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Improving Construction Safety: Lessons Learned from COVID-19 in the United States

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Abstract: During the COVID-19 pandemic, construction accidents in the United States (US) dropped dramatically compared to previous years. This research uses Saunders' research onion approach to conduct a deep and systematic analysis of pre- and post-COVID-19 data to understand this phenomenon. The proposed research framework examines safety and prevention measures implemented by the US government, using data collected from various US government agencies, including the Occupational Safety and Health Administration (OSHA), Centers for Disease Control and Prevention (CDC), and US Bureau of Labor Statistics. COVID-19's effects on construction site health and safety were analyzed and ranked in order of efficacy in a hierarchy of control, and findings reveal a number of safety measures that can potentially be implemented to promote improved construction safety even after COVID-19 is over.

Keywords: Occupational Safety and Health Administration (OSHA); Centers for Disease Control and Prevention (CDC); COVID-19; OSHA recommendations; CDC guidelines; construction safety; health and safety

Citation: Ko, C.-H.; Abdulmajeed, H.A. Improving Construction Safety: Lessons Learned from COVID-19 in the United States. *Sustainability* **2022**, *14*, 7137. https://doi.org/10.3390/su14127137

Academic Editors: Wei Tong Chen, Ying-Hua Huang and Han-Hsiang Wang

Received: 28 February 2022
Accepted: 8 June 2022
Published: 10 June 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

1.1. Research Background

Safety is a constant and urgent concern in the construction industry, where worker safety is regularly compromised by risky working conditions, unsafe work practices, lack of adherence to set safety measures, inadequate material and technical support, and lack of proper communication, making it one of the world's most hazardous industries. In 2019, US construction site deaths totaled 1066, a 6% increase over the previous year and the highest total since 2007 [1]. Beginning in early 2020, the COVID-19 outbreak had a severe impact on construction sectors around the world, particularly in the United States (US) [2], with construction workers roughly five times more likely than employees in other industries to be hospitalized due to COVID-19 infections [3].

In 2020, the US Bureau of Labor Statistics (BLS) [1] recorded a total of 4764 fatal work injuries, representing a 10.7% fall from 5333 in 2019 and the lowest annual total since 2013. Of these, construction workers made up 1008, a fall of 5.3% from 2019 [1]. Figure 1 shows that this drop in construction worker deaths coincides with the outbreak and spread of COVID-19. The authors in [1] state that "the rate of injury cases also decreased in 2020, with private industry employers reporting a rate of 2.2 cases per 100 full-time equivalent (FTE) workers compared to 2.6 cases in 2019". Restrictions implemented in response to the COVID-19 outbreak resulted in a significant drop in safety incidents [4]. Workers are aware of the situation and adhere to safety protocols stipulated by the various occupational safety teams. The year 2018 had lower deaths reported than 2019, with 2019 being the year with the highest number of deaths. The year 2017 had the lowest number of reported deaths, at 971 deaths. In the year 2016, 991 construction laborers died [1].

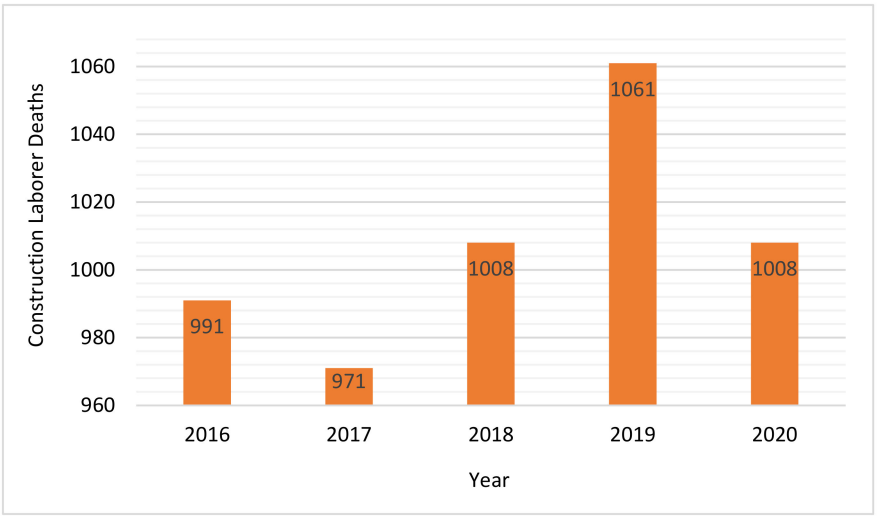

Figure 1. Construction Laborer Deaths in the United States [1].

However, scant research has sought to draw lessons from the impact of COVID-19 on construction worker safety. Existing studies on COVID-19 in the construction industry have examined the impacts of the pandemic on GCC construction [5] and construction safety practices [6]. It was also inspired by the fact that this was one of the major pandemics affecting the whole construction industry irrespective of location, unlike other pandemics, which have only affected specific areas. This made it possible for its impact to be so large, and irrespective of the means the industry took to reduce it, it was still felt. With this understanding, it is necessary to come up with a research paper discussing its impacts and actions taken by different bodies such as OSHA as a precaution in case of another pandemic such as this in the future.

Globally, the construction industry ranks fourth in terms of fatal work injury rates [1]. However, the rapid spread of the COVID-19 pandemic in late 2019 and early 2020 severely impacted construction sites around the world [7–9], resulting in work suspensions and new safety protocols to prevent the spread of the disease [5,6]. While people in many other occupations were able to continue their work remotely, such arrangements are not possible for construction workers. An analysis by occupation in the United States found that construction workers had symptomatic transmission rates of 10.1%, second only to correctional workers at 12% [10]. An additional 5.7% of construction workers were infected asymptomatically, the highest rate among all listed professions, with food service workers a distant second with 3.8% [10].

1.2. Research Objectives and Questions

This study seeks to understand the impact of COVID-19 on construction worker safety and to investigate the impact of the anti-COVID safety measures on general safety on construction sites in the United States. Data on the current health and safety of construction workers were collected from US government agencies, including the Centers for Disease Control (CDC) (https://data.cdc.gov/browse?category=NCHS&sortBy=last_modified, accessed on 15 January 2022), the Occupational Safety and Health Administration (OSHA) (https://www.osha.gov/pls/imis/establishment.html, accessed on 11 December 2021), and the Bureau of Labor Statistics (BLS) (https://beta.bls.gov/dataQuery/search, accessed on 8 January 2022) along with relevant scholarly research.

Three questions are developed to help guide the research and define the study's scope:

- What impacts has COVID-19 had on worker health and safety in the US construction industry?
- What new construction industry health and safety practices have been established by governing bodies in response to COVID-19?

- What are the implications of the new CDC and OSHA safety protocols for the safety of construction workers in the field?

The remainder of this paper is organized as follows. Section 2 explains the research methodology. Section 3 reviews the impact of COVID-19 on construction sites. Sections 4 and 5 respectively discuss OSHA and CDC safety protocols implemented in response to COVID-19 to answer research questions two and three. Finally, research findings are documented in Section 6.

2. Literature Review

Considerable research on the construction industry has recently focused on the impact of COVID-19. Ogunnusi et al. [11] quantitatively explored the impact of COVID-19 on construction procurement and opportunities using data collected from procurement professionals in the United Kingdom (UK). Also in the UK, Sierra [12] conducted a systematic literature review to identify seven major challenges facing building contractors, while another such review by Pamidimukkala and Kermanshachi [13] identified 17 challenges. The authors in [14] conducted 34 telephone interviews with superintendents, designers, engineers, and project managers to assess the early impact of COVID-19 on the US construction industry. However, for the most part, these analyses largely rely on questionnaire surveys, interviews, and literature reviews, without direct assessment of actual COVID-19 cases in the studied regions [15–18].

The impact of COVID-19 on construction delivery is an area of particular concern [19–21]. The duration of construction projects is dependent on time and resource constraints [22,23] regardless of project type [24,25]. The global surge of positive COVID-19 cases raised an urgent need for the rapid construction of critical care units. Zhang et al. [26] used smart construction technologies, real-time module logistics, and automatic modules to build the first COVID-19 quarantine camp in Hong Kong. Another article concludes that effective leadership structures and professional development can facilitate health care delivery models during COVID-19 [27]. In China, urgent emergency hospital projects are also being studied in this unprecedented situation [28].

In addition to duration, cost is a key project success factor [29,30]. Following public health guidelines regarding the disinfection of construction sites will increase construction costs. Kim et al. [31] analyzed the cost feasibility of COVID-19 response guidelines for construction projects in South Korea using CYClic Operations NEtwork (CYCLONE) models [32–34], while Al Mansoori et al. [35] conducted a similar investigation in the United Arab Emirates (UAE). In the US, multiple regression analyses based on K-fold cross-validation sampling and Monte Carlo simulations have been used to forecast cost impacts due to COVID-19 OSHA citations [36].

Various regions and countries have responded differently to the pandemic. As the world's largest economy, the US has served as a broad reference for the approaches adopted by other regions and countries. Previous studies have comprehensively analyzed the challenges caused by COVID-19. Prediction of the project duration and cost under the impact of COVID-19 have been thoroughly analyzed. Construction safety has become a priority in recent years. Worker safety has taken precedence over project progress and costs. However, the impact of COVID-19 guidelines on construction fatality has rarely been addressed.

3. Methodology

The proposed research design adopts the Research Onion Framework to generate a visual representation of the methodology employed in this study (Figure 2) [37] and to design the research scheme (Figure 3). Relevant events are tracked in a timeline to allow for analysis and comparison of pre-COVID and post-COVID statistics. The developed research schema allows for a complete breakdown of the topic, including the core construction safety lessons from the COVID-19 period, along with other relevant aspects, to reach deeper conclusions.

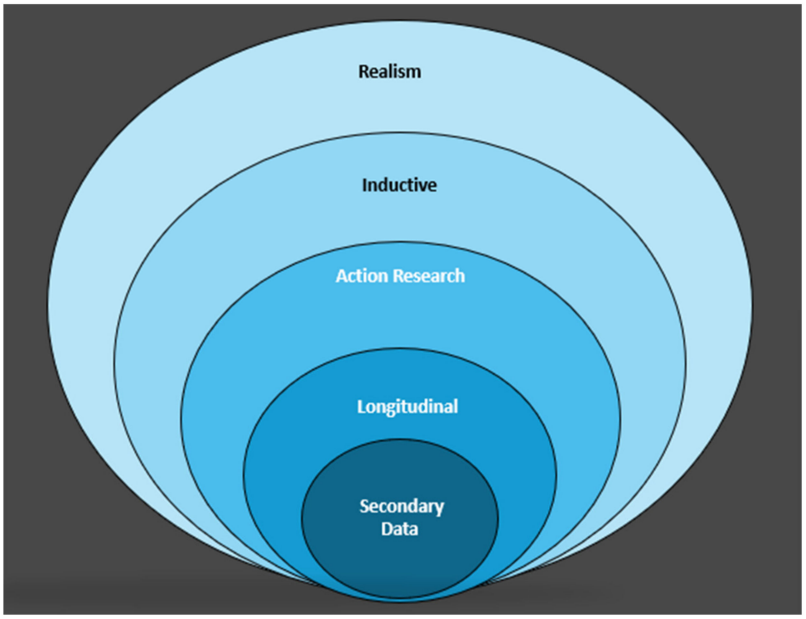

Figure 2. Research Onion Framework [37].

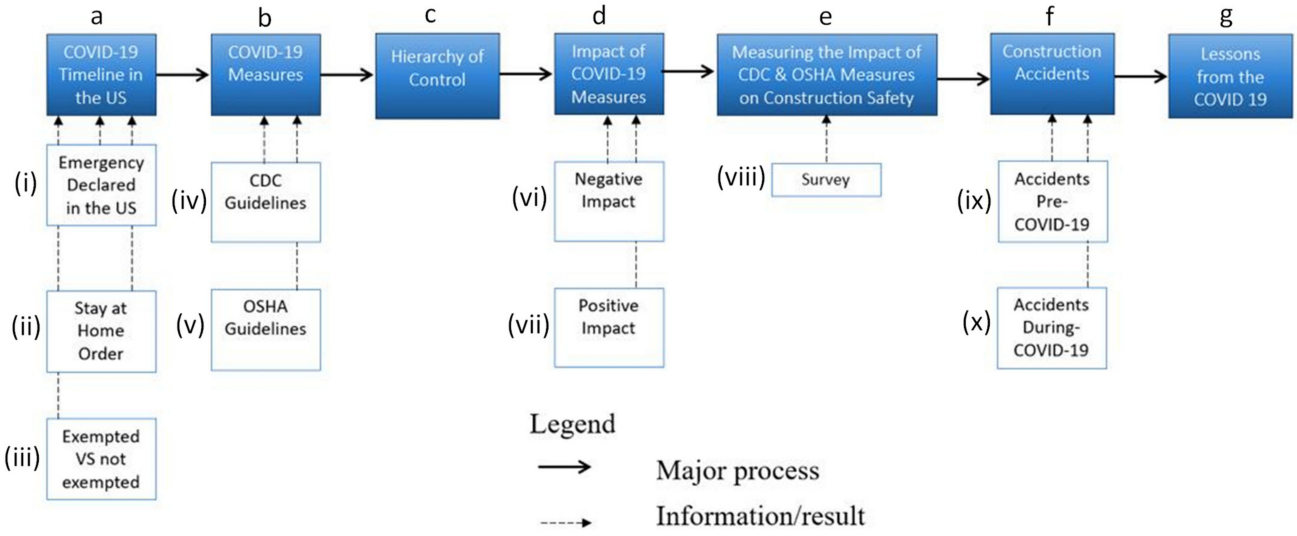

Figure 3. Research Schema.

The present research focuses on investigating the current situation regarding the construction site and laborer safety based on realism. An inductive approach was applied to the previous year's statistics for laborer deaths, with the analysis presented in Section 4 to assess the current state of safety in the US construction industry. The review of construction safety prior to COVID-19 also uses an inductive approach to compare standards before and during the pandemic. The third layer, action research, in which researchers actively participate in planning, implementing, and monitoring, provides a means for achieving a systematic review to obtain information from various sources as a basis for a critical analysis of the measures set by OSHA and the CDC. The construction worker safety data [38] for 2016 to 2020 forms the basis for the longitudinal research. Additional secondary data is sourced from websites, journals, and previous papers to assess trends in construction worker safety standards since the beginning of the COVID-19 pandemic. The websites include CDC, OSHA, and BLS; the literature is searched from the electronic databases of ScienceDirect, Google Scholar, and the American Society of Civil Engineers (ASCE). Selection criteria include keywords of "construction", "safety", and "COVID-19".

This research conducted a systematic analysis of the initial phase of the COVID-19 outbreak in the United States from March 2020 to December 2020 (Figure 3). In the first step, (a) "COVID-19 timeline", we analyzed the offset of COVID-19 in the US, looking at government-implemented precautions. Sub-step (i) reviews the professions deemed essential and allowed to continue working and those deemed non-essential. Sub-steps (ii) and (iii) shows the order in which various workers were transitioned to stay-at-home in all but seven states. In step (b), the two agencies primarily responsible for establishing regulations and guidelines for the general public and workers are (iv) OSHA and (v) the CDC. The next step (c) uses the hierarchy of control [39] to analyze these precautions in terms of effectiveness. The impact of COVID-19 on construction worker safety is analyzed in step (d) and categorized as positive in step (vi) and negative in step (vii). The literature review is then supported by a survey in step (e), which aims to make up for the lack of current statistics available to analyze the impact of COVID-19 using (viii). In step (f), sub-steps (ix) and (x) analyze data on the number of accidents before and during COVID-19 to ascertain the impact of COVID-19 on construction workers' health and safety. The implications of these impacts are assessed, and possible solutions are proposed in order of effectiveness in step (g).

4. COVID-19 Impact Analysis

4.1. Construction Laborer Absence Due to Health Conditions

Construction projects require extensive manual labor, and labor shortages can severely delay project completion. Figure 4 shows trends for US labor absences from January 2012 to January 2022 due to health issues, including an injury, illness, or medical appointment, over the past ten years [40]. Absences markedly increase with the COVID-19 outbreak, reaching an all-time high in April 2020 with around 2.1 million laborers unable to work for health reasons, at a time when many work sites were struggling to meet OSHA and CDC guidelines. The knock-on effects of these productivity drops created a severe impact throughout construction supply chains [22–25].

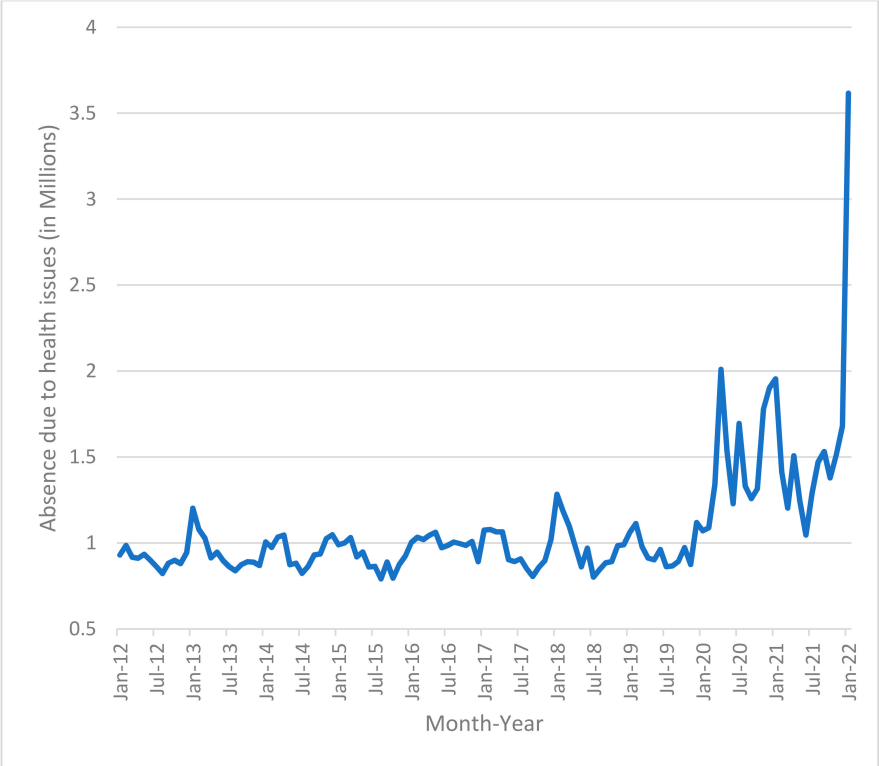

Figure 4. Laborer Absence Due to Health Issues from 2012 to 2022 [40].

4.2. OSHA Construction Site Inspections and Citations

An OSHA compliance officer issues a citation in response to discovering a breach of an OSHA standard or a safety hazard at a construction site during an inspection. The citations present the site owner with a list of violations and the proposed penalty. Citation data was analyzed beginning in 2011 to obtain an extensive view of OSHA inspection and citation practices, to better isolate the impact of COVID-19. To establish statistical significance, Figure 5 shows a gradual drop in both inspections and citations from 2011 through 2019, but a sudden fall in both from 2019 to 2020. The authors in [41] also noted that this fall in inspections coincided with an increase in worker complaints.

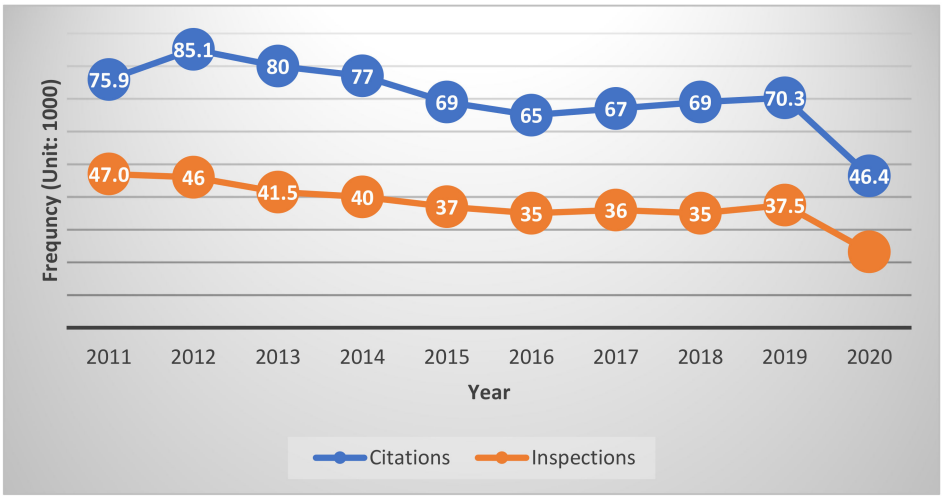

Figure 5. Number of OSHA inspections and citations in construction [2].

4.3. Shortage of Personal Protective Equipment (PPE)

Figure 6 tracks requests for different types of facial PPE over the first half of 2020, showing a dramatic increase in March and April of 2020, led by surgical masks and N95 masks, while requests for face shields and safety goggles were significantly fewer. This reflects a general shortage of PPE due to increased demand from other industries, and the resulting shortage increased the risk of COVID infection and exposure to other construction site hazards such as dust.

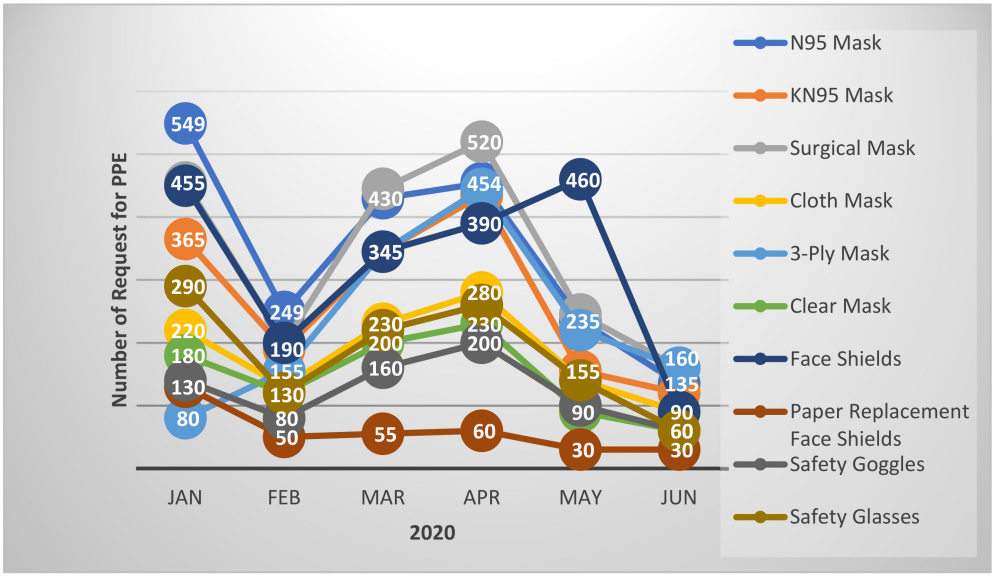

Figure 6. Construction Industry PPE Requests [2].

5. Health and Safety Regulations during COVID-19

5.1. Construction Health and Safety Risks before COVID-19

The risk of viral transmission for construction workers extends beyond job site tasks. Workers must travel to and from the site, use shared cafeterias, restrooms, and tools onsite, and sometimes share onsite housing. While much construction work takes place in the open air, many aspects of construction and renovation projects (e.g., plastering and electrical work) are conducted in enclosed spaces. This results in a higher risk of COVID-19 transmission among construction workers as compared to other occupations. The number of construction industry fatal work-related injuries and health issues remained high.

5.2. OSHA and CDC Construction Guidelines

In the US, health and safety agencies such as OSHA and the CDC play a key role in implementing rules and precautions that govern various industrial practices [4], and both agencies enacted preventative measures early in the pandemic, with CDC recommendations aimed at the general public, while OSHA recommendations specifically targeted businesses and workers.

OSHA worksite recommendations included requiring social distancing of at least six feet in low-risk areas, along with minimizing contact with the general public. OSHA designated medium-risk situations where such minimum social distancing requirements could not be met between workers or between workers and the general public. According to OSHA, people suspected or known to have COVID-19 were prohibited from entering work sites, thus potentially resulting in construction delays [42]. OSHA also advised that in-person meetings should be minimized in terms of frequency, attendance, and duration (including toolbox lectures and safety briefings) [42].

Additional OSHA recommendations encouraged workers to wear face coverings with at least two layers of finely woven breathable fabric (e.g., fabric face masks, surgical masks, or N95), except for jobs that require the use of a respirator. Face coverings should be provided free of charge to all employees, and PPE should be used as a standard control measure to protect workers from other construction-related dangers. OSHA also instructed employers to provide workers with all supplies needed to maintain high standards of hygiene at all times, including alcohol-based hand sanitizers with at least 60% ethanol or 70% isopropanol. In addition, employees are discouraged from sharing tools or equipment, which must be sanitized after each use. Employers are instructed to ensure portable toilets and hand sanitizer dispensers are regularly cleaned and disinfected, that COVID-19 rules and procedures are explained to workers in a language they understand, and that workers should be explicitly encouraged to report any safety or health concerns. Workers are to be checked for elevated temperatures upon arrival at the workplace. Proper ventilation is required for indoor work areas, workers should be encouraged to work from home where possible, and work schedules should be staggered to limit the number of employees onsite at any given time.

The CDC recommended that workers wear masks at all times, maintain a social distance of six feet, avoid large crowds, and wash their hands frequently [43]. Areas in which someone coughs or sneezes without a mask should be thoroughly cleaned and disinfected, and workers should actively monitor their overall health on a daily basis.

Implementation of these guidelines and recommendations should not only help prevent the spread of COVID-19 on construction sites but should also help to reduce injury and fatality due to non-COVID-related accidents.

The worldwide coronavirus outbreak has wreaked havoc on all industries, including construction. Construction workers suffered and continue to face substantial safety and health risks as a result of the pandemic's spread. As a result, building businesses took extra care to ensure the health and safety of their workers while also restricting the virus's spread. The Occupational Safety and Health Administration (OSHA), the Centers for Disease Control and Prevention (CDC), and the Associated General Contractors of America

(AGCA) all gave recommendations and instructions for the extra measures (AGC). These are some of the CDC's recommendations [43]:

- The Centers for Disease Control and Prevention recommended (CDC) that workers remember to put on a mask before beginning their task to ensure they are protected from acquiring the virus from the air. They recommended that the workers should continue to maintain a 6-foot distance between themselves and anyone around them in order to avoid physical contact. The CDC also recommended that workers should avoid large crowds and gatherings as COVID-19 is a communicable virus and that they should keep their hands clean on a regular basis to avoid the spread of the illness. The CDC recommended that in the immediate aftermath of someone coughing or sneezing, they be covered, and that the surrounding area be thoroughly cleaned and disinfected, and finally that the workers should keep track of their overall health on a daily basis in order to ensure that they remain in excellent health throughout time.
- If these guidelines and recommendations are adopted together with other safety measures on construction sites, the number of fatalities and accidents occurring on site will consequently reduce. In addition, this will give construction a better shot at being a safe occupation and protecting the lives of construction workers.

6. Implications of the New CDC & OSHA Safety Protocols

6.1. Observation of Health and Safety of Construction Workers

One of the most pressing challenges facing the global construction industry is a chronic lack of adequate PPE. Canada's construction profession asserts that "health and safety" are now top priorities in the construction business, with the provision of PPE for eye, nose, hand, arms, head, and lower leg [44]. The pandemic also required additional nasal protection, but adequate social distancing was largely unfeasible on construction sites in most continents surveyed.

The implementation of the new COVID-19 rules and regulations changed the working patterns of construction workers. Early in the pandemic, many workers were absent from work due to medical reasons, including COVID-19 infection, thus isolating them from co-workers. As shown in Figure 5, a reduction in OSHA inspections led to a reduction in the number of construction site violation citations, but the implementation of COVID-19 restrictions reduced the number of construction worker deaths in 2020.

On the other hand, the imposition of social distancing requires a reduction in onsite staff, and increased tolerance in those who remain. There is a possibility that these changes could have a beneficial impact on workers' mental health. The urgency of the COVID response has also cast a new light on the importance of safety in the construction industry. The authors in [45] note that increased concern is due to construction workers' mental health, particularly that of foreign workers. The social isolation imposed by COVID-19 restrictions is expected to have long-term ongoing impacts with implications for construction site safety, and construction firms should adopt worksite safety considerations from white-collar workplaces.

Worker safety and hazard mitigation can be addressed through the deployment of a hierarchical system of controls. Figure 7 presents such a system structure based on the impact of CDC and OSHA rules on the construction industry, organized in order from most to least effective. The most successful strategy for controlling COVID-19 was to eliminate potential health threats through the daily monitoring of worker health. Regular site cleaning and sanitizing also effectively reduced the risk of transmission, along with incremental risk mitigation at various process stages.

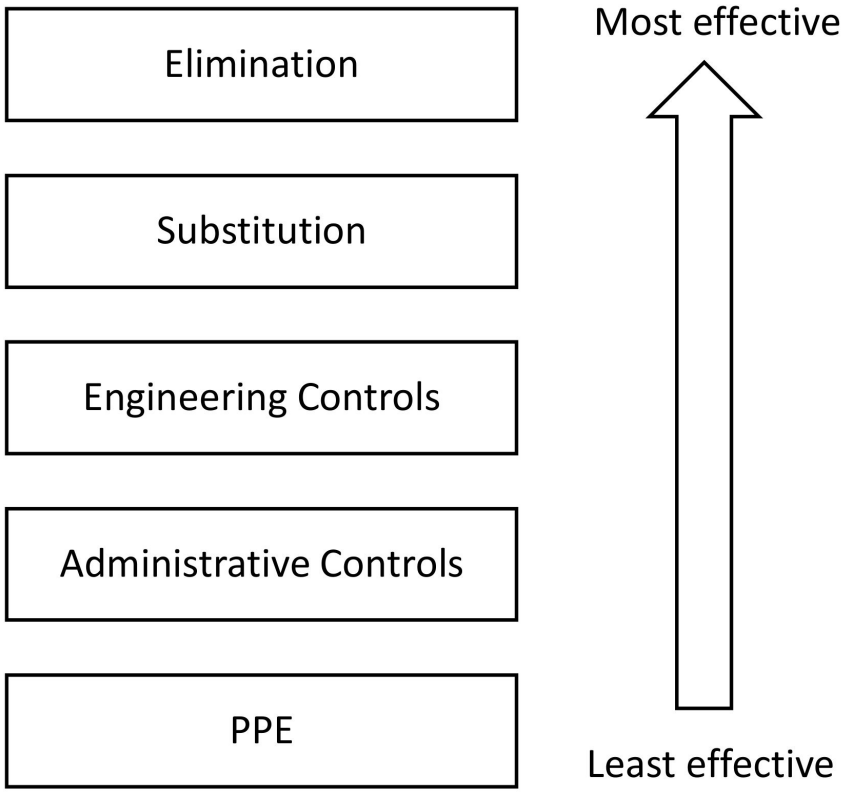

Figure 7. Hierarchy of controls [39].

The third most effective technique for managing COVID-19 transmission risk was the application of engineering controls, including erecting physical barriers, ensuring appropriate ventilation, and providing adequate work breaks throughout the day. Additional safety enhancements were achieved through administrative controls such as reducing meeting frequency, duration, and attendance and through effective safety training. The final option was the use of facial coverings and protective gloves.

6.2. Impact of COVID-19 Measures on Construction Industry Safety

To analyze the impact of COVID-19 on construction safety, this study divides the causal relationship into five stages on a timeline: trigger, COVID-19 countermeasures, impacts, outcomes, and result. The trigger in the first stage is the onset of the COVID-19 pandemic. The COVID-19 countermeasures are the policies and regulations proposed by CDC and OSHA. This research then analyzes the impact of these countermeasures on construction industry safety.

Figure 8 presents a breakdown of the positive and negative impacts of the new CDC and OSHA regulations. The positive impacts identified are summarized as follows:

- Working methods and site setup have been altered to increase work environment safety.
- Hygiene and cleanliness have been significantly improved.
- Worksites have increasingly adopted safer and more efficient construction technologies, such as the widespread implementation of remote online meetings.
- Response speed to health and safety changes has been significantly increased.

However, some negative impacts were also observed, as follows:

- Shortages of PPE.
- Worker absenteeism increased due to quarantine.
- Standards for non-COVID-19 health and safety concerns have deteriorated.
- Worksite safety inspections are increasingly delayed.

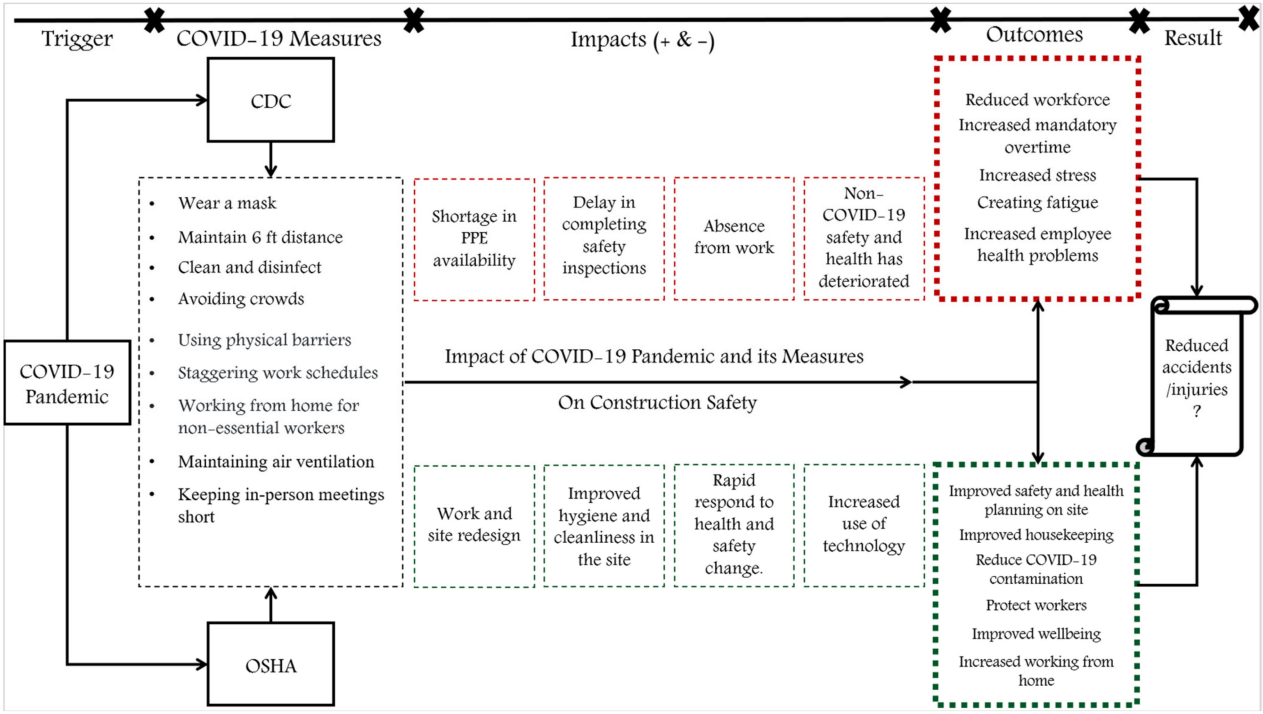

Figure 8. Impact of COVID-19 countermeasures on construction safety.

7. Conclusions

The research analyzes the current state of the construction site and worker safety in the US since the start of the COVID-19 to draw lessons from the onset of and response to the pandemic in regard to construction safety. For construction workers, physical barriers serve as an effective reminder to follow safety guidelines. Reducing meeting frequency and duration provides safety officials and supervisors more time to monitor the job site and workers. Daily health monitoring and staggered work scheduling reduce the likelihood of onsite injury. Improved safety training increases worker familiarity with key safety processes and regulations. Increasing the frequency of jobsite cleaning and disinfection reduces environmental risk and the likelihood of accidents.

This research is subject to certain limitations. This research presents qualitative findings, and future studies should establish and test hypotheses using statistical methods as more COVID-19 data becomes available. Additionally, this study has not addressed the practical implementation of the lessons learned from CDC and OSHA guidelines. Future work could investigate processes for incorporating these lessons through the use of toolbox or huddle meetings.

Engaging construction workers in lengthy surveys may be difficult due to the intensive nature of their work. However, future research would benefit from conducting worker interviews to obtain first-hand accounts and experience. In addition, future work could collect longitudinal data over a longer period along with focus group interviews. In addition, questionnaires or interviews could be used to expand on the study goals.

Author Contributions: Conceptualization, C.-H.K.; Data curation, H.A.A.; Formal analysis, H.A.A.; Funding acquisition, C.-H.K.; Investigation, H.A.A.; Methodology, C.-H.K.; Project administration, C.-H.K.; Supervision, C.-H.K.; Writing—original draft, H.A.A.; Writing—review and editing, C.-H.K. and H.A.A.; Visualization, C.-H.K. and H.A.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Craig and Diane Martin National Center for Construction Safety, Department of Civil, Environmental and Architectural Engineering, University of Kansas, USA, grant number 2225000-725-42297X.

Institutional Review Board Statement: IRB oversight is not required in this project since this is not a "Human Subjects Research". The decision was made by the IRB Administrator on 25 April 2022 at the University of Kansas, USA, with IRB ID STUDY00148627.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are openly available in Centers for Disease Control and Prevention website at https://data.cdc.gov/browse?category=NCHS&sortBy=last_modified (accessed on 15 January 2022).

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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