# COVID-19 Surge Planning in Response to Global Pandemic in a Healthcare Setting: A Lean Six Sigma Approach

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## Abstract

Since the COVID-19 global pandemic surfaced and soon impacted many lives and industries across the globe, many organizations did not even have time to think about how to respond to such a crisis. This paper explores how the use of one such quality improvement methodology: Lean Six Sigma, helped the healthcare sector to be better prepared during the time of a global pandemic. Define, measure, analyze, improve, and control (DMAIC) is a Lean Six Sigma tool for continuous improvement. This paper discusses how DMAIC was instrumental in developing a COVID-19 Surge Planning Strategy for hospitals in the Midwestern US. A dedicated multidisciplinary team can look at the number of patients, trends, and available resources to plan effectively. Being one of the first such studies, the findings are useful for researchers and practitioners.

## Keywords
COVID-19, global pandemic, Lean Six Sigma, DMAIC, healthcare

## 1. Introduction

Quality may mean different things depending on who is defining it, the situation or context, or what it is referenced to. Quality is not an absolute term and it could be qualitative or quantitative. A banker may define quality as a better service, a healthcare worker may define quality as an effective treatment, an employee working in a hospitality industry may define quality as a happy patron, an artist may define quality work as an outstanding painting, and a manufacturer may define quality as a durable product (Ross & Perry, 1999). While there is not a single definition to quality, Karambelkar (2014) argues that quality is not a temporary change, corrective action, fabricated reporting of data, paper chase, one-time activity, only about documentation, and satisfying audits. Harbour and Higgins (2009) mention a quote by Henry Ford, “Quality means doing it right when no one is looking.”

Quality can be traced back centuries to medieval Europe where craftsmen began unifying into unions called guilds. A significant movement in quality seems to have flourished during World War I and World War II when quality was formally used in terms of sampling, inspection, and mass production (ASQ, 2020a). Deliberate quality improvement efforts made huge progress between the mid-1800s and 1900s in industries other than healthcare, mostly manufacturing (Sheingold & Hahn, 2014).

Marjoua and Bozic (2012) argue that the roots of the quality improvement movement in healthcare can be traced back to the work of Ignaz Semmelweis who was a 19th century physician who advocated the importance of hand washing in medical care. Florence Nightingale, an English nurse in the mid-1800s, is also credited with medical quality when she was able to link high death rates of injured soldiers to unsanitary living conditions. In the medical field, quality improvement is often referred to as re-engineering or restructuring existing processes and systems. Healthcare re-engineering includes complying with various accreditation standards and focused peer reviews, incentivizing best performing providers and organizations, reporting quality data and performance publicly, improving in the care delivery method and reprimanding of poor performance.

Mostly during and after World War I and World War II, many quality pioneers are credited with taking the quality improvement movement to the next level. These pioneers include:

Walter Shewart, who introduced the concept of Statistical Process Control and Control Charts;
W. Edwards Deming, who taught Japanese engineers how statistics can be used to control quality and who is also credited with starting the concept of Total Quality Management;
Joseph Juran, who also taught Japanese manufactures and many American companies the basics of quality control and managerial breakthrough;
Armand Feigenbaum, who formally published the first book on Total Quality Control in 1951; and
Philip Crosby, who introduced the concept of zero defects (ASQ, 2020b).

Ernest Codman and Avedis Donabedian, both medical doctors, are credited as pioneers of the quality improvement movement in healthcare. Ernest Codman kept track of his team's errors while providing care to patients, and he published that data publicly in the early 1900s (Neuhauser, 2002). Avedis Donabedian, who understood healthcare as a system, is also known as the father of quality assurance in healthcare. He wrote 11 books and over 100 articles. He advocated for the improvement of healthcare as a system and through his publications divided quality of healthcare measures into structure, process, and outcome, which is a widely used framework in the healthcare industry (Best, 2004).

The term pandemic refers to an epidemic that spreads over several countries and affects many people on a massive scale. An epidemic happens when an agent and susceptible hosts are present in adequate numbers and the agent can be effectively borne from a source to the susceptible hosts (CDC, 2012). Since the early 1900s, as shown in Table 1, four influenza pandemics are known to have claimed more lives than any other disease in such short intervals. The recent COVID-19 pandemic is also listed in Table 1. As of September 17, 2020, there were 195,800 reported deaths in the US alone from COVID-19 and 29.9 million active cases globally.

Table 1: Most Severe Influenza Pandemics in the last 2 Centuries (sources: WHO, 2020a; Stokes et al., 2020; CDC, 2020a; JHU, 2020)

| Influenza pandemic name | Caused by | Years active | Reported deaths | Reported active cases |
|---|---|---|---|---|
| Spanish Flu | A(H1N1) | 1918-1919 | 20-25 million | |
| Asian Flu | A(H2N2) | 1957-1958 | 1-4 million | |
| Hong Kong Flu | A(H3N2) | 1968 | 1-4 million | |
| Influenza | A(H1N1) | 2009-2010 | 100,000 – 400,000 | |
| Coronavirus Disease (COVID-19) | SARS-CoV-2 | 2019-2020 | 195,800 | 29.9 million (as of 9/17/2020) |

Preparing for a pandemic can be challenging because of a multitude of factors, many of which could be new and unique. Pandemics are events that are unplanned. Despite willingness to fight and cure the pandemic crisis, many organizations, countries and societies may have difficulties in securing resources, expertise and funds necessary to fight the impact of a global pandemic (Madhav, et al., 2017). Paleshi et al. (2017) reported a simulation-based optimization approach to reduce pandemic influenza spreads on the basis of socio-demographic characteristics of the population. Apart from socioeconomic challenges of a country's, society's, organization's or industry's ability to tackle a pandemic crisis, quality improvement methodologies can be instrumental in helping narrow down the focus, prioritize initiatives, plan a strategy, and capitalize on unanticipated opportunities, and Lean Six Sigma (LSS) is one such methodology. Lean is about waste reduction (Womack & Jones, 2003; Bader et al., 2020; Badar, 2014), and Six Sigma is about reduction in process variation (Dahlgaard & Dahlgaard-Park, 2006; Andersson, Eriksson & Torstensson, 2006). Because Lean and Six Sigma both have commonality in their procedures and objectives, they are commonly viewed as an integrated methodology, Lean Six Sigma (Taylor et al., 2015) and used DMAIC (Define, Measure, Analyze, Improve, and Control) as a tool for process improvement (Khan et al. 2020; Duffy, 2013; Hoerl & Gardner, 2010).

This study aimed to explore the possibility of applying the LSS quality improvement methodology in the healthcare industry in response to the COVID-19 global pandemic. Specifically, DMAIC – an LSS tool has been used as a strategy in planning for the expected surge of patients in a community-based healthcare setting. The rest of the article is organized as follows. Section 2 presents a summary of the relevant literature review. Section 3 describes the methodology. Section 4 discusses the findings. Section 5 describes conclusions and discussion.

## 2. Literature Review

Lean Six sigma methodology originally was developed for process improvement in the manufacturing industry. However, over the years, it has been used in service industries including healthcare (Bhandari et al., 2020). Li *et al.* (2019) used LSS to improve service process in higher education. Alblooshi and Shamsuzzaman (2020) have found that LSS can be used to impact organizational innovation climate factors. Kostic-Nikoli and Nikolic (2013) used LSS in the food industry. These are a few examples dealing with LSS in general. Since this article is about a specific LSS tool: DMAIC, this section presents a brief review of literature on the application of DMAIC.

Several studies have applied DMAIC in the manufacturing industry. For example, Khan et al. (2020) employed DMAIC to improve productivity in a caravan manufacturing company. Al Theeb and Hayajneh (2018) used this approach for deep drawing process improvement. Rehman et al. (2018) used DMAIC methodology to improve supply chain performance. Singh and Lal (2016) used DMAIC to enhance car muffler production process performance. Singh and Kumar (2016) applied this in stamping production process. Srinivasan et al. (2016) used DMAIC to improve furnace nozzle manufacturing process. Sujova, Simanova and Marcinekova (2016) employed this methodology to enhance sustainable process performance. Malek and Desai (2015) used this to minimize scrap or rework in pressure die casting process. Al–Refaie and Al–Hmaideen (2015) used DMAIC to improve tableting process. Sharma and Rao (2014) used this to improve engine-crankshaft manufacturing process. Hayajneh, Bataineh, and Al-Tawil (2013) applied this for decreasing manufacturing defects in the textile industry. Hung and Sung (2011) applied this methodology in a food industry manufacturing process to minimize quality cost. Sadraoui and Ghorbel (2011) used DMAIC for design process improvement. Meena et al. (2018) and Sokovic, Pavletic and Krulcic (2006) used this technique for process improvement in automotive parts manufacturing.

In the service industry, Belcher et al. (2018) used DMAIC for improving service quality and customer satisfaction. Shamsuzzaman et al. (2018) applied this to increase customer satisfaction, and Bhargava, Bhardwaj and Rathore (2010) used this to improve quality in the telecom industry. Obraz et al. (2017) used this tool to reduce delivery time of products. Khan et al., (2018) used the continuous improvement method to increase organization performance. Kumar and Bauer (2010) used LSS in public housing authorities.

Since the early 2000s, many researchers have used Lean or Six Sigma or hybrid LSS (Gonzalez-Aleu et al., 2018; Williamsson et al., 2016; Dahlgaard et al., 2011; Grove et al., 2010) in healthcare. Antony et al. (2018) have done a systematic literature review and summarized the top three benefits of Six Sigma in healthcare as: improvement in patient safety, increase in productivity, and revenue enhancement. However, there is no study on the application of LSS in general or DMAIC in particular to plan for a pandemic like COVID-19. This study is an attempt to fill this research gap by using DMAIC to develop a planning strategy to deal with the surge in the number of patients in the community-based hospital setting.

## 3. Methodology

This research utilized the LSS tool, DMAIC, to develop and deploy strategy related to COVID-19 pandemic surge planning for community-based hospitals in the Midwestern US. DMAIC is an iterative process (Bhargava, Bhardwaj & Rathore, 2010). Five stages of DMAIC have been explained in Khan et al. (2020). In the Define stage, the problem or undertaking is defined and a responsible team, with their respective roles, is identified. In the Measure stage, important operational measurements are arranged and relevant information is stratified. In the Analyze stage, facts are investigated with the help of fishbone diagrams, Pareto charts, etc. to determine the key drivers of the problem. In the Improve stage, inventive answers for existing issues can be produced and tried. In the Control stage, results of the Improve phase will keep on being followed and controlled in a proactive way so that long-haul achievement will be accomplished.

## 4. Findings

Below is a summary of the findings on how the DMAIC approach was instrumental for the team that was charged to develop a COVID-19 Surge Planning Strategy for the associated regional hospitals. Each subsection discusses the key outcomes from each phase of the methodology.

### 4.1. Define Phase

The first laboratory-confirmed case of coronavirus disease 2019 (COVID-19) in the US was confirmed on January 20, 2020, and reported to the Centers for Disease Control and Prevention (CDC) on January 22, 2020 (Stokes et al., 2020). The COVID-19 pandemic resulted in 5,817,385 reported cases and 362,705 deaths worldwide through May 30, 2020 including 1,761,503 aggregated reported cases and 103,700 deaths in the United States (Stokes et al., 2020). On March 11, 2020, the Novel Coronavirus Disease, COVID-19, was declared a pandemic by World Health Organization (WHO, 2020b). On March 13, 2020, a national emergency was declared in the United States concerning the COVID-19 outbreak (CDC, 2020b). On March 6, 2020, the region associated with this study reported its first case of COVID-19 (Olson & Howatt, 2020). The number of positive cases until May 6, 2020 is shown in Figure 1.

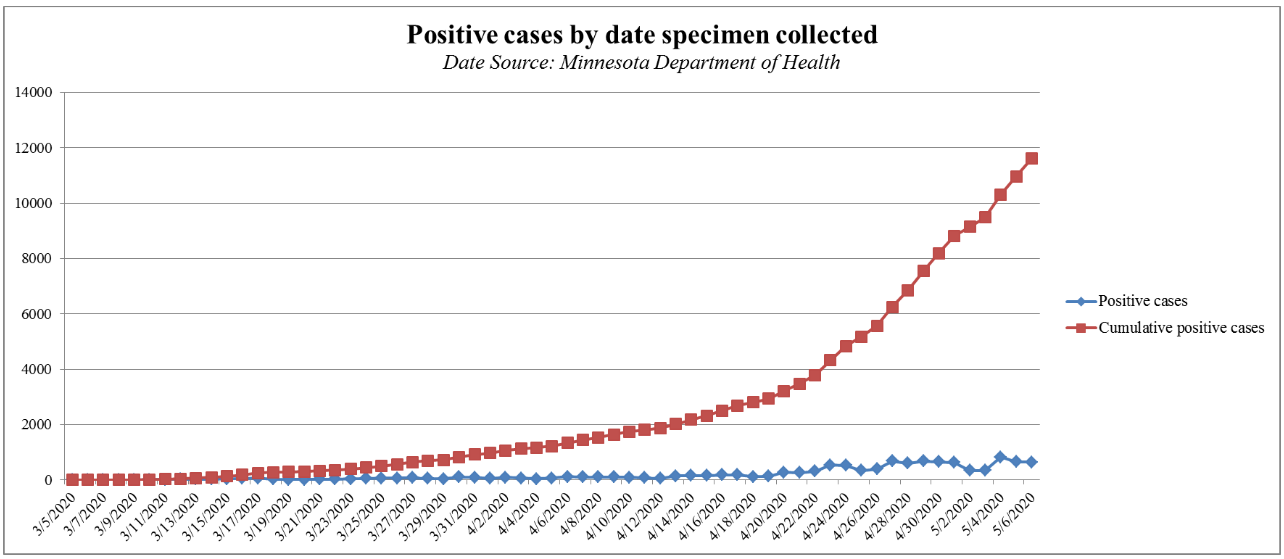


Figure 1. Number of positive cases by date specimen. (Minnesota Department of Health, 2020)

As soon as COVID-19 cases started to emerge across the country in early March, a COVID-19 Surge Planning Core Team was assembled in this study's regional hospital system. This was not a typical project, and the project deliverables were also not finalized when the project was kicked-off. The COVID-19 Surge Planning Core Team was charged to finalize the overall Surge Planning Strategy Tree for the region, which included but was not limited to high level staffing plans, a patient and staff change management plan, tools to help make decisions (status report, charts, flowcharts, guidelines etc.) and documentation of surge plans from all the departments in the region impacted by the potential surge of COVID-19 patients.

### 4.2. Measure Phase

On a traditional and typical LSS project, this is the phase where baseline metrics, target metrics, data collection and measurement system analysis (if applicable), current performance level, benchmarks (if available) and other items related to data are explored, collected, finalized and summarized. For this specific project, the team decided to first identify ways to cohort COVID-19 patients in a care setting as well as from a reporting perspective, develop or utilize previously developed reports from the Electronic Health Record System. Preliminary COVID-19 results from the region were also closely monitored and were compared with hospital system's inpatient census to check the true census of COVID-19 patients and other patients without COVID-19 symptoms and diagnosis daily.

The region was setting up infrastructures to establish resources like ongoing dashboards on case updates and communicating local, state and federal mandates as the pandemic progression increased day by day. As the government entities were setting up reputable communication venues to the its residents, there were multiple sources providing conflicting information regarding COVID-19 cases, adding fear and anxiety in the communities. As local, state and federal officials were working on appropriately managing, monitoring and controlling the spreading pandemic, the associated regional hospital system in this study also continued working towards developing metrics to address immediate and ongoing needs to manage patient care for all patients including COVID-19 patients.

## 4.3. Analyze Phase

This is the phase where a majority of the deliverables were executed. At first, key components of the COVID-19 Surge Planning Strategy were brainstormed and grouped into six main categories as displayed in the form of a fish-bone diagram in Figure 2.

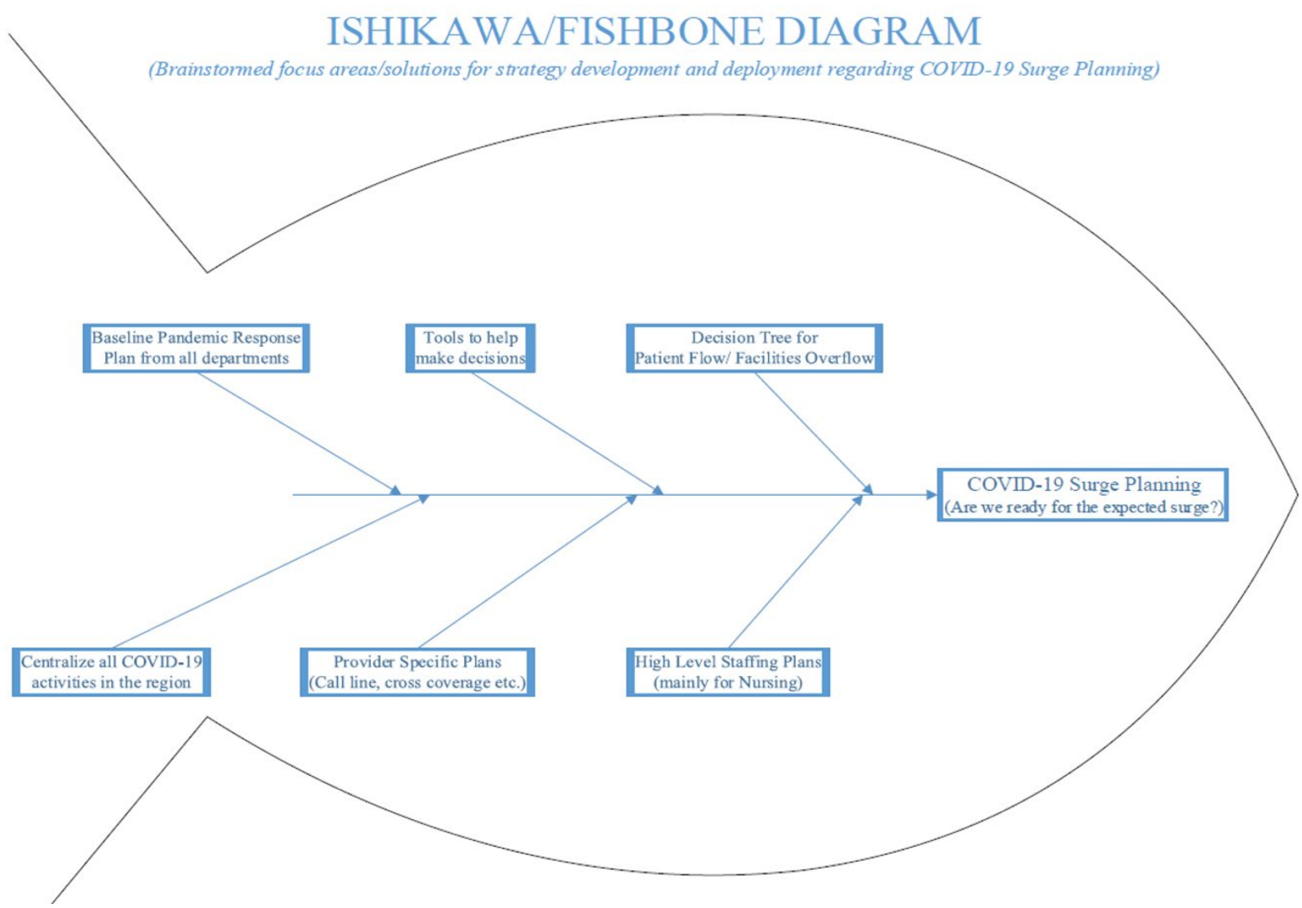


Figure 2. Brainstormed key strategy components of the COVID-19 Surge Planning Strategy

## 4.4. Improve Phase

As part of the development and improvement phase, the key components of the COVID-19 Surge Planning Strategy were executed and/or consolidated. The "Decision Tree for Patient Flow/Facilities overview" category included the algorithms that were developed to assist various departments with the patient flow. One example of an algorithm (flow diagram) tracking when a patient traveled from the emergency department (ED) to the inpatient floor is provided in Figure 3.

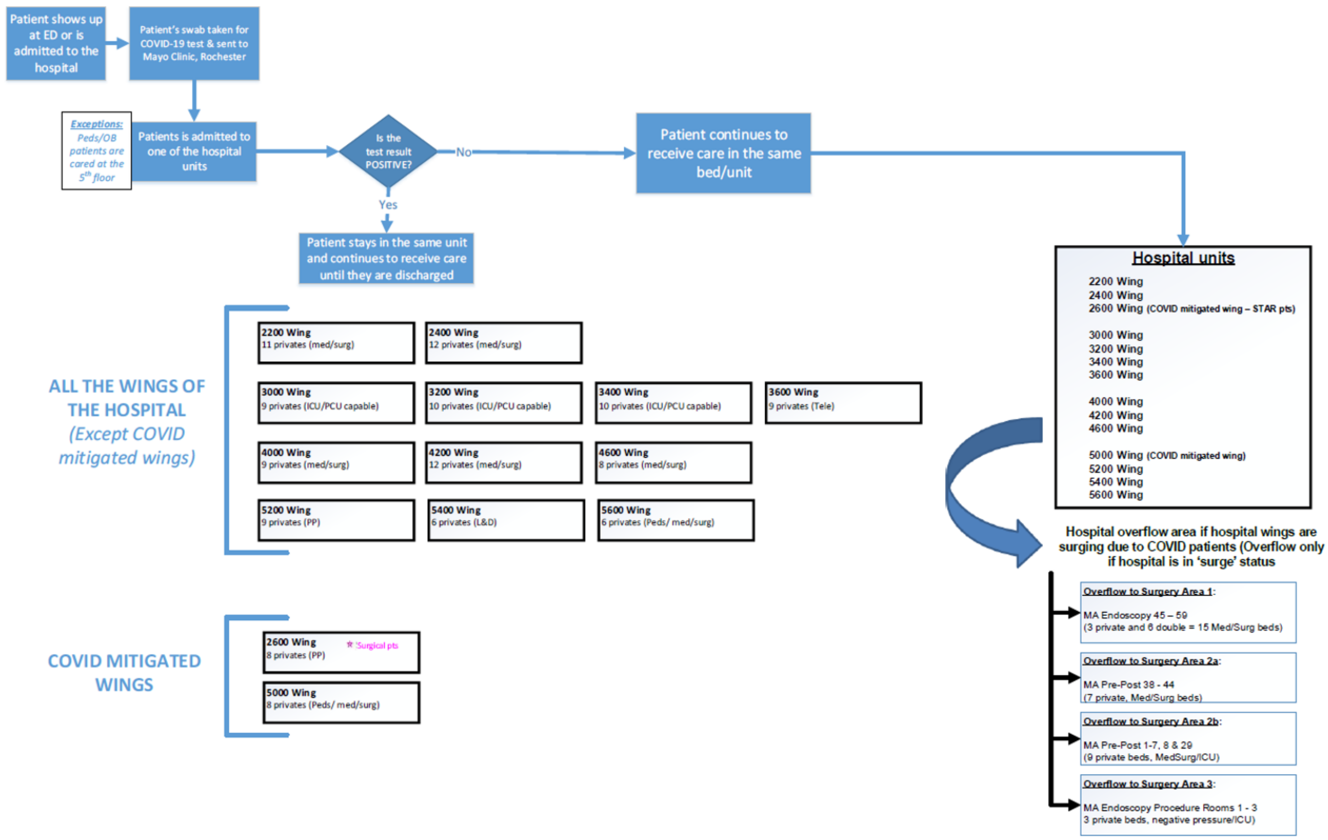


Figure 3. Decision Tree for Patient Flow/Facilities overflow for one of the hospitals in the region

Under tools to help make decisions for hospital leadership, a daily dashboard for COVID-19 Surge Planning for the hospitals in the region was created as shown in Figure 4 using lean concept's Visual Management System. A few other analyses were also carried out on a need basis as the data became more available. One example of such analysis is presented in Figure 5. A COVID-19 Hospital/ED Planning Huddle was set up every day at 9:30 am to review the COVID-19 Surge Planning Daily Dashboard to closely monitor the COVID-19 activities throughout the hospitals in the region. A copy of the COVID-19 Surge Planning Daily Dashboard was sent to all the key stakeholders who were part of the daily huddle. The key stakeholder group is shown in Figure 6.

The Provider Task Force Team established a COVID-19 Surge Levels, emergency call line, cross coverage plans etc. for providers in the clinical departments. The same COVID-19 Surge Levels were used to document the baseline pandemic response plan across all the departments in the region. A SharePoint page (shared common working space) for core team members as well as an Intranet page were set up to centralize all the work done by all the teams related to COVID-19 Surge Planning in the region including departmental surge plans.

The Labor Pool Team established a foundation for cross-coverage among departments that were expected to run low on staffing levels. This was primarily to cover inpatient nursing units by non-clinical staff from surgical and ambulatory services. In an effort to preserve masks and other critical supplies for healthcare workers as well as to reduce the impacts and slow the spread of the COVID-19 pandemic, the governor signed an emergency executive order on March 19, 2020 to delay all non-essential or elective surgeries and procedures (Emergency Executive Order 20-09). Outpatient areas also deferred a lot of upcoming appointments to comply with the hospitals' and the state's various requirements. That would mean reduced shifts or hours in these areas, which enabled staff from these areas to support inpatient areas in need.

**Name:__________ Hospital**

**Legend:** PUI | COVID + | COVID - | Regular - medical | Regular - surgical | Avail = Available | Patients on ventilator | B Patients on BiPAP at the hospital | B-h Patients on BiPAP at home

| | WING | Type | Planned Beds | Total bed capacity | Bed #1 | Bed #2 | Bed #3 | Bed #4 | Bed #5 | Bed #6 | Bed #7 | Bed #8 | Bed #9 | Bed #10 | Bed #11 | Bed #12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ED | | | | | | | | | | | | | | | | |
| | COVID WING 1 (3200) | ICU/PCU | 5 PCU privates, 5 ICU privates | 10 | Bed # | Bed # | Bed # B | Bed # | Bed # | Bed # | Bed # B | Bed # | Bed # | Avail | | |
| | COVID WING 2 (3400) | ICU/PCU | 10 privates (ICU/PCU) | 10 | Bed # | Bed # | Bed | Bed # B | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | | |
| | COVID WING 3 (3000) | ICU/PCU | 9 privates (PCU but ICU capable) | 9 | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Avail | | | |
| | COVID WING 4 (4200) | Med/Surg | 7 privates, 5 semi privates | 12 | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Avail | Avail | Avail | Avail |
| | COVID WING 5 (4000) | Med/Surg | 9 privates | 9 | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | | | |
| | COVID WING 6 (4600) | Med/Surg | 5 privates, 3 semi privates | 8 | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | | | | |
| | COVID WING 7 (2200) | Med/Surg | 11 privates | 11 | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | |
| | COVID WING 8 (2400) | Med/Surg | 12 privates | 12 | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # |
| | | | | | | | | | | | | | | | | |
| | (Surgical Pts) (2600) | Med/Surg | 8 privates | 8 | Bed # | Bed # | Bed # | Avail | Avail | Avail | Avail | Avail | | | | |
| | Med/Surg (3600) | Med/Sug (Tele) | 9 privates | 9 | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | | | |
| | Peds/MedSurg (5000) | Med/Surg | 8 privates | 8 | Bed # | Bed # | Bed # | Avail | Avail | Avail | Avail | Avail | | | | |
| | Peds/MedSurg (5600) | Med/Surg | 6 privates | 6 | Bed # | Bed # | Bed # | Bed # | Bed # | Avail | | | | | | |
| | Reserved for PP (5200) | PP | 9 privates | 9 | Bed # | Bed # | Bed # | Bed # | Bed # | Bed # | Avail | Avail | Avail | | | |
| | L&D (5400) | L&D | 6 privates | 6 | Bed # | Bed # | Bed # | Bed # | Avail | Avail | | | | | | |

Figure 4. COVID-19 Surge Planning Daily Dashboard

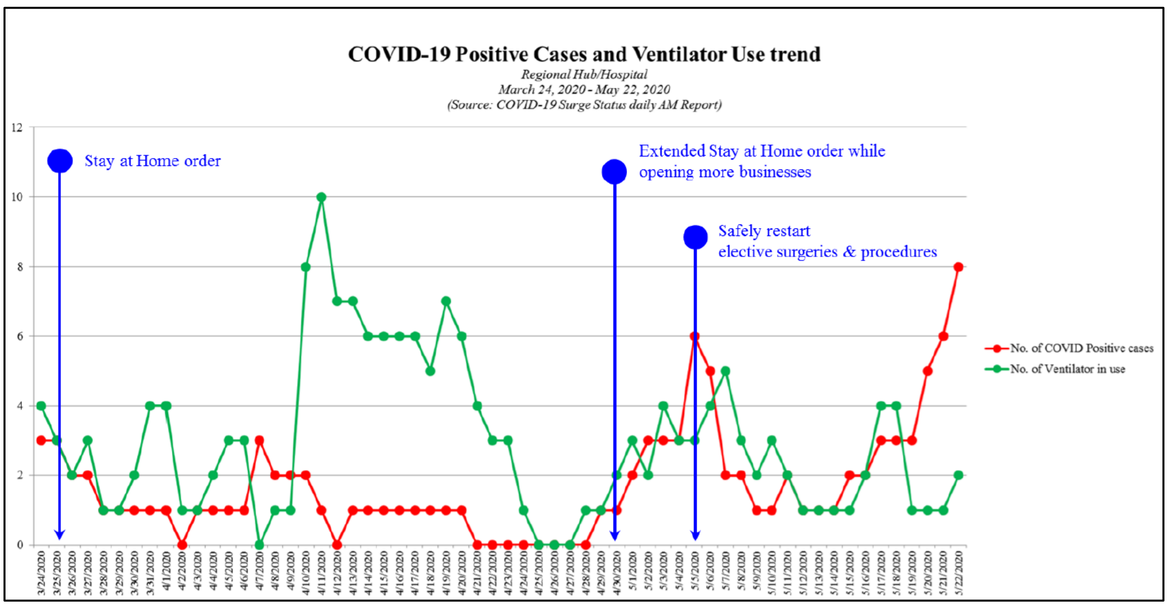


Figure 5. Trend analysis of COVID-19 positive cases and ventilator use

| | |
|---|---|
| Clinical leadership | Social Work/Case Management |
| Critical Care/ Intensive Care | Facilities |
| Hospital operations leadership | Radiology |
| Regional Hospital Incident Command Center | Lab |
| Hospital Nurse managers | Pharmacy |
| Hospital Nursing leadership | Healthcare Technology Management |
| Surgery nursing leadership | Food Services/ Nutrition |
| Surgery operations leadership | Regional Leadership |
| House supervisors | Operations and Nursing leadership |
| Infection Prevention and Control | Regional Operations leadership |
| Labor Pool | Site leadership, Region |
| Supplies/ Supply chain | Nursing practice team |
| Emergency Department | PT/OT/Speech |
| Environmental/ Linen Services | Information Technology |
| Bed Management/ Transfer | Hospital Registration - Outpatient |
| Respiratory Therapy | Hospital Registration - Inpatient |
| Quality | Management Engineering and Consulting |

Figure 6. Key stakeholder groups engaged on a daily basis

### 4.5. Control Phase

Under the monitoring and control phase, an ongoing cadence of daily COVID-19 Hospital/ED planning huddles is still active and in operation. The Surge Planning Daily Dashboard has been improvised from a manual process of extracting the data to automation (report runs automatically every day and goes to the distribution list), and it is still being used on a daily basis. The daily COVID-19 Hospital/ED planning huddle has morphed into a venue where overall COVID-19 modeling (projections of future positive cases/case trends etc.), staff exposures, risk levels at various settings in the community (like Skilled Nursing Facilities), surgery plans, and impact on daily operations due to COVID-19 patient census are all reviewed on a daily basis on weekdays.

As of December 2020, few vaccines to prevent COVID-19 have been authorized for emergency use by FDA in the US. Hence, vaccinations have started to be administered on a priority basis to people such as first responders, healthcare providers, and elderly but hospitals and organizations across the nation are still keeping track of total COVID-19 cases in their organizations and their communities. Similarly, the hospital system in this study continues to closely monitor trends and newer as well as existing cases in the hospital and communities. A lot of tools, techniques, and strategies developed and finalized as part of the Surge Planning Core Team are in place and for good reasons, a lot of what was developed in March, 2020 when all this was started has been replaced by improvised workflows, processes and systems.

## 5. Conclusion and Discussion

This work is among the very first studies that used the LSS tool – DMAIC in developing and deploying a strategy in response to the COVID-19 pandemic. Hospitals have seen a patient surge in light of the pandemic and have been facing challenges in resource allocation. Resources include healthcare providers and other staff, emergency rooms, ICU beds, in-patient rooms, ventilators, personal protective equipment (PPE), etc. Of course, from the public's perspective, anxiety stems from not knowing if the hospital system will have a bed in place if a person becomes acutely ill, and it stems from not knowing if the hospital system will have a ventilator if a patient becomes critical.

The present work has summarized each of the five phases of DMAIC in hospitals in the Midwestern US. A core team has been formed in this specific healthcare system to respond to the surge of COVID-19 cases due to the pandemic. A fishbone diagram, decision tree for patient flow/facilities overflow, and COVID-19 patient surge planning, and a daily dashboard have been developed. A plot depicting the trend for COVID-19 positive cases and ventilator use has been presented. In the cycle of Improve and Control, data tracking and analysis allowed the hospital system to keep rooms and ventilators available during the initial surge. For example, in late May, the team's analysis showed that number of ventilators in use was not directly related to the increased number of COVID-19 patient admissions. In other words, the higher number of COVID-19 patients in the inpatient units did not mean we would need more ventilators. Use of ventilators was dependent on the acuity level of all types of patients, not just COVID-19 patients.

This helped the team reinstitute the existing guideline of transferring patients who needed ventilators when all of the hospital's available and back up ventilators were in use.

With the help of the hospital leadership and the local and state government coalition, analysis helped the hospital system shift staffing needs and better compete for the purchase and distribution of PPE. Iterative analysis assured the necessary lead time needed for other decisions, add negative pressure rooms, proactively purchase correct quantities of PPE etc. It even helped with conditional restaffing as healthcare workers became exposed and were forced to quarantine. These are not just-in-time reactions, they are timely improvements.

This study has important implications for researchers and stakeholders in healthcare in comprehending the successful application of DMAIC as a strategy for patient surge planning in light of the pandemic. A dedicated multidisciplinary team can look at the data, trends, and available resources to plan effectively. This planning results in better preparation for patients who can be treated, which in turn enhances patient as well as healthcare provider satisfaction. Senior managers and policy makers need to fully understand the significance of DMAIC as a powerful problem-solving methodology.

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