintaining an appropriate total bed count.