Impact of COVID-19 on Household Cleaning Supplies

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Abstract
The COVID-19 Pandemic has brought unprecedented changes to companies' supply chains in every sector of the economy. One of the most impacted segments of our economy has been the cleaning supply industry. In this research, we determine the extent of the impact that the COVID-19 Pandemic has had on supply chains and the overall production of cleaning supply companies. The Pandemic has exponentially accelerated demand for cleaning products such as disinfecting wipes and cleaning sprays, causing a nationwide shortage. Ostensibly, companies were not prepared to meet the sudden increase in demand as shortages of products from both companies have plagued supermarkets and goods retailers since the Pandemic began. This paper discusses the supply chain operation pre-pandemic and the ripple effect the increase in demand has had on the supply chain. We analyze how the supply chain has coped with the strain brought on by the new demand and determine which tactics and strategies were most effective in meeting these challenges.

Keywords
Household Cleaning Supplies, COVID-19, Demand, Shortages, Supply Chain

1. Introduction
1.1 Background
SARS-Cov-2, better known as COVID-19 or coronavirus, is a viral respiratory illness that first emerged in Wuhan, China, in early December. As of November 22, 2020, there have been nearly 58 million cases, with over 1.375 million deaths (Sauer 2020). On January 30, 2020, the Director-General of the World Health Organization (WHO) declared COVID-19 a Public Health Emergency of International Concern (World Health Organization 2020). Since then, governments worldwide reacted to this new pandemic with stay-at-home orders, mask mandates, social distancing measures, and deeming businesses essential vs. non-essential. While citizens have reacted in many ways to government regulations worldwide, one common trend among the public has been panic buying resulting in shortages of many different products.

1.2 Problem Identification
The rise of the COVID-19 pandemic has impacted many different industries throughout the entire world. One of the most affected has been household cleaning supplies, including products like aerosol sprays, disinfecting wipes, multipurpose cleaners, and hand sanitizer. As COVID-19 spread globally, consumers began hoarding and bulk buying household cleaning supplies causing the demand to rapidly increase to a level that companies could not have predicted. From January to June of 2020, there has been an average increase of 23% in production volume of cleaning and sanitizing products compared to production in January to June of 2019 (ACI 2020).

This unpredictable spike in sales has forced companies to make adaptations to their current production. In this paper, we will be analyzing the changes in the supply chain due to increased demand from the COVID-19 pandemic and evaluate what has been most beneficial in combating these unexpected numbers. We will also suggest the next steps for supply chains in the household cleaning supplies industries once a vaccine is released and the demand for products is expected to decrease.

1.3 Objectives

The COVID-19 pandemic created once-in-a-generation issues for the global supply chain. The surges in demand and supply shocks that accompanied established the importance of investigating how successful companies were able to cope with the new demand and supply constraints. Thus, the objectives of this study are:

- Determine how the cleaning product supply chain has been impacted by the increase in demand from the COVID-19 pandemic.
- Determine which tactics and strategies were the most effective in meeting these challenges.
- Provide analysis of the tactics and strategies as they relate to meeting these challenges.
- Suggest future steps to be taken once vaccine administering begins

2. Literature Review

2.1 Sales and Demand Trends

We began our research by analyzing quantitative data in terms of the sales and demand trends since the beginning of the COVID-19 pandemic. It was important to start our research to better understand the exponential spike in demand that resulted in shortages of disinfection products around the world. Some of the data we found included things such as percent sales growth of certain disinfectant products (Statista Research Department 2020), consumer answered shortages of disinfectant products (Conway 2020), and production increase of disinfectant products (ACI 2020). A good example of statistical data we analyzed is shown below. Figure 1 shows the growth rate of the disinfectant market and ethanol over the past five years in China (Klemes 2020):
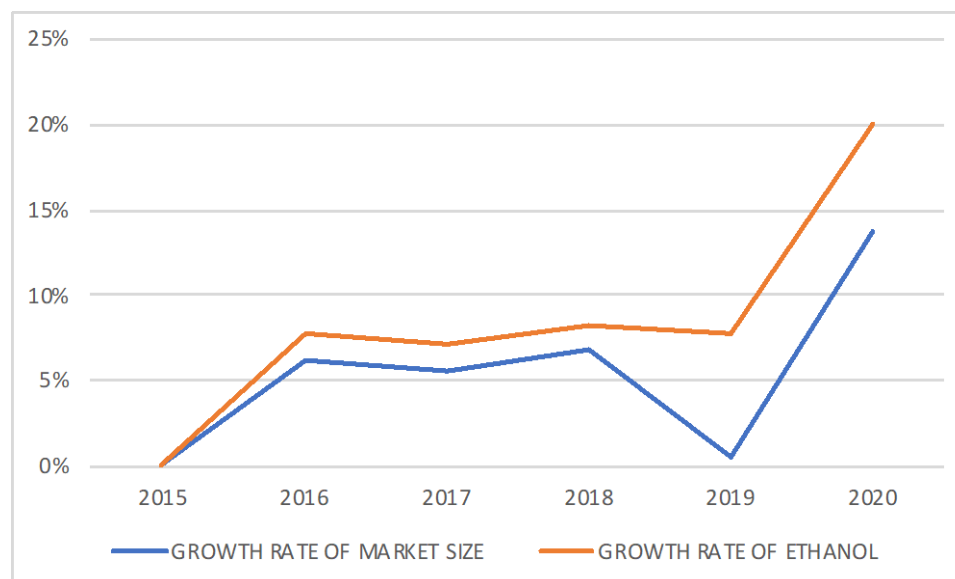

Figure 1. Growth rates of the disinfectant market and ethanol in China

2.2 Supply Chain Relationships

In any industry, understanding the supply chain relationships is crucial. But when demand is unpredictable and both sales and demand are experiencing exponential growth, it is even more important. Within the supply chains we analyzed the relationships of suppliers and distributors of household disinfectants. For supplier relationships, we make the distinction between tier 1 and tier 2 suppliers and benefits both bring to the supply chain as well as outsourcing of suppliers (Buckley 2020). Benefits of companies incorporating additional supply chain methods such as the inclusion of new technology will also be discussed (Barter 2020).

2.3 Effective Methods for Supply Chains

In addition to supply chain relationships, we also looked into effective supply chain methods, specifically those affected by COVID-19 (Barter, 2020; Esper, 2020). We first looked into forecasting as a method to combat the unknown future demand, but unfortunately, our research proved that there is not one specific method to forecast demand during COVID-19 (Nikolopoulos, K. et al. 2020). One prominent way that came up in our research was

product prioritization. Many companies have slowed production or completely stopped production on certain products whose demand has not been affected by COVID-19 to help focus their attention on shortages within other products (Cosgrove 2020).

3. Methods

When the pandemic forced a shelter in place order at the beginning of March, cleaning supply companies witnessed a buying frenzy, completely wiping out a typical month or so worth of inventory in retailers and a couple of months' worth of inventory in the supply chain, in just a matter of weeks (Chain Drug Review 2020).

In an attempt to catch up with the current and plan for a future increase in demand, cleaning supply companies immediately started running their plants 24/7. However, to continue production without pause, companies first ensured the safety of their own workers. These safety measures included virus education, transmission methods, adjusting operating processes to operate safely during a pandemic (social distancing of workstations and scheduling break room times), and setting up on-site testing protocol (taking temperature, symptom questionnaires). Essential companies have recognized the vitality of its people, especially during this time. Therefore, many have modified pay and sick leave policies and implemented temporary wage increases, special bonuses, and an employee emergency relief fund (Sorokanich 2020).

The life of a cleaning supply product spans a wide variety of supply chains, from manufacturing the cleaning agent, packaging, and labeling. Because there are so many elements involved in the supply chain from start to finish, many companies have been vital to increasing communications with their suppliers. It has been crucial during the pandemic that companies take the time to work with each partner in the process to understand individual supplier capacities and capabilities. Without the suppliers, the end product is not possible, and companies can only increase their capacities if their suppliers' capacities allow for it as well. Recently, to meet this ongoing demand, many companies have also begun to outsource production to external manufacturers and qualify additional suppliers to increase capacity and capability (Sharma et al. 2020).

Due to the pandemic, thousands of businesses have mandatorily shut down operations. Cleaning supply companies have been categorized as an essential business and therefore have not been directly affected by these shutdowns. However, many factors within the supply chain, such as transportation, have been heavily disrupted. To combat these disruptions, some companies have partnered with government entities to ensure vital components in the supply chain are able to remain open. For example, the majority of products in the cleaning supply chain are transported via truck. These trucks cover thousands of miles and need food and rest stops along the way. Companies have partners with government entities to keep rest stops open along tuck routes to ensure transportation can continue safely and uninterrupted (Sorokanich 2020).

Another vital change that cleaning supply companies have had to make to meet the demand for certain cleaning products is cutting down on their variety of products they offer (Neff 2020). Companies are finding it vital during this time to focus production efforts on the current market need, sanitization. For many companies, this included temporarily discontinuing certain products that are less in demand, eliminating product features such as scents, and even introducing newer, simplified product types to reduce production cost and time. In the specific case of a company like Clorox, with the unprecedented demands, Clorox cut down on their variety of scents and packages and focused its manufacturing companies on producing only the essential products for their consumers.

Aside from the cleaning supplies in-store, the e-commerce of cleaning supplies also soared. Freudenberg Household Products (FHP) pure e-commerce profits alone went up by 60%. As sales continue to grow, companies also want to ensure that their products are continuously being accessible to all of their consumers. Thus, many of them started services such as "order and pick up" and deliveries. Through these different channels, the cleaning supply companies are ensuring that they are providing a channel for their consumers to buy their products and continuously grow their profit.

The various methods implemented during this pandemic have temporarily helped keep up with the increasing and unpredictable demand. However, the actions taken in response to COVID-19 will, in turn, reshape manufacturing, transportation, and other elements within the supply chain in the future years to come (Brannen 2020).

4. Data Collection

This pandemic has arguably brought the greatest uncertainty that the supply chain has ever seen. Companies must adjust their supply chain methods to best fit the market need to combat the unpredictable demand for cleaning supplies. Table 1 identifies various models and combinations that can perform more accurately than methods used pre-COVID-19. Examples of forecasting methods and their corresponding categories of forecasting are listed below in Table 1:

Category	Method
Time-series	Naïve, Moving Averages (four models 2,3,4,7), SES, ETS, ARIMA, Theta, TBATS, ANN_AR, G&M (1985)-Damped trend (Gardner & McKenzie, 1985), Holt - Trend, ns-HW (non-seasonal Holt-Winters), ARFIMA, GARCH(1,1) (six models, wih: GED, SGED, NORM, SNORM, STD, SSTD), ARIMAx, Naïve-d with drift (ten models with step of 0.1 for the drift[a])
Machine Learning	Multiple linear regression (MLR), Ridge regression, Decision Trees (DT), Random forest (RF), Neural Network (NN), Support vector machine (SVM).
Deep Learning	Long-Short Term Memory networks (LSTM)
Others	Splines, Sigmoid, Partial Curve Nearest Neighbor methods (PC—NN), Multivariate Clustering based Partial Curve Nearest Neighbor methods (CPC—NN)
Epidemiological	SIR (two models with: beta=1.16, gamma=0.38[b]; beta=1.4, gamma=0.3[c])

Table 1. Forecasting methods

These methods establish logic that the demand will depend on the country (i.e., lockdown procedures, case increases). Therefore, the forecasting method should also be separately determined based on the country.

Partial Curve Nearest Neighbor Forecasting (PC-NN) - finds similarities between the parts of a curve - in this case, the curve will measure the start of the time series of COVID-19 in a country until the date on which the forecast is made.
    Steps:
1. Collect data for a period of T days on daily cases for a set of N countries
2. Fit a smooth curve to each data series from each country separately
3. Calculating the daily changes in the smooth curve for each country
4. Compare the daily changes curve of each country
5. Define groups for each country and its closet nations
6. Forecast

Clustering and Partial Curves and Nearest Neighbor Forecasting (CPC-NN) are similar to the PC-NN method but use a multivariate data set and a clustering algorithm. The data set includes COVID-19 related factors and well as socioeconomic and climate factors that should be considered during formulation. Implementing the algorithm groups countries into clusters that are likely to face similar situations and challenges surrounding the effects of COVID-19 in the future (Ivanov 2020).

Government regulations and policies have heavily dictated consumer behavior when it comes to cleaning supplies. For example, a government lockdown or quarantine could generate anxiety and result in increased purchasing or even hoarding. Forecasting during a pandemic needs to be dynamic to account for the variability within the demand. The model also needs to account for changes in external circumstances and constantly has to be adjusted with new information taken into account. It has proven to be challenging to forecast within cleaning products supply chains because it is one where demand is variant on the perception of individual needs. Research shows that consumers often make non-realistic estimates about their own inventory levels with unrealistic assumptions and limited data (Chandon,

et al. 2006). During a pandemic, consumer buying behavior is heavily influenced by their environment. It is difficult to forecast when demand is volatile and relies on individual consumer's evaluations and fear of a stockout.

While forecasting methods utilized for various supply chains will differ, during a pandemic, supply chains should implement two general concepts:
1. High volumes of inventory should be produced for essential products before a lockdown occurs or COVID-19 cases spike.
   a. This conclusion is based on data of actual product needs and also takes into account often bias and irrational buying behavior during a pandemic
2. Forecasting methods need to be continuously adjusted to account for changing needs and perceptions.

5. Results and Discussion
5.1 Evaluation of Sales and Demand Trends
The household cleaning products supply chain currently relies on a just-in-time supply chain approach. This means that materials are moved just before they are needed in the supply chain, which reduces the need to store excess materials in the warehouse. Because of this, the cleaning products supply chain has proven ineffective to combat short term changes in demand due to the limited excess stock. Figure 2 shows the percent of consumers unable to find typical household cleaning products due to the inability of the supply chains to meet demand (Conway 2020):
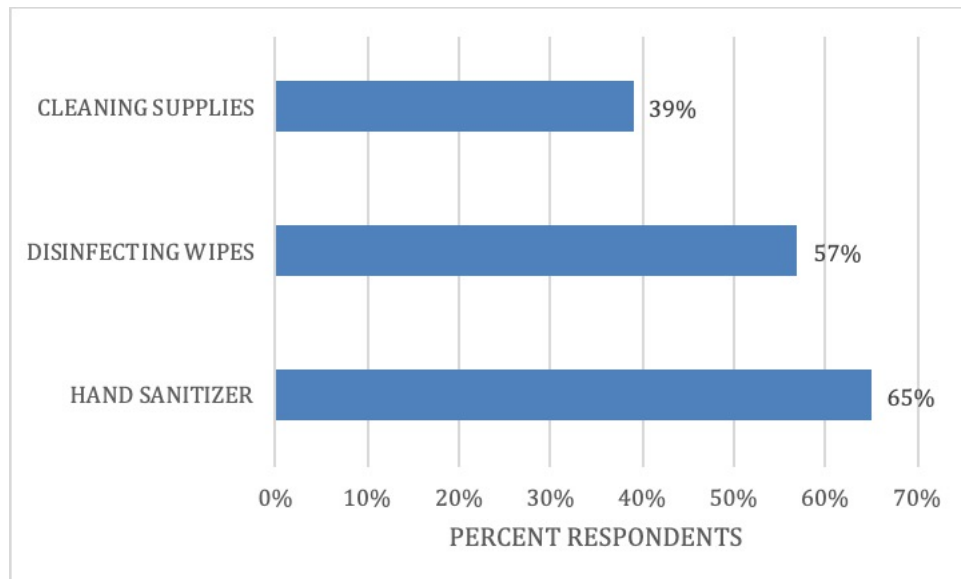

Figure 2. Products consumers are having trouble finding in stores (April 2020)

In addition to the just-in-time approach, supply chains for household cleaning supplies are also struggling due to the shortage of raw materials. Two key ingredients in disinfecting products are ethanol (rubbing alcohol) and hydrogen peroxide. Below is a graph showing the sales growth of ethanol and hydrogen peroxide from February 1, 2020, to February 29, 2020, in the United States (Statista Research Department 2020):
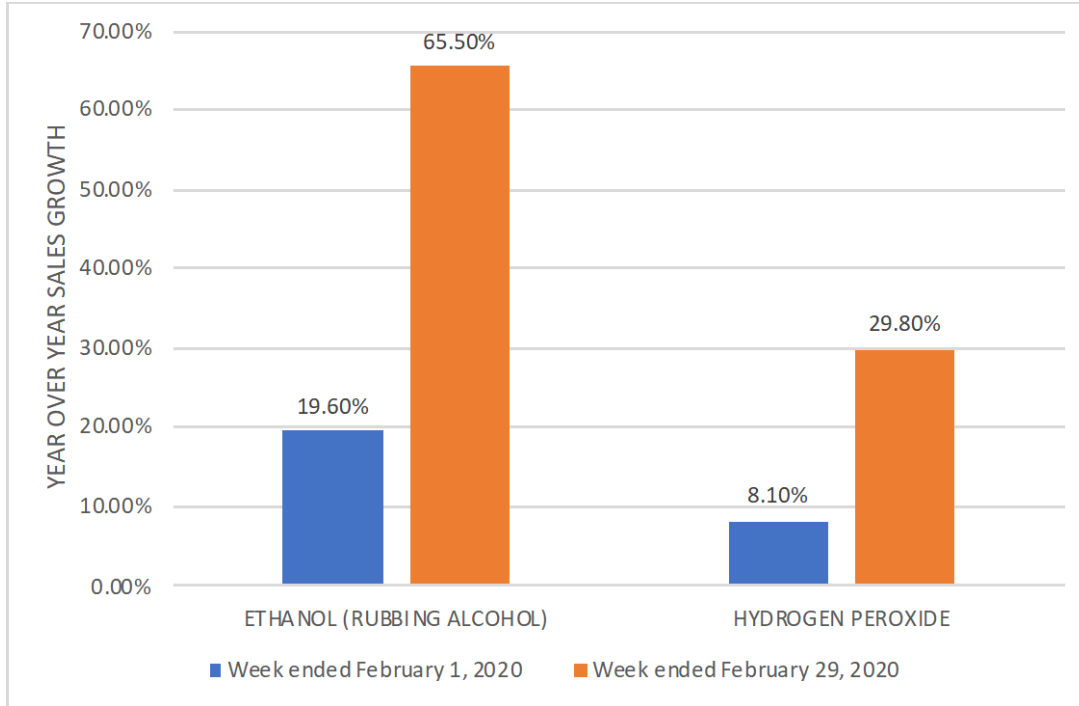
Figure 3. United States sales growth of disinfecting ingredients in February 2020

In the United States, three manufacturers produce almost all of the disinfecting compounds used in products like disinfecting wipes, sprays, and hand sanitizers. They cannot keep up with the current demand. Because of this, prices of products like ethanol (rubbing alcohol) have gone up, with one-pound costing between 6-8X more than what it was before COVID-19. This has led countries like the United States to outsource materials from companies worldwide and with the Environmental Protection Agency (EPA) relaxing regulations to get products out quicker.

5.2 Analysis of Successful Tactics and Strategies in the Supply Chain

For many years, a cross industry has focused on reducing cost in the supply chain–optimization to utilize assets efficiently, minimize costs, and reduce inventory size necessarily removes buffers that absorb delays and disruptions. Therefore, many companies were not able to fully understand their risk position and their vulnerability to shocks through their supply chain relationships. Those companies that were able to leverage new supply chain technologies, develop intimate supplier relationships before the pandemic and increase agility through production planning were able to cope with the sudden supply chain shocks, and the tangential demand increase brought on from the pandemic (Barter 2020).

Fundamentally, the intimacy of supplier relationships was a huge factor in being able to meet demand. According to a study in the successes of the companies who were able to adapt to the changes brought on from COVID, the companies who were initially successful were able to pinpoint Tier 1 supplier risk and mitigate that risk effectively. Critically, they were able to garner sufficient understanding of their Tier 1 suppliers' ability to meet supply requirements and the potential risk level of that supplier well before the pandemic demand came in force: This primed these companies for the huge influx in demand. (Barter 2020)

Successful companies built intimate relationships and gained direct access to Tier 1 suppliers, their production schedules, and their purchase order fulfillment status. These companies were also able to source direct and immediate information from an allocation perspective in the event of inventory and capacity shortages from their supplier. Active communication and formulating alternative plans became critical to minimizing the supply chain impact on the producing company. For reference, a Tier 1 supplier provides what the manufacturing company needs to make its products. Tier 1 suppliers have sub-suppliers who provide them with materials to make their devices; these are the Tier 2 suppliers. Having a nuanced understanding of the Tier 2 suppliers in the supply chain was also an important

factor in company success. In fact, companies with complex supply chains that embraced IoT and digital approaches to visibility in the supply chain were the least likely to experience disruption due to increased demand (Barter 2020).

Successful companies were also able to source multiple alternatives for a single component in both Tier 1 and Tier 2 suppliers. In fact, the Companies who were able to move quickly to activate secondary supplier relationships in order to secure additional critical inventory and capacity found greater degrees of success than those who could not (Barter 2020). Shared resource pools for raw materials inventory is part of this tactic. In fact, abroad, particularly in Asia, successful companies have used this approach in the past in times of crisis.

Another example of a supplier relationship developed in light of COVID-19 has been the use of breweries and distilleries to make hand sanitizers and other disinfecting agents (Nissen et al., 2020). Breweries and distilleries already have the infrastructure and most of the raw materials making the transition to the production of hand sanitizers and disinfectants fairly simple. According to The American Craft Spirits Association, about 75% of its distillery members are now producing alcohol for use as a disinfectant (Buckley 2020). Companies have also expressed concerns with outsourcing as this could create unintentional competitors. Outsourcing to breweries and distilleries decreases the chances of this happening (Kaplan 2020).

The prioritization of certain products and scheduling agility in the production schedule was also necessarily a successful function. By prioritizing which products, the companies would produce in the event of raw and direct material inventory shortages, and they were able to develop action plans that would negate the negative consequences of having significant shortages by meeting the demand of another product (Cosgrove 2020). This became critically important where a component part was used in multiple finished goods. The companies ensured they were able to better meet demand by preparing to refine production schedules based on the inventory available, changing demand, and *manufacturing capability.* At the same time, these companies ensured they did not overuse component parts that would cause stockouts of their most in-demand products. The traditional planning and scheduling processes and the so-called "dead" or "frozen" periods to allow production to run efficiently, were found unlikely to work well for these companies. Those companies who did not have the tools to support rapid re-planning and scheduling could not keep up with the increase in demand without dedicating expensive resources to emergency production re-planning (Barter 2020).

A case study of the scenario involves the cleaning supply company Clorox. To meet unprecedented demand, they had to reprioritize production and cut back on the variety of products sold to produce the specific ones in high demand. As a result, this ate away at their market share for certain products, but the increase in demand did increase their revenue. According to Lisah Burhan, VP of investor relations, "Clorox has left sales on the table and given up market share due to stockouts. While we've been able to add significant capacity, demand still far exceeds supply, leading to continued out-of-stocks for many products" (Cosgrove 2020).

5.3 Future of COVID-19 Affected Supply Chains

As we get closer to a COVID-19 vaccine, companies may face another drastic change in demand. With the vaccine administration, it is suspected that the panic buying phenomenon related to the pandemic will begin to cease. It's predicted that the vaccine will not be fully dispersed until late 2021 at the earliest. Below is a table showing the phased COVID-19 vaccine dispersal plan for the United States from the National Academy of Medicine (Weise 2020):

	PERCENT POPULATION	RECIPIENTS OF VACCINE
PHASE 1A	5%	- Front-line health workers - Ambulance drivers - Cleaners (hospitals, clinics, etc.) - First responders
PHASE 1B	10%	- Those with underlying conditions that put them at significantly higher risk - Those with two or more chronic conditions - 65 and older in group living facilities

PHASE 2	30-35%	- Critical Workers in High-Risk Situations - Teachers - Childcare workers - Those with underlying conscious that put them at moderately higher risk - All people under 65 who are in prisons, jails and detention centers - Everyone else in 65 and older age range
PHASE 3	40-45%	- Young adults and children (if safe for them) and people who work in industries such as: - Hotels - Banks - Higher Education - Factories
PHASE 4	5-15%	- Everyone else residing in the U.S.

Table 2. COVID-19 vaccine dispersal plan

The exact timeframe of each phase in the COVID-19 vaccine dispersal plan is unpredictable, especially when there is no set start date to begin vaccine administration. Thus, the best strategy and recommendation would be to be ready for the change in demand and arrange the company strategies and resources accordingly. For example, based on the table above, roughly 50% of the population will have been vaccinated after the completion of phase 2. With most of the population vaccinated, it's likely the demand for household cleaning supplies will drastically decrease. Because of this, companies should create a plan in phase 2 to alter their current supply chains, such as decreasing the amount of outsourced materials or easing production. Overall, household cleaning product companies should reevaluate supply chains over shorter periods of time and increase flexibility to better prepare for the vaccine rollout.

6. Conclusion

The long-time industry focus on reducing cost in the supply chain removed buffers that absorb delays and disruptions that would have allowed cleaning companies to better handle the demand shock from the COVID-19 pandemic. Many companies we analyzed were not able to fully understand their risk position and their vulnerability to shocks through their supply chain relationships and as a consequence were underprepared and under-equipped to handle the enormous supply shocks and demand shocks brought on by the pandemic.

There are, however, a variety of factors that influence whether cleaning supply companies were able to meet the demand brought on by the COVID-19 pandemic. Of importance was the ability to adjust production forecasting models to reflect changes in consumer demand instantaneously accurately. However, this is easier said than done for most companies, especially those who did not previously allocate sufficient resources to produce accurate and timely production planning. Another pivotal factor in the companies that were able to meet the demand was their supply chains' knowledge. In general, the greater the knowledge of their supply chains, the greater ability these companies had to forecast potential issues, especially deeper in their supply chains such as within their tier 1 and tier 2 suppliers

Companies that were able to prioritize key products and schedule in an agile way to meet the new production constraints found higher rates of success than companies who were unable to do so. By prioritizing which products, the companies would produce in the event of raw and direct material inventory shortages. They were able to develop action plans that would negate the negative consequences of having significant shortages by meeting the demand of another product. High volumes of inventory should be produced for essential products before a lockdown occurs or COVID-19 cases spike.

As the COVID-19 pandemic continues to accelerate and vaccine rollout begins, demand and supply will ostensibly be in states of uncertainty for the near future. Therefore, as these companies move forward in the "COVID Economy," it becomes paramount to establish counteractions to demand and supply shocks. Based on the findings in our report,

companies who wish to be successful should increase visibility in their supply chains and assess demand within a nearsighted window. Companies should also continuously update their production strategies to accommodate these changes in demand until economic conditions and demand stabilize.

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Biographies

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Morgan Cameron is in her last quarter at California Polytechnic State University, San Luis Obispo, studying Manufacturing Engineering and hopes to enter the medical device industry. After graduating in June, she plans to make a cross country trip with friends. Her interests include traveling, going to the beach, watching movies, and painting.

Jack Ng is an undergraduate senior at California Polytechnic State University, San Luis Obispo, studying Industrial Engineering interested in project/program management. After graduation, Jack hopes to find a full-time IE position in the tech industry and continue his education by either pursuing a master's degree in engineering management or business administration.

Brandon Yowakim is an undergraduate at California Polytechnic State University, San Luis Obispo, majoring in Industrial Engineering. He's interested in operations research, engineering test design/analysis, and data system design. After graduation, he hopes to continue research and education in those areas as well as quantitative economics. His unrelated activities include producing music, making films, and writing.

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.