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Extending the Value of Predictive Analysis for Demand Forecast and Scheduling Reconsideration

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The COVID-19 pandemic has put a lot of pressure on the healthcare and construction industries. The high transmission rate of virus variants and the low rate of return to work after patients recovered from the disease are the main reasons for this situation. This research focuses on the influences of construction project management challenges on scheduling considerations. After the literature review, this paper compares three event-study methods to establish a methodology for both a regional and a national project demand forecast. Then, this paper explains the process of data collection on economic impacts on labor-intensive markets like construction and demand forecast. In this research, the available datasets were extracted and analyzed from the Department of Health and Human Services and the National Healthcare Safety Network. The analysis indicates that around 20-60% of the population in the U.S. was influenced by the pandemic on the national level. About 30% of the population was affected in the selected state. Using case studies, expert knowledge, and statistical simulations, the data analysis identified causes of resource shortages and substances of scheduling reconsideration. The results indicate that project managers should carefully assess the changed resource limitations that call for flexible and resilient scheduling approaches.

Key Words: Project Capacity Analysis, Value Prediction, Project Management, Scheduling

Introduction

The COVID-19 pandemic, also known as the coronavirus pandemic, is an ongoing global pandemic of coronavirus disease 2019 (COVID-19) caused by the severe acute respiratory syndrome-coronavirus-2. On November 1, 2020, Coronavirus Disease Dashboard Global data, there had been 45,942,902 confirmed cases of COVID-19, including 1,192,644 deaths reported in 219 countries and territories, and more than 18.5 million people recovered (WHO). Moreover, from January 3 to November 1, 2020, there were 8,952,086 confirmed cases of COVID-19 with 228,185 deaths in the U.S. Globally, the United Nations faced a global health crisis unlike any in its 75-year history. The New York Times (DePillis, 2022) reported on Sept. 12, 2022, that the COVID pandemic had caused a loss of at least 500,000 people in the U.S. labor market. The high transmission rate of virus variants and the low rate of return to work after patients recovered from the disease are the main reasons for this situation. Experts predict that if the infection rate in the U.S. cannot be effectively contained, the labor gap may exist for a long time. In early 2022, global economic conditions were weaker than expected (IMF, 2022). Countries have reintroduced measures to limit the movements of people as new Omicron mutants continue to spread. Inflation has risen more than expected, particularly in the U.S. and many emerging markets and developing economies, driven by higher energy prices and supply disruptions. In many labor-intensive markets like construction and hospitality, they used to absorb large numbers of youth employment. Currently, many young people have been laid off or unemployed after graduation, unable to find decent jobs. Since the shortage of skilled construction laborers has been considered a serious issue (Kim et al., 2020), the relevant consideration needs to be thoroughly sorted out.

In the construction industry, such a labor shortage even causes project delivery delays and cost increases. The influences of the pandemic in the U.S. on the labor market are obvious. One million Americans died, unfortunately, and 260,000 of them did not reach their retirement age (DePillis, 2022). Not only that, millions of Americans are retiring early or forced to leave their jobs to care for their families and children. Today, although companies have gradually resumed production and operations, the data shows that the overall willingness of Americans to work is still not as good as before the epidemic (DePillis, 2022). Americans already employed or were looking for a job accounted for 62.4% of the population in August, 1% lower than before the outbreak. Edelberg, director of the Center for Economic Policy at the Brookings Institution, explained that the demand is higher than the supply in the current labor. Therefore, project managers and schedulers should thoughtfully examine resource limitations like skilled labor shortages.

Current scheduling practices often consider weather impacts regarding durations and costs (Marzoughi et al. 2018). Yet, with the skilled labor shortages and unexpected sickness leaves, more practical deliberation should be given to the analysis and predictions of labor shortages and duration extensions. The paper first compares three commonly used event-study methods of a mean-adjusted model, market-adjusted returns model, and risk-adjusted returns model for data analysis. Then the paper discusses the predicted labor demand and calculates the statistics of labor shortages. The following sections show how the construction industry is striving and adjust project schedules to accommodate labor shortages during COVID-19 and how the shortage of capacity can be overcome.

Background

The huge associated number of cases of COVID-19 leads to increasing pressure on hospitals, particularly ICUs, around the globe. The acute shortages of ICU beds, facilities, and staff raise multiple ethical dilemmas related to how to efficiently share the limited available resources to ensure the best possible outcomes (Hao, 2020). Overwhelmed hospitals had to reject patients because of the shortage of life-saving resources and overworked doctors. In the U.S., 20-60% of the population was affected by the disease (Health Affairs Blog. 2020). Among those who develop symptoms, most (about 80%) recovered from the disease without needing hospital treatment (meaning patients with mild symptoms can be treated at home). About 15% became seriously ill and require oxygen and 5% became critically ill and need intensive care. Lispsitchs et al. (2020) estimated that 98,876,254 individuals would be infected, 20,598,725 individuals would require hospitalization, and 4,430,245 individuals would need ICU-level care based on 40% prevalence throughout the pandemic.

Medical facilities like hospitals became the main source for the majority of infected or symptomatic people to seek treatment. The facilities were usually restricted by their capacities when the number of cases increased (especially those in critical condition). The ability of one facility to recover from the influences caused by disturbances is considered its resilience, which depends on its preparedness. Low resilience affects the sustainability of health services.

Researchers are skeptical about whether the U.S. has enough hospital beds to fight the virus spread. CNBC. (2020, April 30); According to a study by Johns Hopkins University, if the U.S. were hit with moderate to severe pandemic outbreaks like the flu of 1918 (a.k.a., Spanish flu), 1 to 10 million people across the county needed to be hospitalized. The New York Times (2020, March 17). Before the outbreak, the NY state had 53,000 beds in 187 hospitals. But that was not enough because more than 57,000 people have been hospitalized for COVID-19 infections in New York alone as of April 26, 2020. There are two main reasons that the U.S. healthcare system is so ill-equipped to handle a crisis (Baldwin 2020; Flynn 2020). The first reason is that over the past four decades, U.S. hospitals have shed more than half a million beds. Secondly, there is a decades-long trend of hospital mergers and closures that have reduced access to care in communities across the nation. Furthermore, it is critical to flatten the infection curve and mitigate the devastation of the coronavirus pandemic (Medical Express 2020). Blavin (2020) suggested that if the curve was not flattened, hospitals across the country would not have the capacity 'to deal with the surge in hospitalizations associated with COVID-19'. The New York Times (2020) also indicated that in 40% of markets around the country, hospitals would not be able to make enough room for all the COVID-19 patients even if they could empty their beds of other patients.

Even though the market of healthcare construction projects seems to grow rapidly, the skilled labor shortage that the construction industry is experiencing has been intensified by the pandemic. For example, Bettisworth (2018) noticed that the availability of skilled labor resources had a significant influence on project success, which, however, was often considered as a risk factor, instead of a project execution effort. The data from the California labor market showed that workers 55 and older represented 18% while the workers between the ages of 16-25 counted for 9%. The former is almost twice the number of the latter one. After five years, the age-occupation relationships among four categories of workers on a construction site, including carpenters, cement masons, laborers, and operating engineers may have changed. Nevertheless, operating engineers have the most baby boomers than the other occupation types, and this labor group will retire and exit the labor market in the next five years. Given the current labor market situation, the skilled labor of operating engineers will continue to see a shortage for a decade. It becomes a warning sign to the construction industry when the age distribution among occupation types is imbalanced. The age make-up of laborers in the construction market of California may not represent the situation in the entire country, but operating engineer jobs require more training and experience than the other types. Approximately 70% of laborers were over the age of 36 and 50% of workers were over the age of 46. Since this survey was completed before the pandemic, this alarming tendency may very likely continue or even deteriorate because young people (25 or younger) are entering the workforce at a lower rate while much more old people (55 or older) are retiring.

The following comparison (Table 1) between the event-study methods of a mean-adjusted model, market-adjusted returns model, and risk-adjusted model for data analysis, is to identify event causes. This research analyzes the data collected from different sites and validates the accuracy of the data reported by hospitals and published at the state and national sites. The mean-adjusted model is effective in the analysis of cross-sectional analyses like resource shortage, the discrepancy between the state and national reporting, and the projected demand calculated. Though COVID-19 impacted different countries in diverse ways and to varying degrees, this pandemic has demonstrated that sharing best practices is crucial. For example, Kim et al. (2020) suggested that more effort should be spent on the analysis of the impacts of skilled labor shortage on construction project management. An integrated system dynamics can combine the advantages of statistical analysis and simulation to identify the causes and impacts of such shortages. Yet, they only established simulations for five scenarios, which restrained the implementation of their findings (Kim et al., 2020). Researchers affirmed that the construction industry needs to close the gap in knowledge on scheduling reconsiderations caused by the pandemic. This research proposed to study a practical and predictive analytical method for the influence forecasts of skilled labor shortages. The corresponding research objectives are to help industry practitioners understand the trends and impacts of skilled labor shortages and the causes of such situations and to make recommendations for scheduling reconsideration based on recent best practices.

Table 1

Comparison of event-study methods

Method	Definition	Example
Mean adjusted model (Larsen and Resnick, 1999)	A mean-adjusted model corrects statistical averages that included obvious imbalances because of outliers in the dataset, for instance, by inserting categorical variables that separate the data more precisely.	Health Affairs Blog (2020, March 17) used a middle-level estimate of the COVID-19 infection rate of 40%, assuming lengths of stay based on published studies. The model assumed that 50% of pre-occupied beds could be freed up to care for COVID-19 patients. They found that a hospital's referral region affected inpatient and ICU bed capacity significantly. They also observed large variations in the availability of both regular and ICU beds across communities, for instance, some rural communities have adequate numbers of regular beds but often large shortfalls of ICU beds, whereas many more-populous communities have inadequate numbers of total beds but smaller shortfalls of beds.
Market-adjusted returns (Larsen and Resnick, 1999)	Market-adjust returns models use market values at the time to calculate the coefficient adjustments.	This compartmental model can estimate the daily numbers of hospital bed shortages for patients with mild, severe, and critical COVID-19 situations, taking into account underreport and diagnosis delay. The NCBI (2021) used a mathematical model to simulate the epidemic curves of COVID-19 in 51 cities after the adjustment for temporal variation in reporting rates and estimated the shortage of inpatient and ICU beds. They confirmed that the healthcare system was weakened significantly and delayed the provision of healthcare to patients during the lockdown.
Risk-adjusted model (Konchitchki and O'Leary, 2011)	A risk-adjusted model offsets the risks of an individual event.	The NCBI PMC7685049 (2021) investigated global hospital bed (HB), acute care bed (ACB), and ICU bed capacity and determined any correlation between these hospital resources and COVID-19 mortality using a risk-adjusted model. This cross-sectional study utilized data from the WHO and other official organizations regarding global HB, ACB, and ICU bed capacity and performed descriptive statistics and linear regressions. They proved that high-income regions had the best resource allocations of HB and ICU beds, whereas upper-middle-income regions had the highest mean number of ACBs. A weakly positive significant association was discovered between the number of ICU beds and COVID-19 mortality. No significant associations exist between the number of HBs or ACBs and COVID-19 mortality.

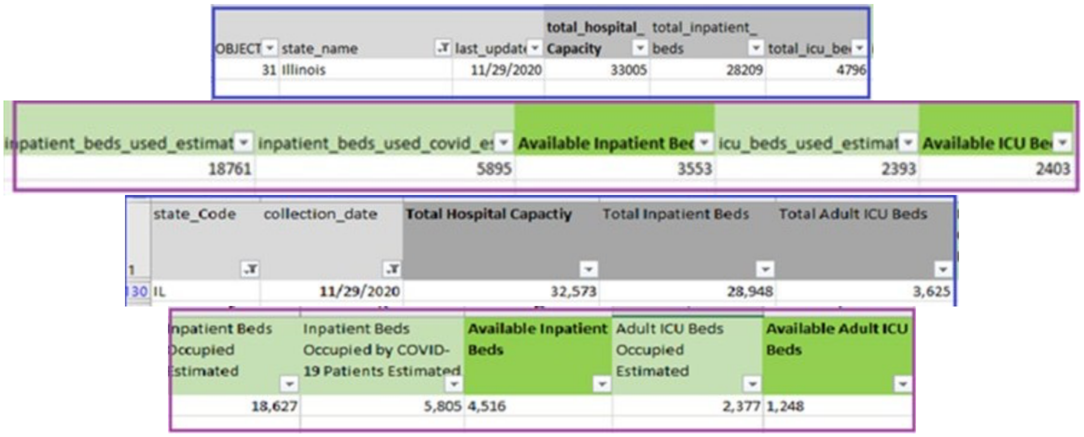
Methodology

The research assumes that real-world data is useful to gather evidence on utilization, population health, and the impact of interventions during COVID-19. The data is collected from reports about U.S. acute care hospitals, critical access hospitals, inpatient rehabilitation facilities, inpatient psychiatric facilities, and long-term acute care hospitals. These hospitals report the COVID-19 data to have access to the data analysis tools through the NHSN applications. Facility-level data is shared in public health emergency response activities by CDC's emergency COVID-19 responses. The DHHS requires all hospitals licensed to provide 24-hour care to report certain data necessary to the all-of-America COVID-19 response CDC. This report of Hospital Data Coverage is representative of the prior week from Friday to Thursday and lists the information of each hospital in the state, the percentage of mandatory fields reported, the number of days reported at 100%, whether a hospital is required to report on Wednesdays only, and each required field with the number of days that specific field was reported for the week. For facilities that are only required to report once a week, the overall count of days will state "100%" and individual field counts will show as "7" if reported successfully or "0" otherwise.

Many hospitals were under unprecedented strains of resources, with limited capacity to treat patients. The Food and Drug Administration (FDA) encourages users and facilities who are concerned about the distribution of a medical product, or anticipate a potential or actual shortage, to notify them. Estimates of hospital capacity are available at the national and state levels on the HHS, CDC, and definitive health care has the overall U.S. hospital beds dashboard. The main pandemic data tracking system is run by the HHS and NHSN. Estimated hospital utilization data are available for the U.S. states, and territories. This data is estimated from hospital submissions, either reported through their state or reported through HHS Protect or NHSN COVID-19 Module.

Organizations monitor data on hospitals' utilization and capacity rates to help researchers, healthcare leaders, and the public identify places with low capacity. They also leverage real-world data to design modeling tools that can help hospitals and health systems plan for critical care surges (Health IT Analytics 2020). Publicly available epidemiological data on COVID-19 and clinical outcomes data from multiple hospitals can help to build the interactive data platform and track hospital bed capacity. State-level organizations also utilize real-world data to demonstrate the impact of COVID-19 on certain communities. These are reliable data sources.

The available data sets were extracted from the HHS and the NHSN of the CDC. The following uses Illinois to analyze the available tools and databases for accuracy (Figure 1). This research utilized several monitoring tools, such as ArcGIS Dashboard® (GARMIN 2020), Definitive Healthcare®, and the Illinois department of public health, to validate the data values. The following activities were performed after the data access was granted: (1) Extracting the data from the databases for each state, based on the selected categories, and creating a master data file in excel. (2) Merging the data files through excel based on the selected data elements for the master data file. (3) Cleaning up the data, by removing invalid and duplicate values. (4) Construct the data where needed based on the research hypothesis. (5) Analyzing only Illinois state data along across all the datafiles and monitoring tools for accuracy. (6) Understanding the conditions used for predictions of demand in healthcare.



OBJECT	state_name	last_updat	total_hospital_ Capacity	total_inpatient_ beds	total_icu_be
31	Illinois	11/29/2020	33005	28209	4796

inpatient_beds_used_estimat	inpatient_beds_used_covid_es	Available Inpatient Bec	icu_beds_used_estimat	Available ICU Be
18761	5895	3553	2393	2403

	state_Code	collection_date	Total Hospital Capactiy	Total Inpatient Beds	Total Adult ICU Beds
130	IL	11/29/2020	32,573	28,948	3,625

npatient Beds Occupied Estimated	Inpatient Beds Occupied by COVID-19 Patients Estimated	Available Inpatient Beds	Adult ICU Beds Occupied Estimated	Available Adult ICU Beds
18,627	5,805	4,516	2,377	1,248

Figure 1. Screen Shot of Data Files

Results

Estimates of hospital capacity are available at the national and state levels. At the same time as the COVID-19 pandemic continues to disrupt the status quo, the industries turn to real-world data to better understand, monitor and prepare for risks. But not all the results published are straight forwards, and there are many internal factors to determine how the published data could affect a project schedule. As each healthcare facility and organization considers different data elements for reporting and calculating, the capacity and utilization of the reports show different values. Such difference is captured in Figure 2 for the state of Illinois, based on the data reported and collected from all the counties by the Illinois Department of Public Health and the Definitive Healthcare COVID-19 Capacity predictor.

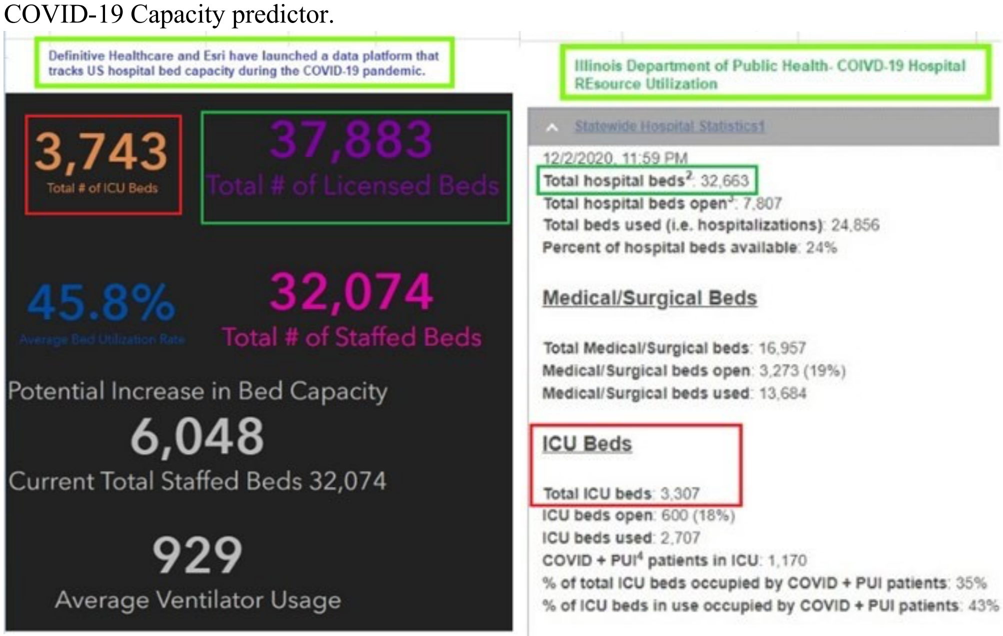


Figure 2. Screen Shot Comparisons from Definitive Healthcare COVID-19 Capacity Prediction and Illinois department of public health COVID-19 Hospital Resource Utilization.

In the U.S., among those who develop symptoms, most (about 80%) recover from the disease without needing hospital treatment, but studies also show that many hospitals across the U.S. regularly operate with most of their beds taken by patients, limiting their ability to handle a sudden increase of COVID- 19 patients. As of December 2022, the infectiousness of a COVID-19 patient usually begins to decrease after day 5, but the patient should continue isolation for at least 10 days if in moderate or severe situations (CDC, 2022). A construction schedule should include the possible influences caused by both the continuing skilled labor shortage and the volatile absence caused by the pandemic.

The number of activities and the number of participants in a construction schedule rely on its complexity. Assume a construction project schedule has 100 activities. It includes 20% critical-path activities, which require 80 people as human resources. Using a 95% confidence level, if the same population (approximately 80) were to be sampled on multiple occasions, the estimates of a parameter (in this case, the delay of each critical-path activity) were made on each occasion, this confidence level means that the most-likely average of delay (a.k.a., the true population parameter) falls in the resulting intervals is approximately 95% of the cases. Let n = 40 (50% of 80); x = 7.5 days (based on (CDC, 2022)); s = 2.5 days. The *z* value should be 1.960. The confidence interval of the average delay is calculated using Equation 1. Hence, the CI is $7.5 + 1.960*2.5/\sqrt{40} = 8.275$ days. In the worst-case scenario, the 20 critical-path activities would have 165.5 days of delay. Using the result from Figure 2, 35% - 45.8% of patients could be COVID-positive. Using the mean adjusted model in Table 1, the most likely delay of the project is 165.5 * 0.35 = 58 days.

$$CI = \bar{x} \pm z\frac{s}{\sqrt{n}} \quad (1)$$

Conclusion

The surge in demand for healthcare projects triggered the expected shortage of mechanical systems and other construction materials in the entire market. Construction companies should be ready for the ripple effects of the market caused by the number of infected patients. Project schedules should be adjusted to incorporate the availability uncertainty of skilled construction laborers. This research shows an approach to estimate the most-likely delay of a construction project schedule using publicly available data and a mean adjusted model. More discussions should be encouraged on the project control recommendations amongst team members. This could improve the economic recovery from the pandemic for the country.

This research focuses on the predictive analysis for labor demand forecast and scheduling reconsideration of construction project management. One limit of this research is the data of actual project delay issues because of time duration and scarcity of recorded cases. Future research should consider how to tailor the existing training settings of the construction industry and help reduce structural unemployment.

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