Inefficiencies of the COVID-19 Vaccine Distribution in California

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Abstract
As we enter the new year, two companies' COVID-19 vaccines have been authorized for emergency use in the United States. While they are only in the beginning stages of distribution, we have already seen many complications in the United States as each state has a unique policy on its distribution process. Within the state of California, the different counties are dealing with COVID-19 differently depending on the size of the population and geographical location. Depending on these factors, the counties throughout the state have their own ways of distributing the vaccine that is advised by the state. Even though each county has its own distribution method, California as a whole ranked 35th out of the 50 states for efficiency in vaccine distribution as of February 28, 2021. With the efficiency so low, and cases at an all-time high, states need to more effectively distribute the vaccine to those who need it most: at-risk individuals, frontline healthcare workers, and older adults. With the discovery of a new strain, counties within the state must properly contain the spread while administering vaccines in order for the country to rebound from extended lockdowns. Our paper addresses the distribution of the vaccine within California and provides insight on how the state can effectively and adequately do so.

Keywords
Covid-19 Vaccine, Coronavirus, California, Distribution, Pandemic

1. Introduction

On December 11, 2020, the U.S. Food and Drug Administration (FDA) issued the first emergency use of the Pfizer/BioNTech COVID-19 vaccine. This was shortly followed by Moderna, which was issued approval on December 18, 2020 [10]. These relatively quickly mRNA vaccines are meant to slow the spread of the contagious SARS-CoV-2, or COVID-19, which caused the world to experience its first pandemic in over a decade. After initial approval of these vaccines, the FDA recommends who gets vaccinated first with the initial limited supply. After the recommendation, each state, tribe and territory is responsible for developing its own plan for who will be vaccinated first and following groups. "Experts say about 85% of Americans will need to be vaccinated to bring the COVID-19 pandemic under control" [12]. In our project, we are analyzing the plan developed by California and its counties.

The current problem is that the state of California is not distributing the vaccine to its residents at an efficient rate. As of February 28th, 2021 California's resident vaccination rate in units of doses administered per doses distributed to the state is ranked 35/50 states at 73.6% efficiency. The objectives of the paper include breaking down the current distribution process, determining the inefficiencies, and creating improvements that can be made.

2. Literature Review

Many topics of research were necessary to learn about the past, present and future logistics of the COVID-19 vaccine. Research was conducted for the following topics as of February 2021: types of vaccines and manufacturing processes, transportation of vaccines to the state of California, transportation of the vaccines to the counties within California, decisions on people able to get the vaccine, and if people are getting the vaccine when it is available to them.

2.1 Types of Vaccines and Manufacturing Processes

In California, there are two types of vaccines that are currently being offered: Pfizer/BioNTech and Moderna. These vaccines use messenger RNA to add a surface protein to the genetic code of cells in the body, activating the immune system to develop antibodies. Both vaccines have proved to be 94-95% effective in preventing symptomatic COVID-19, when the recommended two doses are received [20]. The manufacturing process of a Covid-19 vaccine is far from easy. It begins with snippets of DNA called Plasmids. Like mentioned above, the plasmids carry genetic material that codes a spike protein on the SARS-CoV-2 virus. The spike protein hooks onto other cells so it can take over the cell and reproduce. This DNA is made in large tanks holding hundreds of gallons of designed E. coli bacteria. This bacteria uses Biosynthesis to produce trillions of DNA plasmids every few weeks. The next step in this process is a purification process that removes everything besides the loops of DNA. A linearization process for the loops using enzymes to cut the circles. From here the batch is frozen, quality checked, and shipped to another facility for RNA conversion. In the next facility, the lines of DNA are transcribed into the mRNA mentioned above. This process occurs in vessels full of enzymes in a 4-5 day period. Next, the mRNA is separated from the liquid it is made from, frozen, quality tested and sent to the last phase. During this last phase, the MRNA is put into tiny balls of fat, allowing them to travel from syringe to the bloodstream without any dissolving. When the vaccine is ready to be placed in vials, it is thawed and put into a vial filling machine [20]. The whole manufacturing process takes thoroughly three days to make.

2.2 Transportation of Vaccine to California

Pfizer's distribution centers are located in Kalamazoo, MI and Pleasant Prairie, WI; these distribution centers ship all of their vaccines safely directly to the location that they will be used. The methods of transportation will be via air to the major hub, then by ground to each of the points of use. The expected time of arrival from when the vaccines are shipped is one to two days to reach the point of use. Using a just-in-time system, the Pfizer vaccines are able to be transported throughout the country while being stored properly. The proper shipping storage for the Pfizer vaccine requires it being frozen by dry ice in an ultracold freezer, thermal shipping container, or refrigerator.

The Moderna vaccine is manufactured with partners from Catalent and Lonza. Working together, these companies are able to ship the vaccines throughout the country from their distribution center in Olive Branch, MS. Moderna will rely on a medical distribution company called McKesson to distribute its vaccine. Shipments from Olive Branch, MS will be shipped to the McKesson distribution centers (cities of Chino and Fullerton in CA) and then they will be delivered by other carriers like UPS and FedEx to the points of use. To be stored properly, this vaccine is to be stored frozen (not by dry ice) and also protected from light when it is being shipped.

2.3 Vaccine Distribution for Counties Within California

As the most populous state in the country, California as a whole has somewhat effectively distributed the COVID-19 vaccine to residents, but results have varied amongst counties within the state. In efforts to expedite the distribution process, the state government has worked to distribute the vaccine in mass quantities by utilizing large, public, drive-in facilities such as stadiums and arenas for distribution. However, even in early stages, there is significant room for improvement. As of February 2021, roughly 74% of the vaccines that have been delivered to California have been administered, and it is expected that this percentage would be higher as the vaccine is in very high demand.

Specifically looking at counties within California, the three counties that have administered the most vaccines in terms of sheer quantity are Los Angeles, San Diego, and Orange Counties as of February 23, 2021. This is logical, as these are the three most populous counties in the state in respective order. As of late February, Los Angeles county has distributed nearly 2 million doses of the vaccine (1,854,920 to be exact), yet this only includes roughly 18.4% of the county's population (4). Urban counties including the aforementioned Los Angeles, San Diego, and Orange have been consistent, with the majority of these urban counties having distributed the vaccine to 18-24% of the counties' population. Rural counties, such as Napa, Humboldt, and Kern Counties have similar percentage ranges as the aforementioned urban, densely populated counties.

A broad look at these numbers may lead someone to believe that there is little disparity in how effectively urban and rural counties are distributing the vaccines. However, it can be observed that the urban counties are

distributing the vaccine more effectively than rural counties in the context that the urban counties have much higher populations and citizens of these counties have drastically higher demand to receive the vaccination.

2.4 Decision on Who Gets the Vaccine and When

California has opted to distribute the vaccine in phases. The goal of the phase-oriented rollout is to ensure equitable distribution and to prioritize based on age and risk. In Phase 1A, healthcare workers and long-term care residents became eligible to receive the vaccine. Phase 1A began on December 14, 2020, as the first COVID-19 vaccine was administered in California, specifically in Los Angeles County. In Phase 1B, individuals 65 and older as well as sector populations such agriculture, education, and emergency services, became eligible to receive the COVID-19 vaccine. This phase began in January of 2021. Phase 1C, estimated to begin on March 15, 2021, will include individuals aged 16-64 deemed at high risk due to severe health conditions that include chronic pulmonary disease, pregnancy, heart conditions, diabetes, and several others [4]. As of February 23, 2021, it is estimated that 9.8 million vaccines have been distributed across California, while approximately 7.6 million residents have received the vaccine.

Following Phase 1, California will enter Phase 2, along with the rest of the nation. In this phase, vaccine priority will be based on age. Most details about this phase have not yet been released. Phase 2 will likely include the general public for vaccine consideration [4].

Many people are getting the vaccine when they are supposed to according to their status within their county; however, because eligibility differs from country to county, this distribution process varies throughout the state. A notable percent of Americans still have concerns about the vaccine, with one in five saying they are reluctant to get the vaccine. About 7% of adults say they would only get the vaccine if it is required and 15% say they definitely will not get it.

3. Methods

To understand the full scope of the vaccine distribution in California, extensive research was done to evaluate vaccine distribution within the state of California. Facts sheets and articles from Moderna and Pfizer pertaining to their respective vaccines were used to understand similarities and differences between these two vaccines' distribution statuses. The authors also incorporated dashboards tracking numbers of vaccines distributed, delivered, and shipped within California, and these dashboards also show percentages of county citizens who have received the vaccine as of a given day. The group of researchers also applied information from articles on the logistics aspect of the vaccine, especially from FedEx, to analyze the transportation methods for the vaccines. Rankings showing how states stack up against one another in terms of vaccine distribution percentage provided insights on how well California is doing in distribution compared to the rest of the United States (percent of vaccines administered compared to vaccines received). Data from vaccine manufacturing processes also came into play when analyzing the Moderna and Pfizer vaccines' manufacturing processes.

4. Data Collection

Our group has comprehensively analyzed all of the most credible news sources and journals to collect the most accurate data on COVID-19 vaccination distribution. The data collected aims to analyze the most accurate and informative data to reveal how the supply chain has performed over time.

The variables collected from the sources are broken down below [12]:

Table 1. Analyzed COVID-19 Variables

Variable	Cumulative/Not Cumulative	Units	Where it was collected:
Total administered doses	Cumulative	(Administered doses)/(time)	California Department of Public Health
Total available doses	Cumulative	(Available doses)/(time)	California Department of Public Health
Percentage of used doses	Cumulative	(Administered doses)/(Available doses)	California Department of Public Health
Vaccine doses administered per day	Not Cumulative	(Doses Administered per day)/(time)	California Department of Public Health

The variables above were used to create numerical and graphical results that will be further analyzed to see the progression of the COVID-19 vaccination distribution and administration over time.

5. Results and Discussion

i. Numerical & Graphical Results

During our graphical analysis and data collection, we first looked at the historical data pertaining to California's vaccine distribution throughout the first two months of 2021. Below are the two charts showing the historical data, the first showing the percentage of received doses that were administered, and the second shows how California has ranked in comparison to the other states throughout 2021 [4].

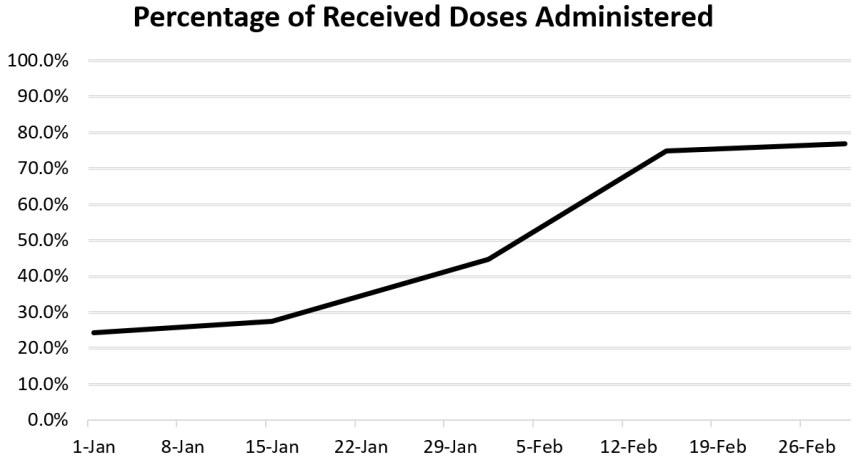

Figure 1. Percentage of Received Doses Administered

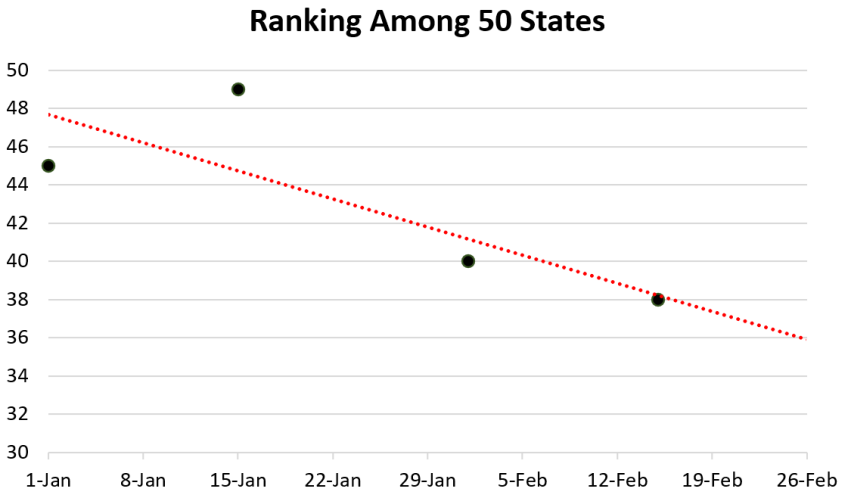

Figure 2. CA Vaccine Administration Efficiency Ranking

Next, data was collected on California's current state, specifically looking at the state's ranking among the 50 states, total doses received, total doses administered, and specific data pertaining to the distribution among the 58 counties within the state [4].

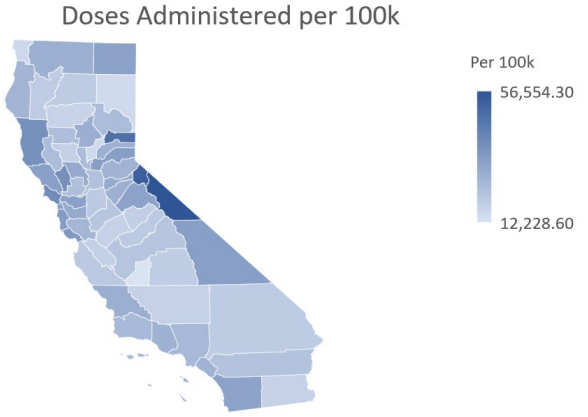

Figure 3. Doses Administered per 100K Citizens

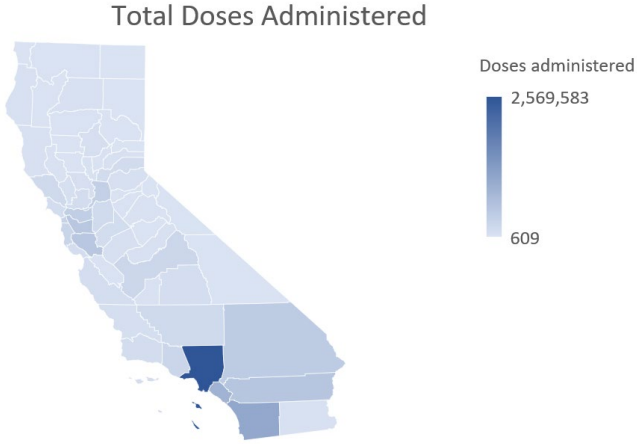

Figure 4. Total Doses Administered in CA

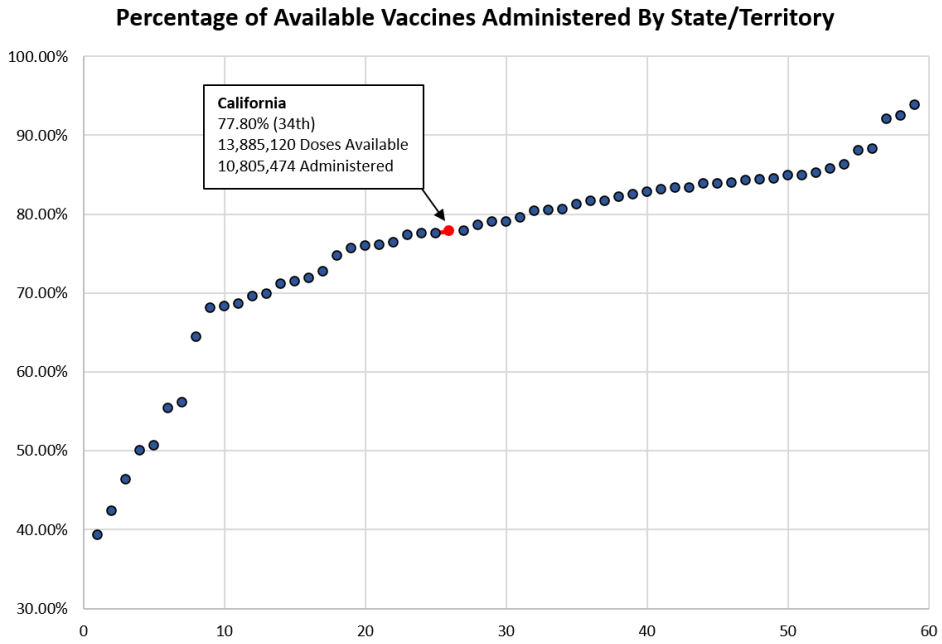

Figure 5: Percentage of Available Vaccines by State/Territory

ii. Proposed Improvements

While California has done an adequate job of distributing the vaccine within counties, the state as a whole can improve to distribute the vaccine to those who need and want it. One step that the state is taking to improve is the implementation of a new program, where the state government will start using the third party enterprise Blue Shield to oversee vaccine distribution [11]. The new program, which has a planned start date of March 4, 2021, will use data-driven hotspots to target populations that have been decimated by the pandemic (based on high death and infection rates) by increasing allocation of these areas for vaccine distribution. The new Blue Shield program intends to increase vaccine distribution in counties where COVID-19 has had the most severe impact on citizens, and it is one improvement that will help California effectively distribute the vaccine to citizens.

In addition to the novel Blue Shield program, another change the state could make pertains to the time sensitivity of the vaccine itself. As the vaccine distribution is time sensitive due to the vaccine's cold storage temperature, states including California had surplus doses that expired after they were unable to administer them within the timeframe required by the time-sensitive vaccine [21]. Storing the vaccine at cold temperatures has proven to be difficult in terms of storage costs, as the costs associated with vaccine storage requires refrigeration, dry ice, and other high-expense storage methods. In order to reduce costs and increase the number of vaccines that go to use, California should gauge the number of people that will accept the vaccine if the opportunity presents itself. This can be done by publicly educating citizens on the benefits of vaccination and canvassing citizens to see how many will want the vaccine if they are presented the opportunity based on state-regulated eligibility criteria.

Another way that California can improve their vaccine distribution process is by expanding the state's eligibility criteria, as the initial doses of the vaccine went to primarily older citizens (per CDC recommendations). In the initial phases of distribution, California made the vaccine available to elderly citizens and frontline workers, yet not all of these individuals actually wanted the vaccine. In order to expedite the distribution process, California state government officials should look to prioritizing those who not only are prioritized but also want to and will receive the vaccine. For example, grocery store workers and other people who interact with others face-to-face on a daily basis should be eligible to receive the vaccine if they have an opening and are willing to receive the vaccine if the situation presents itself.

iii. Validation

To ensure the efficiency of the proposed improvements, validation would include a large-scale supply chain and public sector audit. Part of the audit would involve a system that tracks vaccine shipments and alerts citizens near

where the shipments are received that vaccines are available. The audit could additionally extend to the distribution companies, ensuring they have the assets and resources to properly store and transport the vaccines. On the public sector side, California should survey their citizens to get a more precise idea of how many people will take the vaccine if it is available to them. An audit could be utilized in this scenario in order to check whether each county is doing their part to vaccinate the population and create a standard amongst local government and healthcare of devoting resources to end the pandemic.

6. Conclusion

The coronavirus began spreading in Wuhan, China at the end of 2019 and then by January 2020, China began their lockdown. Soon later, most of the world was on lockdown, including California in March of 2020. "On March 30th, the U.S. Department of Health & Human Services (HHS) started a program they coined "Operation Warp Speed," (OWS) in an attempt to expedite a COVID-19 vaccine" (Brothers). On December 11, 2020 the FDA issued the first Pfizer vaccine, and on December 18, 2020 the Moderna vaccine was approved.

One factor that has caused inefficiencies in California's distribution thus far is the disparity in population densities and demand of vaccines between urban and rural counties within the state. Since urban counties such as Los Angeles, Orange, and San Diego Counties have many citizens who want the vaccine, the demand is much higher in these counties. Taking this into account, these urban counties' citizens are expressing their frustration with the state's inability to fulfill this demand, whereas it is not an issue in rural counties. To alleviate this and ensure that distribution meets the demand, state regulators must incorporate policies to streamline distribution while accounting for the vaccine's time sensitivity and cold storage.

One step California is taking to improve vaccine distribution is the Blue Shield program, which will streamline distribution by taking pressure off the state. The third party Blue Shield will take a data-driven approach by giving vaccines to communities that have been severely affected by COVID contamination and death as a result of the virus. This will help resolve some of the problems that COVID has caused in these communities. Regarding the manufacturing of the vaccine, Pfizer Inc. CEO Albert Bourla announced on February 19, 2021 that the company will add additional capacity to its Kalamazoo site. In addition to the expansion of the site, Pfizer has contacted two new manufacturers to help with production. These efforts will hopefully bring the current manufactured rate of 5 million doses per week to around more than double [8]. Moderna plans to achieve a similar amount of vaccines manufactured per week to around 10 million doses by April 2021 [15]. Moderna plans to achieve the production goals by working closely with partners and the federal government to address production bottlenecks and accelerating production.

With Blue Shield, hopefully distribution efficiency will improve so that 85% of the population can be vaccinated, which is the target number, in order for the pandemic to be considered under control.

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Biographies

Matthew Grywczynski is a fourth-year Industrial Engineering major at Cal Poly San Luis Obispo, with a passion for project management, operations, and technical sales. He has previously worked as a Sales Engineer Intern for Meter, Valve & Control, Inc., a small manufacturer's representative located in the San Francisco Bay Area. Matthew is currently working on a project with Driscoll's Berries to improve their sample cup labeling process. He hopes to continue to learn how to use data to develop advanced business solutions.

Jared McMullen is a senior Industrial Engineering major at California Polytechnic State University, San Luis Obispo. Jared has interned at companies with position titles, "Manufacturing technician," "Process Engineer", and "Sales Engineer." He is currently working as a Sales Engineering Intern for the company Shiphawk, an industry leader for order fulfillment automation software. Outside of school, Jared enjoys ice hockey, surfing the California coast, and traveling.

Matt Akins is a senior Industrial Engineering major and Entrepreneurship minor student at Cal Poly San Luis Obispo. Since starting his education at Cal Poly, Matt has interned at Center Street Lending as a Junior Associate, E. & J. Gallo Winery as a Supply Chain Engineer, and at Niagara Bottling as a Packaging Developer. He is currently working on a project with teammate Jack Rocca to develop an augmented reality solution to be used in the building and design industry. After graduating this upcoming March, Matt plans to continue to work for Niagara Bottling as a Packaging Engineer.

Carter Bergquist is a senior Industrial Engineering major at Cal Poly, San Luis Obispo. He is passionate about process improvement, project management, and technical sales and is on the executive board of Cal Poly's Sales Engineering Club. He previously interned as a Process Improvement and Manufacturing Intern at Northwest Aerospace Technologies, a subsidiary of Safran Aircraft Interiors. He currently works with fellow collaborator Jared McMullen on conducting additional research on productivity for the start-up SitFlow, an under-desk apparatus used for simultaneous exercise while working in a seated environment for Senior Project. After graduating this June, he plans to enter the Sales Engineering Development Program with Ingersoll Rand.

Jack Rocca is a fourth-year Industrial Engineering student at Cal Poly, San Luis Obispo. Jack currently works as a Manufacturing Facility & Supply Chain Design intern for Demant Hearing Devices and is the Project Analyst on Cal Poly's Systems Optimization Club's project with WhiteFox Defense Technologies. Jack is also working on his senior project with Matt Akins, working to find a solution for Augmented Reality in the building and design industry.

Mohamed Awwad is an Assistant Professor in the Department of Industrial and Manufacturing Engineering at California Polytechnic State University (Cal Poly), San Luis Obispo, CA. He received his Ph.D. and M.S. degrees in Industrial Engineering from the University of Central Florida, Orlando, FL, USA. Additionally, he holds M.S. and B.S. degrees in Mechanical Engineering from Cairo University, Egypt. Before joining Cal Poly, San Luis Obispo, Dr. Awwad held several teaching and research positions at the State University of New York at Buffalo (SUNY Buffalo), the University of Missouri, Florida Polytechnic University, and the University of Central Florida. His research and teaching interests include applied operations research, logistics & supply chain, blockchain technology, distribution center design, unconventional logistics systems design, and OR applications in healthcare and the military.