Thesis Project Portfolio

The Effect of COVID-19 on Construction Labor Productivity at the new Student Health & Wellness Center

(Technical Report)

How the COVID-19 Pandemic Changed Construction Work Life

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Hayden Hunter

Spring, 2023

Department of EN-Engr

Sys & Environment

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Sociotechnical Synthesis

How the COVID-19 Pandemic Changed Construction Work Life

The emergence of the COVID-19 virus led to a worldwide pandemic affecting virtually every industry. The construction industry was one of those that was impacted significantly and whose repercussions are still felt at present. Construction companies were forced to implement new technologies and strategies in order to combat these challenges induced by pandemic.

The technical aspect of the paper discusses the impact of the COVID-19 pandemic on the construction industry in the United States, with a specific focus on the construction of the Student Health and Wellness Center (SHWC) on Brandon Avenue. The pandemic caused issues with the supply chain, worker availability, and safety, leading to delays, increased costs, and reduced productivity. The paper explores the changes in construction methods and technologies that emerged in response to the pandemic and examines the potential for further technological innovations to minimize the impact of future global events on the industry. The technical aspect of the paper involves an analysis of data from the SHWC project to understand how the pandemic affected labor productivity. To address this issue, our team developed a prototype application to streamline communication and data for construction projects.

The STS aspect of the paper examines the role of technological innovation in shaping the construction industry's response to the pandemic. The research methods used were a literature review and interviews with various industry professionals. Using Actor Network Theory, the relationship between technology introduced during the pandemic and construction industry workers can be analyzed. I found that the employment status of the construction industry worker dictated the technological innovation's effect on their well-being. Workers who had the opportunity of keeping their job during the pandemic were aided by the new technologies and strategies implemented. On the other hand, workers' well-being of those who lost employment in the industry was negatively impacted. In concert with the technical aspect of the paper, these research topics are significant because both shed light on our responsibility of innovating technology in ways that improve individuals' well-being.

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Technical Project Team Members

Brant Flici

Alexander Maleski

Ryan Naddoni

Jackson Quinn

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Diana Franco Duran and Matt O'Malley, Department of EN-Engr Sys & Environment

The Effect of COVID-19 on Construction Labor Productivity at the new Student Health & Wellness Center

Ryan Naddoni, Jackson Quinn, Hayden Hunter, Alexander Maleski, Brant Flici

University of Virginia

Special Thanks to Matt O'Malley, Diana Franco Duran, & The Barton Malow Team

Diana M. Franco Duran

Abstract

COVID-19 had a paramount impact on the construction industry, and it affected all construction projects in some way. Barton Malow, the general contractor on the new Student Health and Wellness Center (SHWC) at the University of Virginia (UVA) wanted to know the impact that COVID-19 had on labor productivity at the new SHWC project. Labor productivity can be hard to track on larger projects with many activities going on at once, especially during the pandemic, a time in which the construction industry felt a noticeable obstruction in being able to effectively communicate between trades and the general contractor. This report presents our findings on how COVID-19 impacted labor productivity on the new SHWC project using a combination of document analysis and interviews with relevant parties. Overall, we believe that the Barton Malow team performed moderately well given the unprecedented situation. The project never had to shut down due to rising cases stemming from the project site, and manpower actually increased during the pandemic with little to no increase in worker safety incidents. However, a lack of communication between stakeholders led to a significant drop in quality which Barton Malow had to spend the next ~1 year correcting. Given these findings and the potential for another pandemic, the team proposed a set of future recommendations addressing some of these issues. Moving forward, the team will be developing the prototype application detailed in the discussion section to facilitate better tracking of labor productivity on future construction projects.

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Introduction

In January 2020, the People's Republic of China started noticing increasing cases of a virus called the coronavirus, also known as COVID-19, in the city of Wuhan (CDC, 2022). Initial concerns were muted but as cases rose and news agencies started reporting the outbreak, the government became increasingly concerned and started issuing lockdown orders to reduce the spread. Unfortunately, these measures were far too little, far too late, and COVID-19 managed to spread to other countries. Fast forward to March 2020, the virus had infected so many people that the World Health Organization declared COVID-19 a global pandemic (CDC, 2022).

Defining the Problem

The COVID-19 pandemic was unprecedented, affecting nearly every industry worldwide. In particular, the construction industry suffered unique challenges such as unmet contractual obligations, material delays and shortages, and in some cases, government-mandated suspension of operations (New York State Government, 2020). Construction cannot be done in a virtual setting unlike other professions, workers must be on site and working in person with others in order to execute the project. These challenges resulted in projects struggling to make schedules, budgets, and maintain the health and safety of on-site staff. During the onset of the pandemic, several projects around the University of Virginia's (UVA) Grounds were also affected; among them was the new Student Health and Wellness Center (SHWC). The project marks a renewed commitment by the university to prioritizing student health. The new ~$73,000,000 four story facility features two levels of underground parking and a wide range of services

from general medicine to radiology to counseling & psychological services (CAPS). Additionally, the building houses a pharmacy, teaching kitchen, and serves as the new home of the kinesiology department. The space was designed to be more than a medical facility and also acts as a hub for the Brandon Avenue redevelopment project with various lounge & study spaces for students. The SHWC project was constructed by Barton Malow, a construction firm based out of Southfield, Michigan. The SHWC project execution team encountered numerous hurdles during the pandemic, such as equipment delays, labor attrition, transportation problems, and lack of inter-trade coordination. Barton Malow attempted to combat these issues through a combination of communication with stakeholders, resequencing work, and enforcing health & safety protocols, but many of these issues were far out of their control and they simply had to keep the project moving forward as best as they could.

Defining the Solution

Although the Barton Malow project execution team was flexible in combating the aforementioned problems, not all the solutions were effective. In preparation for the next major global event that will significantly affect the construction industry, Barton Malow has tasked our team with first examining how the COVID-19 pandemic impacted Barton Malow's subcontractors, how labor productivity at the SHWC was affected, and what could have been done differently to preserve project continuity throughout the pandemic. Our findings and analysis are presented in this report. From these findings, our team will then propose a better way to measure labor productivity in the field and will provide

Barton Malow with some recommendations to counteract the effects that a future pandemic/significant global event might have on construction labor productivity.

Stakeholders

Civil engineering projects are a conglomeration of people working together to build a physical structure. Therefore, there are numerous stakeholders to consider, but they can be condensed into three major groups: the owner/client, the design/engineering team, and the construction team. On the owner/client side, the major stakeholders of this project are UVA Health, UVA Facilities Management & Capital Construction, the Board of Visitors, the Office of the Architect, and UVA students. The lead architectural firms on the design/engineering team were VMDO and Duda Paine Architects. The Construction Management firm Barton Malow led project execution. Barton Malow procured numerous subcontractors across all the divisions in addition to self-performing some work.

Our UVA Civil Engineering Capstone team is a fourth group to consider that was not directly attached to the project. The team is composed of five undergraduate civil engineering students and two capstone advisors. Working with the previously mentioned three major stakeholders, our team hopes to develop a solution to combat future drops in labor productivity due to pandemics.

Methodology

The SHWC project documentation is the primary source of quantitative data for the report. Barton Malow gave our capstone team access to most of the project documentation, including requests for information (RFI's), specifications, project schedules, submittals,

construction documents, and a detailed manpower summary. Given the breadth of information, our team delegated parts of the project documentation to individual members to analyze.

Ryan Naddoni and Hayden Hunter analyzed the project's monthly reports. The monthly reports give an overview of the project's activities and progress. The information included are the contractors on site, RFI's and submittals for the month, and monthly manpower hours, to mention a few. By totaling up these metrics over the duration of the project, we were able to visualize general trends in regards to safety, weather, and more.

Alexander Maleski and Brant Flici reviewed the project's RFI's. RFI's are an essential tool for coordination on any major construction project. Collectively, RFI's serve to not only enable effective communication between the general contractor, designers, subs, and stakeholders, they also provide a sort of 'receipt collection' of when hindrances and 'moments of need' occurred during the construction project. Particularly, some RFI's are flagged in Barton Malow's system as either 'URGENT' or 'HIGH PRIORITY' (both presumably hold the same value for intents and purposes). These are particularly advantageous resources for analysis, as each provides key insight into moments in which information was perhaps relayed less effectively or needed to be completed more urgently due to communication obstructions. When analyzing the meaning of this in the context of the research problem, Alexander and Brant carefully noted the frequency of 'HIGH/URGENT PRIORITY' RFIs with respect to the timeline of COVID-19. There are some observable trends in RFI activity, which are displayed in the analysis portion of the report. Specifically, a graph is included which displays the total amount of RFI's vs. the amount of HIGH/URGENT PRIORITY RFI's for each month of the SHWC Construction Project. This data is presented in both line chart and bar chart for ideal viewing/trend observation.

Jackson Quinn reviewed the detailed manpower summary report. In order to analyze the data, the daily totals of hours and number of workers were taken from each day. From this, graphs could be made showing how the number of workers on site and the number of hours worked changed over the project lifecycle. The manpower summary report also included descriptions of what task each subcontractor was performing each day, these descriptions also sometimes included COVID-19 related events. In order to find any descriptions that were COVID-19 related, a document search using keywords such as “sick”, “ill”, “COVID”, “corona”, and “virus” was used.

The entire team worked together to analyze the project’s numerous schedules. The team utilized Primavera P6, a scheduling software, as the main tool in the analysis. The team compared the initial May 18, 2019 schedule against the later May 11, 2020, May 29, 2020, September 11, 2020, July 21, 2021 schedules. This was accomplished by setting the May 18, 2019 schedule as the baseline for the other schedules and computing the finish date variance. We also compared the May 11, 2020 schedule (baseline) to the May 29, 2020 schedule since May was the only month that had two schedule updates.

Regarding qualitative data, the primary source is interviews with various stakeholders and/or industry members. Sets of questions were developed for each interview and notes were taken on the responses. None of the interviews were recorded. The following interviews were conducted:

- An online interview with Amy Christine Eichenberger, a senior project manager at UVA Facilities Management/Capital Construction and Renovations who helped lead the project on UVA’s behalf. See the questions and notes in Appendix A.

- An in person interview with Cliff Smith, a superintendent at Barton Malow, who led/coordinated work and subcontractors during the duration of the SHWC project. See the questions and notes in Appendix B.
- An in person interview with Tom Carolan, the director of scheduling at Barton Malow. See the questions and notes in Appendix C.
- An online interview with Matt Ferguson and Sal Binundo, an estimator and project manager at Masonomics who estimated, coordinated, and performed exterior façade work at the SHWC. See the questions and notes in Appendix D.
- An in person interview with Ryan Byrd & Paul Hahn, a project executive and project superintendent at Hourigan Group who lead, coordinate work, and manage project finances at the UVA Contemplative Commons project. See the questions and notes in Appendix E.

Each of these interviews were invaluable to the team providing key insights into the construction industry as a whole, along with varying approaches and viewpoints on the COVID-19 pandemic. The notes taken from each interview were used to corroborate our quantitative findings and to provide insight into the sentiments of the different parties involved.

Analysis

The below analysis combines both the quantitative and qualitative data to make inferences and conclusions on the effect of the pandemic on labor productivity (and more) at the Student Health & Wellness Center.

RFI's

Presented below is the total amount of RFI's vs 'HIGH PRIORITY' RFI's for each month. Perhaps the most immediate takeaway that is noticeable from Figures 1 and 2 is the downward spike in the total RFI's around March 2020, which was uncoincidentally the exact month in which COVID-19 emerged globally. Of course, this observation was highly expected given the framework for the research, yet it is interesting to note the consistency in which RFI's were not being sent to the previous frequency in the remaining months of the project. Alexander and Brant noted that this is common for almost any project, as RFI's are certain to be more rapid-firing in the beginning half of the project. However, it is impossible to deny that there was an immediate downward shift in communication from March 2020 until virtually the end of the project. The team made the irrefutable connection that COVID-19 had an incredibly profound effect on these occurrences, and certainly provided a significant communication hurdle for everyone involved in the UVA SHWC project. From a qualitative perspective, Alexander and Brant individually worked through the RFI's to analyze the notes and what information was communicated/needed. These notes were used to supplement and contextualize the quantitative trends that are observable in Figures 1 and 2.

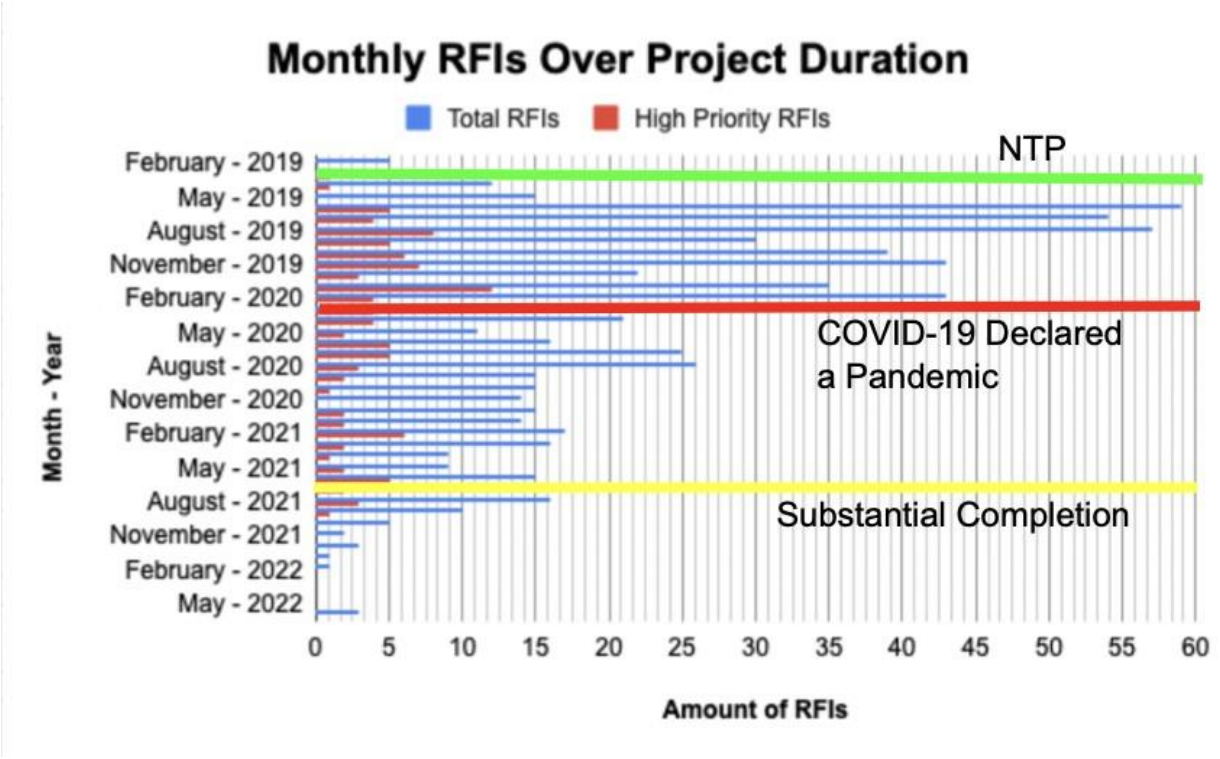

Figure 1: Total Amount of RFI's vs. High Priority RFI's per month

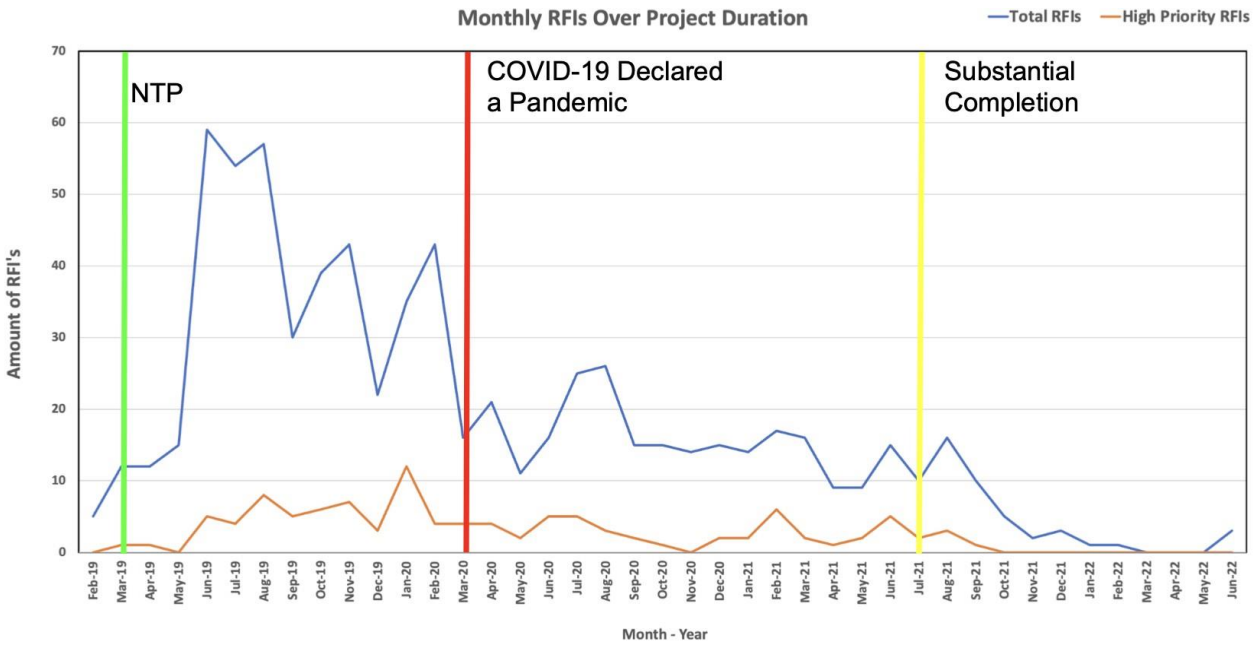

Figure 2: Total Amount of RFI's vs. High Priority RFI's per month

Detailed Manpower Summary

The detailed manpower summary provided by Barton Malow was a daily record of who was on site (subcontractors and Barton Malow staff) and for how many hours they were on site. The summary also included a description of what task each group of workers performed each day. These descriptions also detailed instances in which COVID-19 impacted the labor force. During the project there were 26 recorded instances in which COVID-19 or another unknown illness prevented workers from working on site. See Appendix F: Detailed Manpower Summary Notable Events for a complete list of illness or COVID-19 related events recorded in the manpower summary. The manpower summary also allowed for visualization of how the labor force on the SHWC project changed over time.

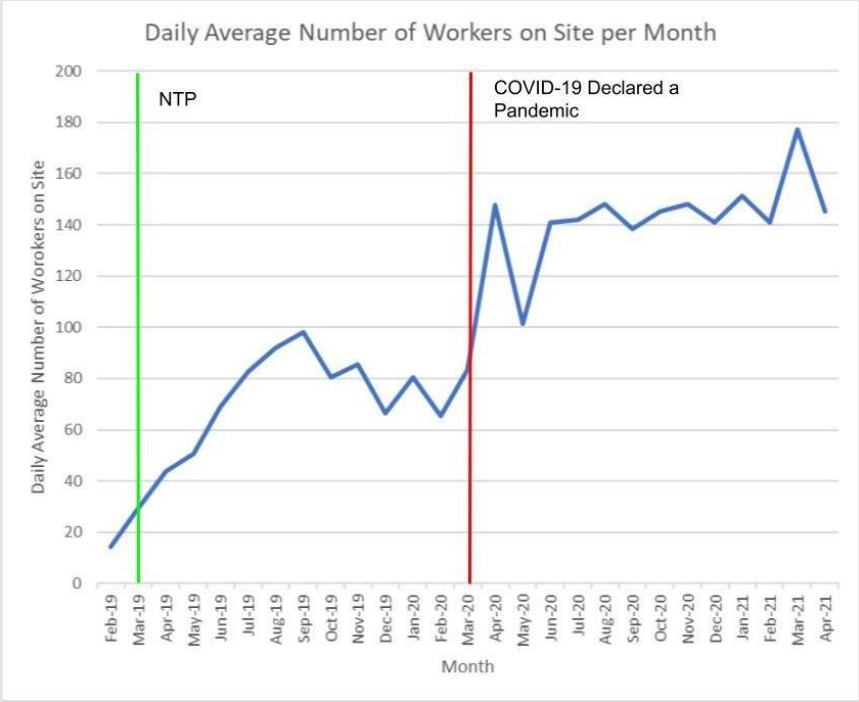

Figure 3: Daily Average Number of Workers on Site per Month

In Figure 3 we observed that at the onset of the global pandemic the daily average number of workers on site increased dramatically from March 2020 to April 2020. This dramatic increase in labor was then shortly followed by a sharp decline going into May 2020. This sharp increase was likely due to the project requiring more trades to be on site in order to stay on track with the project schedule. The decline moving into May 2020 correlated greatly with the sharp increase of COVID-19 instances on site. As Appendix F shows, there were 19 instances of COVID-19 from late April 2020 through the end of May 2020. These COVID-19 instances affected multiple subcontractors and prevented multiple days of work for specific trades. Below in Figure 4 you can see the same trend seen in Figure 3, with the daily average of hours worked increasing from March to April 2020 and subsequently decreasing sharply into May 2020.

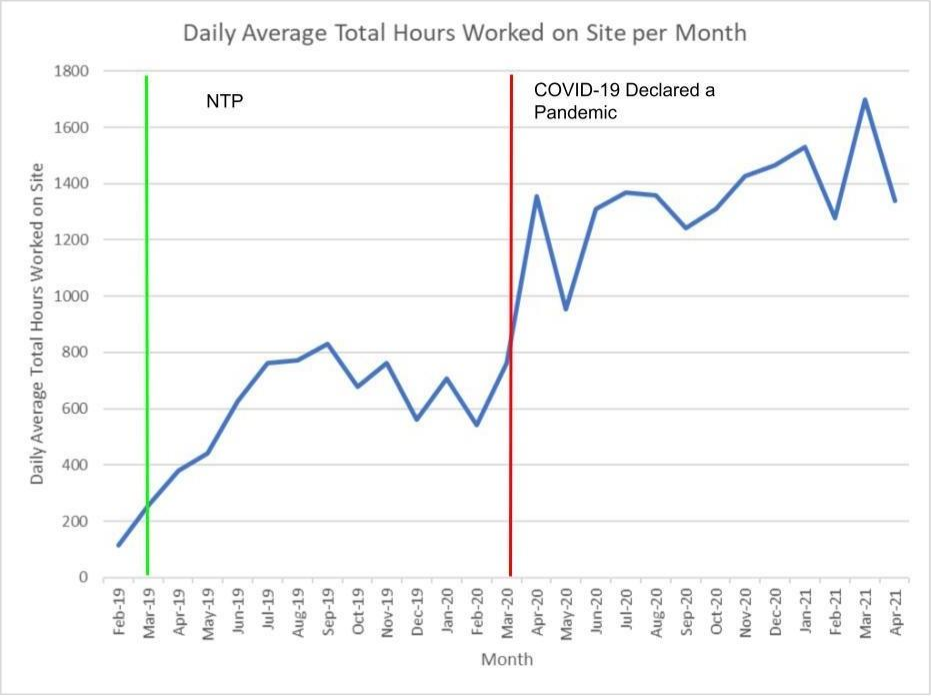

Figure 4: Daily Average Total Hours Worked on Site per Month

Schedule Analysis

By comparing various schedules from different periods of the project lifecycle, we were able to determine which activities occurred during the onset of the COVID-19 pandemic and were significantly delayed. Our first comparison was between the initial schedule provided to us from 2019 and the final one from 2021. We focused solely on activities that occurred between the months of March 2020 and June 2020. Barton Malow, UVA Facilities Management, and one subcontractor we interviewed stated that during this period they experienced delays and other issues due to the COVID-19 pandemic. This gave us a general idea of which operations occurring during the onset of the pandemic finished behind schedule. We used statistical analysis to determine which activities had delays that were outliers in the data set to prove this hypothesis.

Schedule Comparsion - 2019-2021		
High Item		Variance
	Activity	
Structural Concrete		9
	Slab on Grade	9
Structure & Misc Steel		-37
	Stair #1	-37
	Stair #2	-29
	S4 Deck	-12
	S3 Deck	-7
	S4 Erect Tier	-6
	Garage Stair	-4
	Steel Topping Out	-4
	S1 Deck & Detail	5
	S2 Deck & Detail	5
	Slabs on Metal Panel	7
Building Envelope		-5
	North Elevation	0
	West Elevation	0
	South Elevation	0
	East Elevation	2
	Roof	4
Interior Fit Out		0
	P2 Interior Fit Out	-1
	P1 Interior Fit Out	-2
	Level 1 Interior Fit Out	-5
	Level 2 Interior Fit Out	-1
	Level 3 Interior Fit Out	0
	Level 4 Interior Fit Out	0
	Shafts	0
Final Sitework		-7
	Underground Storm Drain System	-32
	Yard Inlets West Side	-28
	Sanitary Piping	-12

Figure 5: Schedule Comparison between 2019 and 2021

As can be seen from Figure 5, numerous activities were not finished on schedule. The two operations delayed the most were Structure and Miscellaneous Steel, namely Stair #1 and Stair #2, and Final Sitework. Structure and Miscellaneous Steel was 37 days behind schedule while Final Sitework was delayed seven days. However, each of the three activities that make up Final Sitework was roughly delayed two to four weeks. There are many variables throughout the project lifecycle that could have contributed to these delays, so we compared multiple schedules from different time periods to hone in on when these delays occurred.

Schedule Comparsion - 05/18/2019 to 09/11/2020		
High Item		Variance
	Activity	
Structural Concrete		9
	Slab on Grade	9
Structure & Misc Steel		-33
	Stair #1	-33
	Stair #2	-29
	S4 Deck	-12
	S3 Deck	-7
	S4 Erect Tier	-6
	Garage Stair	-4
	Steel Topping Out	-4
	S1 Deck & Detail	5
	S2 Deck & Detail	5
	Slabs on Metal Panel	7
Building Envelope		0
	North Elevation	0
	West Elevation	0
	South Elevation	0
	East Elevation	0
	Roof	0
Interior Fit Out		0
	P2 Interior Fit Out	0
	P1 Interior Fit Out	0
	Level 1 Interior Fit Out	0
	Level 2 Interior Fit Out	0
	Level 3 Interior Fit Out	0
	Level 4 Interior Fit Out	0
	Shafts	0
Final Sitework		0
	Underground Storm Drain System	-33
	Yard Inlets West Side	-28
	Sanitary Piping	-12

Figure 6: Schedule Comparison from 05/18/2019 to 09/11/2020

This comparison similarly indicates that both Structure and Miscellaneous Steel and Final Sitework fell behind schedule from the start of construction to September 2020. The Building Envelope and Interior Fit Out had no calculated delays across this schedule update.

Schedule Comparsion - 05/11/2020 (pre-covid) to 05/29/2020		
High Item		Variance
	Activity	
Structural Concrete		9
	Slab on Grade	9
Structure & Misc Steel		-13
	Stair #1	-13
	Stair #2	-29
	S4 Deck	-12
	S3 Deck	-7
	S4 Erect Tier	-6
	Garage Stair	-13
	Steel Topping Out	-4
	S1 Deck & Detail	5
	S2 Deck & Detail	5
	Slabs on Metal Panel	7
Building Envelope		-2
	North Elevation	-2
	West Elevation	-8
	South Elevation	-8
	East Elevation	-15
	Roof	0
Interior Fit Out		-1
	P2 Interior Fit Out	-47
	P1 Interior Fit Out	-15
	Level 1 Interior Fit Out	-2
	Level 2 Interior Fit Out	-2
	Level 3 Interior Fit Out	-1
	Level 4 Interior Fit Out	-1
	Shafts	-1
Final Sitework		0
	Underground Storm Drain System	0
	Yard Inlets West Side	-29
	Sanitary Piping	0

Figure 7: Schedule Comparison from 05/11/2020 to 05/29/2020.

This comparison shows schedule delays caused during the month of May 2020. Looking at Figure 7, it can be seen that the majority of tasks are delayed by some amount of time. P2 Interior Fit Out was notably delayed by 47 days. Yard Inlets West Side continues its trend of being delayed by approximately a month. All elevations of the building envelope were also set back to varying degrees.

Interestingly, the overall impact of these activities getting set back did not delay the entire project. Barton Malow did not explain to us how they managed to complete the project on the originally planned date. During our interview with the subcontractor

Masonomics, they mentioned that if one of their crews contracted the virus that crew could be rotated off the project to quarantine and replaced with another crew. This could explain how some subcontractors managed to mitigate these delays over the course of the project, while others without a large available workforce fell behind schedule. We did not have enough information provided to be able to make an assertive conclusion as to how these delays were mitigated so that the project still finished on time.

Monthly Reports

By reviewing and analyzing the monthly reports the team was able to identify key metrics such as the number of safety incidents over the project (Figure 8), adverse weather days (Figure 10), etc. For safety, the team found that during the beginning of the pandemic, March 2020 and April 2020, there were no safety incidents. This could possibly be attributed to country wide unease leading individuals to be more careful in regards to their health & safety as well. As the world somewhat opened back up during the summer, SHWC safety incidents remained minimal with only one incident per month from May 2020 to August 2020. Interestingly, during both of these periods, manpower on site increased (See Figures 3 & 4) but the ratio of safety incidents to manpower hours (Figure 9) was actually much less than compared to the start and end of the project. In this scenario, more people on site did not lead to more injuries/accidents as one would typically expect.

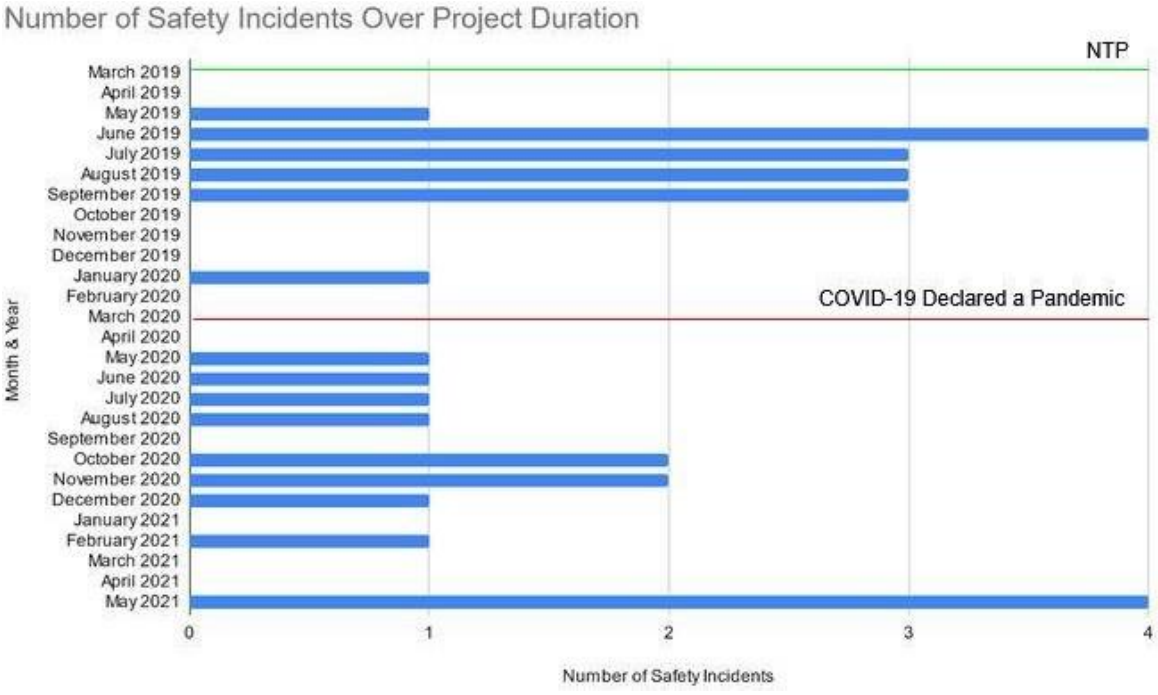

Figure 8: Number of Safety Incidents Over Project Duration

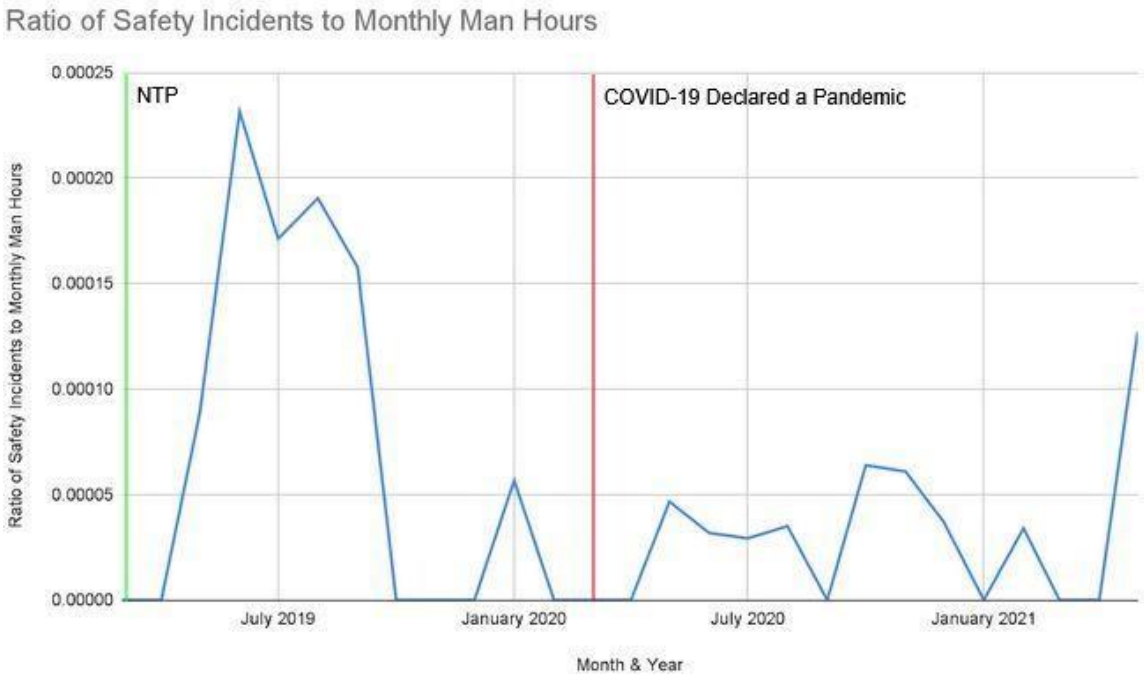

Figure 9: Ratio of Safety Incidents to Monthly Man Hours

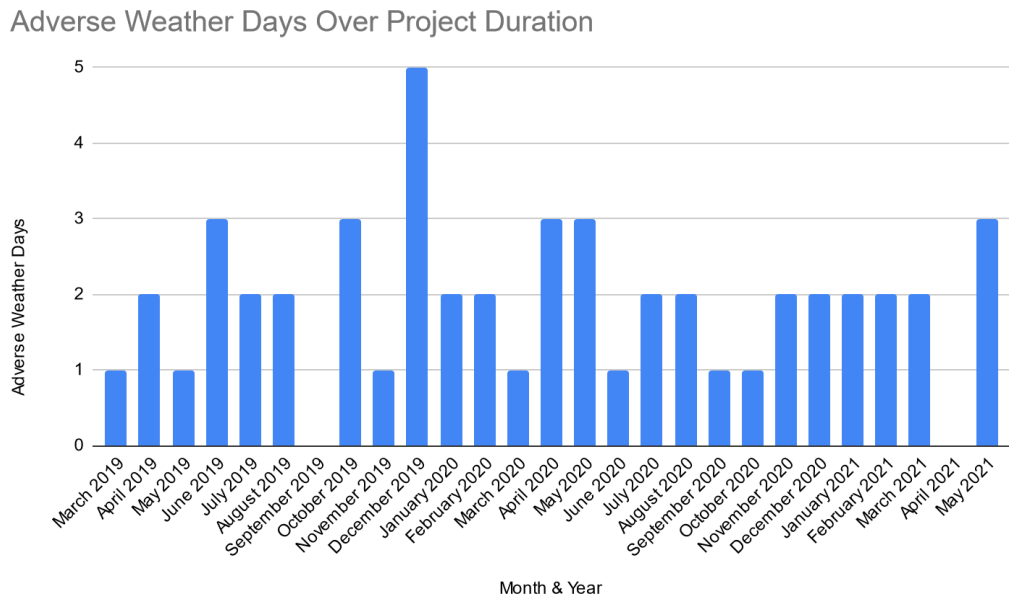

Figure 10: Adverse Weather Days Over Project Duration

Another key item that the monthly reports tracked was upcoming challenges. The reports detailed various challenges depending on the phase of the project but a consistently noted challenge was coordination of multiple trades and subsequent scopes of work. It is important to note that this challenge was present prior to the pandemic but according to stakeholder interviews was exacerbated during.

A surprising finding was that COVID-19 was not mentioned as an upcoming challenge until June of 2020 despite the 19 COVID-19 cases from April 2020 to May 2020. It is possible that the challenge may have been listed in the June 2020 monthly report as a way to address the case counts of the previous months. Whatever the reason, from June 2020 onwards enforcing COVID-19 guidelines was listed as a challenge.

Interviews

By interviewing the involved stakeholders, SHWC's superintendent, principal scheduler, neighboring UVA Contemplative Commons project, owner's representative, and subcontractor of Masonomics, we were able to gain greater insight into the different perspectives on the effect COVID-19 had on the SHWC project.

Cliff Smith, the superintendent on the SHWC project was able to provide many first-hand insights during our interview with him. Smith did not comment directly about any specific labor productivity issues but said that labor productivity and the quality of the project was severely impacted by COVID-19. Smith said that the fear and confusion that came with the onset of the pandemic affected the "flow" of the project and changed the way that subcontractors interacted with one another. On top of a loss of communication, there were also many days lost due to trades leaving the project due to a positive COVID case or fear of contracting COVID from others. In the case of a positive test, crews would be sent home until test results indicated that it was safe for them to return to the job site. To combat the spread of the virus, health and safety protocols such as social distancing were enacted with relative success as no trades transmitted COVID-19 to one another. The total extent that these measures had on labor productivity is unknown, but in our discussion with Masonomics they noted no productivity losses given that their work on the exterior façade already requires their workers to socially distance for efficiency.

Additionally, Smith noted that many senior workers on the project decided to retire from the construction industry during the pandemic which led to significant losses in trade knowledge being passed from generation to generation. Furthermore, the

reduction in talent entering the construction industry meant that these roles could not be filled quickly. Smith also commented on masking stating that he did not encounter any issues with potential carbon dioxide decision making impairment from mask wearing. However, during the subcontractor interview with Masonomics they cited trouble with wearing safety glasses and a mask. The mask would cause the safety glasses to fog up, which impacted the workers' vision. Despite this, safety glasses were still required to be worn at all times. In fact, Smith noted that following the release of the mask mandate, many workers still choose to wear masks as a form of general dust protection while on site.

Prior to meeting with Smith, our team interviewed Barton Malow's principal scheduler, Thomas Carolan, who provided insight on our schedule analysis and Barton Malow's scheduling system. Thomas commented directly on the scheduling software, Primavera P6, used to create all of Barton Malow's schedules. Thomas stated that due to COVID-19, labor productivity has taken a significant downward trend. He mentions this could be due to the fact that older generation skilled laborers are retiring because of the US stimulus bill. This would result in the younger generation of skilled laborers not getting the opportunity to learn from mentors. Thomas comments that this gap between the older and younger generations will impact overall performance and productivity.

Our team also interviewed superintendents at UVA's Contemplative Commons project. While not directly related to the SHWC project, it provided another perspective on how labor productivity is tracked with a different general contractor on another university project. At the Contemplative Commons project, labor productivity is not tracked directly by the general contractor, instead it is tracked by individual

subcontractors and usually kept private by those subcontractors. The only time the general contractor gains knowledge about the labor productivity of different trades is when the schedule is falling behind and they need to assess the situation. As far as carbon dioxide impairment is concerned, the superintendents on the contemplative commons project did not see any effects from required masking.

Then, we interviewed with UVA's owner representative, Amy Christine Eichenberger. Similar to what Cliff Smith had said, Amy saw many experienced workers leaving the industry, which likely impacted quality and efficiency. Amy also emphasized the importance that relationships and communication have on a construction project, she believes COVID-19 impacted how people communicated with one another and created extra tension on the project which damaged some relationships. Some of the extra tension due to COVID-19 came from material shortages with doors, switchgears, and glass.

Finally, we interviewed a SHWC subcontractor, Masonomics. From this interview it was clear that from a subcontractors point of view, tracking things like productivity and materials can be difficult. Different general contractors use different softwares, and being able to adapt and effectively use each software asked of them is important. Their team also believes that since their scope of work is predominantly on the exteriors of buildings, they avoided high COVID-19 cases compared to other trades.

Masonomics also cited lots of COVID-19 impacts in the construction industry such as coordination challenges due to different channels of communication, losing the personal connection you get when talking to someone face to face, and more emails than ever before. Many of these issues have persisted past the pandemic as many people have become more comfortable with using online communication tools such as video

conferencing or emailing, which they believe has damaged the effectiveness of communication. They also noted that many of their older, more experienced staff struggle with newer technologies, and that the transition or increased reliance on technology during the pandemic was difficult for them. The goal of our application is to bridge the gap between the workers on site and the people working in the office. The application we develop will be a tool used to communicate data collected by foreman and other leaders on site, that will take advantage of the digital communication skills that everyone had to learn during the pandemic.

Discussion

This below discussion reveals the key lessons learned from the analysis sections. The means for sensible discussion allows for conclusions on the effect of the pandemic on labor productivity (and more) at the Student Health & Wellness Center to be made.

Schedule Discussion

Our group selected schedules and focused on construction tasks that occurred prior to and during the onset of the pandemic to determine its effect on schedule delays. The schedule comparison between the start of the project in 2019 and its completion in 2021 indicates that there were variables that impacted the timelines of numerous construction operations. However, the scope of this comparison is too large to draw any specific conclusions concerning COVID-19's effect on the project. We attempted to take a closer look by evaluating the schedule comparison between start date and 09/11/2020. This also shows that across this time period there were events that occurred that delayed several of the construction tasks, namely Structure and Miscellaneous Steel and Final

Sitework. This is still too large of a time frame to make any inferences on how the pandemic altered the schedule progression of the project, so we next compared the two schedule changes that occurred in May of 2020. This month is significant because this was still in the onset of the pandemic, which brought changes to the industry that required Barton Malow to make two schedule updates within this same month.

Within May 2020, every task's completion date was altered – most of which were delayed. Some tasks were delayed more than others which could be due to the subcontractor's crews contracting the virus during this month requiring them to quarantine. It could also be due to supply chain disruptions that made it difficult to acquire materials necessary for these tasks to be completed (Smith, 2022). The operations that were impacted the most during May 2020 were Structure and Miscellaneous Steel, P1 and P2 Interior Fit Outs, East Elevation of the building envelope, and Yard Inlets West Side. The schedule comparisons confirm that there was a major event(s) that significantly altered the progress of construction. Given this month's proximity to the initial global lockdowns in March and April, we can assume that the pandemic was the predominant cause for delays on the project.

As for the final completion date of the project, it was not delayed. It is not understood how Barton Malow managed to limit the effects of schedule delays for various subcontractors while maintaining the original completion date. They did not provide us with any information concerning this observation. However, there are a couple inferences our team can make. While interviewing Masonomics, they mentioned that they had enough crews to rotate into the project when one had to take leave in order to quarantine when they contracted the virus. In addition, we noticed that manpower hours

increased after this period. This could be due to students being sent home due to the pandemic, leading to increased work rate of the crews.

RFI/Communication Discussion

Despite the claim that COVID-19 had an incredible impact on communication, there were some gaps in the RFI data which may have impacted the analysis. For starters, Alexander had some intermittent gaps in his sections of the RFI's. Some of these spanned to 10-20 RFI's, and one of the gaps was close to 30 RFI's, which irrefutably impacted the count for the later months compared to months prior. Contrarily, Brant hardly had any gaps, so we speculate this disparity may have affected the total count. Given this, it is hard to say with certainty that RFI outflow and general communication were hindered solely by the pandemic given that several RFI's were inaccessible. However, it can certainly be speculated that there was a decrease in communication. To clarify, there were not less questions, but rather people felt less of a need to communicate on smaller, trivial matters given the "big-picture" concerns of COVID-19. Furthermore, people may have been distracted by concerns for their health or felt less able to communicate due to the life-stresses of the pandemic. Ultimately, the lack of general communication lost in face-to-face meetings, coupled with the decrease in RFI flow could've had later impacts on quality. Although not every RFI was present, it is reasonable to make this claim.

Preliminary Framework

Due to the lack of widespread data tracking for labor productivity, general contractors, such as Barton Malow, have struggled to find an effective way to counteract the negative effects they experienced, especially during COVID-19. By developing a

system, Barton Malow will utilize this data to put procedures and policies in place to mitigate the risk of experiencing significant decreases in labor productivity. Our group started designing a potential wire framework for the solution of tracking the abstract factors of labor productivity. Looking at Figure 11, the framework starts at the top left where the construction laborers (subcontractors) input their daily manpower and progress reports into a multi-lingual tracking app. This system will also source data from the scheduling software used, Primavera P6 in this case, to analyze and create labor productivity reports/results. Then, these results will be given to the general contractor team on site, which can help improve the scheduling data and repeat the cycle. These results can be formatted in a report style for the team to easily digest and create policies to mitigate further labor productivity issues. This application will be further developed in Spring of 2023.

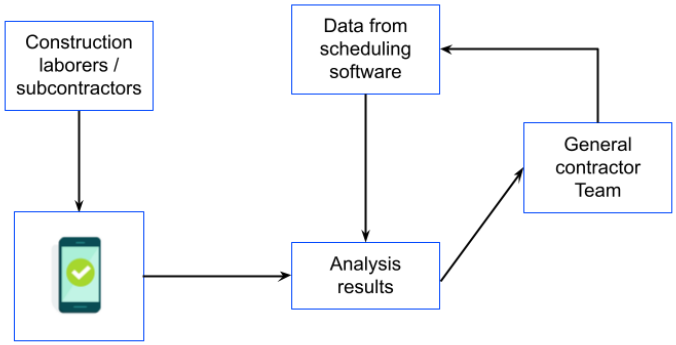

Figure 11: Proposed Wire Framework for Tracking Labor Productivity

Future Recommendations

Although the COVID-19 pandemic was an unprecedented global event that altered nearly every aspect of normal life, it will not be the last. There is growing consensus that pandemics may become more frequent due to modern globalization and

human inflicted environmental damage (Caruso, 2022; Penn, 2021). For Barton Malow, this means that the team cannot rest easy and must instead prepare for what's next. Below are our team's suggestions moving forward.

Updated Meeting Structure

As mentioned prior, inter-trade coordination was a major obstacle during the pandemic. Teams were not conversing with each other which led to clash issues between different scopes of work and a general reduction in quality. To combat this in future projects, we suggest an updated meeting structure.

- Level 1 Meeting:
  - Frequency - Daily (Every morning)
  - Attendees - All trade foremen and the project superintendent
  - Content/Purpose - Discussion on every trade's scope of work for the day. This gives all supervising staff a general idea of what activities will be taking place on site.
- Level 2 Meeting:
  - Frequency - Prior to whenever trade teams will be in close contact
  - Attendees - Individual trade foreman, trade workers
  - Content/Purpose - Discuss the details of their work and ways to minimize contact via activity sequencing
- Level 3 Meeting
  - Frequency - As needed
  - Attendees - Individual trade workers

- Content/Purpose - To confirm that everyone understood and will apply the plan discussed in the level 2 meeting. To communicate typical challenges associated with their work and determine solutions.

To prevent the spread of disease during meetings and ease worker fears of becoming ill, all meetings will take place outside, socially distanced, and with all parties wearing masks (Note: In the case of another pandemic, masking will most likely be mandatory onsite at all times anyway). Having this meeting structure is necessary to facilitate the "flow" that is key to project success that Smith discussed in his interview.

Health Safety Protocols and Supplies Stockpiles

Given the unknown nature of how a future pandemic will spread it is impossible to be completely prepared, however there are steps that can be taken. First and foremost is acquiring and storing a backup supply of personal protective equipment such as masks, gloves, etc. These items can be purchased in bulk and distributed to workers when they arrive on site. Cleaning and hygiene supplies such as disinfectant spray and hand sanitizer should also be stockpiled. As for determining fitness for duty prior to coming on site, Barton Malow should maintain or pursue a new relationship with an employee health screening company that can support multiple job sites. Barton Malow should also establish a base set of health protocols that can be rolled out early in a pandemic; COVID-19 health protocols are a good starting point. Lastly, Barton Malow must remain flexible, being able to adjust their protocols and safety measures to align with

guidance from public health officials as more information is discovered. As they pivot, Barton Malow must maintain clear, direct communication between all project stakeholders to ensure everyone is on the same page. Company wide policy changes should be issued by the company safety coordinator whereas project specific changes should be communicated by project safety managers.

Early Procurement

It is well known that the pandemic severely altered many project timelines through material delays to project sites and the SHWC was no exception. At the SHWC project, it took an additional 9 months for the project's switch gear to arrive on site and there were other issues when procuring doors, paint and sealants. Our team suggests that in order to combat volatility in the supply chain, Barton Malow should procure important elements, such as switch gears and façade systems, as soon as possible. Coordinating with the design team is key to success as they need to finalize building systems so suppliers and subcontractors can begin manufacturing products. Similarly along those lines, it may also be beneficial for Barton Malow to invest into a warehouse space to store materials that are procured early and that are not ready to be on site. The cost of storing materials off site consists of the initial purchase price or lease of a warehouse and the transportation costs when moving material. Depending on the contract type these costs may fall on the general contractor, however the benefits offered by off site storage are considerable and may offset the cost of potential project delays.

Conclusion

The construction industry was one of the few industries that managed to power through the entirety of the COVID-19 pandemic, however it is irrefutable that there was a considerable impact on numerous facets of the industry, most notably the effectiveness and ease of communication. Additionally, there were intermittent complications stemming from COVID-19. Some of these obstacles were a direct result of the COVID-19 pandemic, such as occasional absences in trade laborers and even entire trade forces being off-site for days on end. Other hindrances were less obvious, but are profoundly observable through analyzing the data of the SHWC project. As mentioned prior, communication was highly impaired in wake of the pandemic. Between navigating state health policy, on-site safety recommendations, and of course balancing the demands of scope, budget, and timeline, there was an incredible amount of stress on the entire SHWC project. The aforementioned stance became incredibly clear as soon as we began analyzing the data, however after conclusively interpreting everything it is clear that the effect of COVID-19 on the SHWC project is nearly immeasurable in the sense that there was a never-before-seen change in many of the defined metrics of the construction project, i.e. downward spike in flow of RFI's, changes in scheduling, shifts in manpower, etc. Ultimately, Barton Malow navigated the field of uncertainty resulting from COVID-19 relatively well, which is undeniably an impressive task considering the construction industry is heavily reliant on predictability, safety, and risk-aversion.

Addendum: Spring 2023 App Development

Utilizing the above Fall 2022 findings, our team set out to develop a prototype mobile application for construction professionals to better track project progress. Initial development began with first expanding on the proposed wire framework, Figure 11. This initial phase is critical in the design process as it tends to guide full phase development. During this phase we sought out feedback from our advisor, Matt O'Malley a Preconstruction and Commercial Market Lead at DPR Construction, Abigail Richardson an Estimator & Project Manager at Barton Malow, and Cliff Smith a retired Superintendent from Barton Malow. Receiving feedback at this early stage in the process allowed our team to make adjustments to our plan which led us to allocate our time and resources more efficiently when it came to full development. Our team ended up settling with the updated framework as shown in Figure 12.

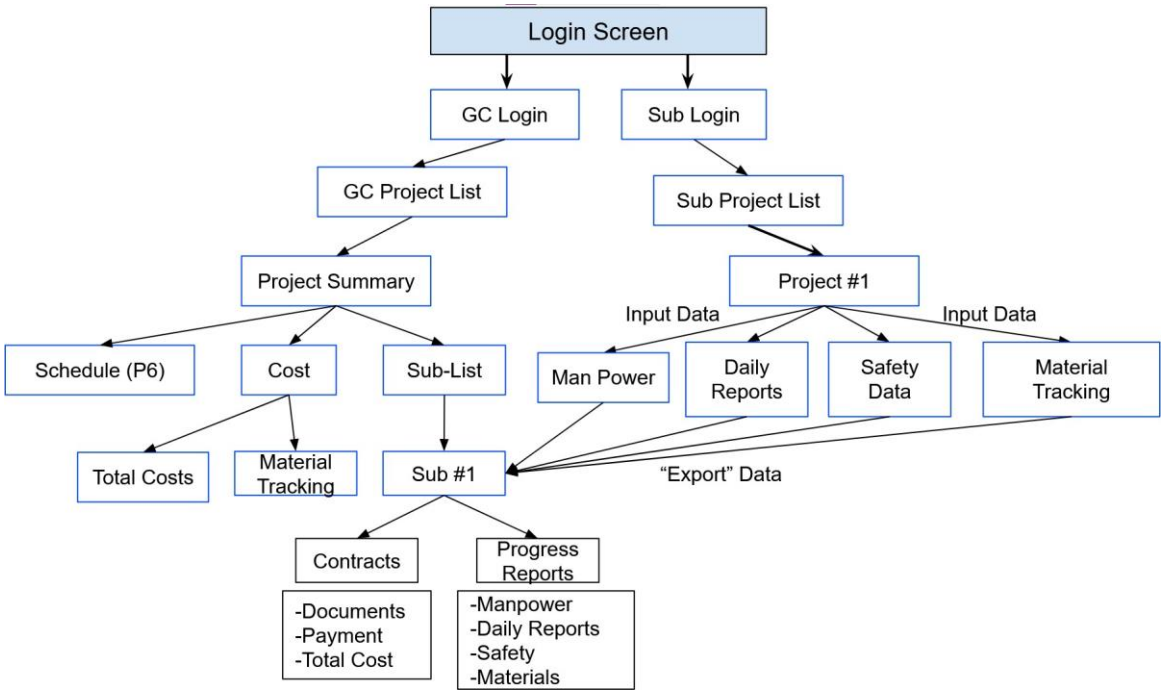

Figure 12: Proposed Wire Framework for Tracking Labor Productivity

The development platform our team decided to use when creating the app was Figma. Figma is an interactive, non-coding based development platform that prides itself on its simple tools that allow for advanced app development. This platform was chosen specifically because our team lacks significant coding experience and also because the way Figma is designed lends itself perfectly for developing prototypes. Furthermore, Figma allows multiple users to work in the same design space simultaneously, which is an advantageous feature for group work.

For the early stages of developing the prototype we took feedback from Barton Malow to lay out some goals. The first is that our prototype would be accessible to everyone in the construction industry. This meant creating a user interface that was simple and accommodating to people who may not be technologically savvy, since there are many older people in the construction industry who are not familiar with apps and smartphones. This also meant showcasing that our app would have two language offerings (English and Spanish), since a majority of the construction labor force in America speaks one of these two languages. Another goal was that our prototype would add features that would be useful to construction professionals, while avoiding features that already exist with other softwares. Our group understood that things like scheduling and tracking safety data already had comprehensive software tools, and our prototype did not attempt to ‘reinvent the wheel’ in regards to these existing technologies. One final goal that we had was for our prototype to have functionality for both the general contractor and the various subcontractors on any given project. We got feedback from construction professionals that some information (ex. financial information) is not freely shared among companies. Hence, we created two separate logins, one for the general contractor and one for a subcontractor. Depending on your login, you have access to different features and

different data. With these goals in mind, we began development of a prototype for the app MARKR.

Upon entering the MARKR app, users are presented with a screen that allows them to specify whether they are affiliated with the 'General Contractor' or 'Subcontractor.' This page, as well as every page within the app, displays an American flag in the bottom right corner, which serves as the button to modify the language preference for users. Additionally, there is an icon of a person located in the bottom center of each frame, which allows users to view and edit their profile information. After making the appropriate selection between 'General Contractor' and 'Subcontractor,' the user is then prompted to either 'Sign In' or 'Sign Up.' Once the user has either signed in or created an account, the app moves them into the 'Project List' page, which provides them with multiple construction projects from which they can choose to edit, as shown in Figure 13 below. The project list screen has the same view for both the general contractor and subcontractor, however the editing features that are available after choosing a project differ for each.

Figure 13: User View of Project List Within MARKR

From the side of the general contractor, there are four elements of a project that can be viewed and edited within the app. These are ‘Cost,’ ‘Schedule,’ ‘Subs,’ and ‘Docs,’ all of which are displayed in Figure 14. To increase accessibility, each of these items is written in large text and accompanied by a sizable icon that is associated with its meaning. If users select the ‘Cost’ option, they are able to either view the budget for a particular project or view its change orders. Viewing the budget provides a list of cost codes and the respective part of the project each corresponds to, while viewing the change orders presents an index of each project’s modifications to the construction process.

Figure 14: General Contractor View of Project Features Within MARKR

If a user associated with the general contractor selects the ‘Schedule’ button, they are presented with a page that depicts the overall completion for the chosen project, which is displayed in a percentage format and is marked as either green, yellow, or red depending on the completion status. Furthermore, the general contractor schedule page presents the user with four options. The first choice is to ‘View Schedule,’ which allows the user to view the project

schedule, which is extracted from Primavera P6 for each project. The next button is labeled 'Current Activities' and gives users a list of the ongoing activities that are occurring on-site. After selecting a particular activity, the start date, end date, and duration are displayed. Additionally, a notation is included that clarifies whether the selected activity is on the critical path, as well as buttons to 'See Drawings' or 'See Specifications' for the activity. The next feature of the schedule page is a button that lists the future activities that will occur on-site, which is labeled 'Upcoming Activities.' Lastly, there is a button labeled 'View Progress Data' that functions as a catalog for the information related to each activity, such as the corresponding subcontractor and an option to view the schedule notes associated with the activity that is selected. A general contractor view of the schedule page is shown below in Figure 15.

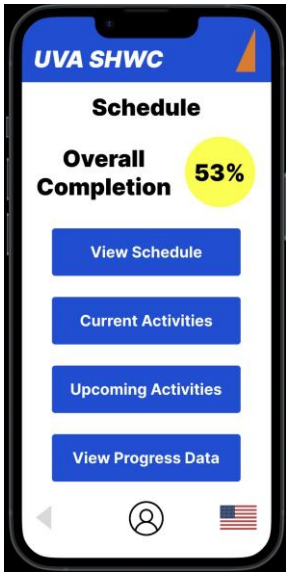

Figure 15: General Contractor View of the Schedule Page

If a user associated with the general contractor selects the 'Subcontractors' button, they are presented with a list of subcontractors on the project. After selecting one of the subcontractors, such as AG Dillard, two buttons are shown 'Project Progress' and 'Personnel'.

Clicking the ‘Project Progress’ tab leads to a menu of options: Manpower, Daily Reports, Safety, Materials. The ‘Manpower’ and ‘Daily Reports’ options allow users to view past reports and create new ones utilizing a standard format as seen below in Figure 16. The ‘Safety’ option leads to a transfer screen to the general contractor’s desired third-party safety app. The ‘Materials’ tab takes the user to a screen listing out project materials along with their cost and an option to view more details such as ordered, shipped, and delivered dates as seen in Figure 17.

Figure 16: New Manpower Report Screen

Returning back to the main screen and selecting the ‘Personnel’ tab takes the user to a page with search functionality to find information on any workers on site. The information offered includes an individual’s mobile phone number, email address, site safety training status, hours worked, and any safety incidents. There is also an ability to add a new worker’s information to the database.

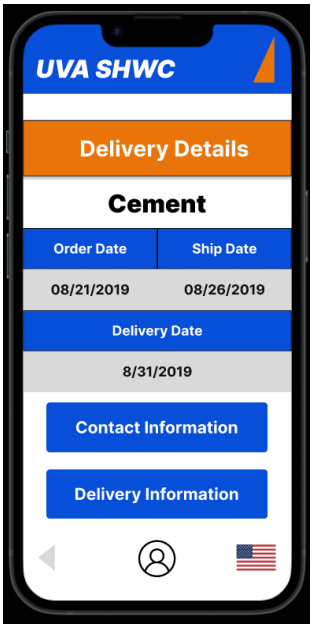

Figure 17: Materials Delivery Details Screen

If a user associated with the general contractor selects the 'Docs' button, they are presented with a list of industry standard documentation including tabs of 'Drawings', 'Specifications', 'Contracts', 'Payments', 'Submittals', and 'RFI's' as seen in Figure 18.

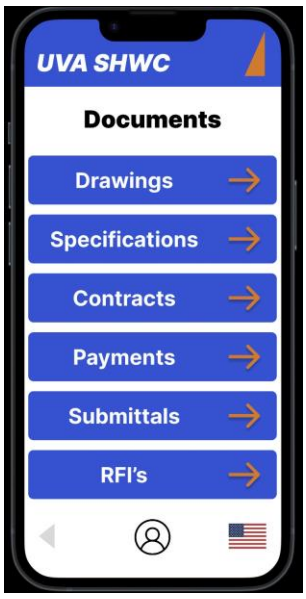

Figure 18: General Contractor Documents Screen

The ‘Drawings’ and ‘Specifications’ tabs link to scrollable screens that present each respective document numerically listed. The ‘Submittals’ and ‘RFI’s’ tabs present a search feature to quickly find the desired page among thousands of documents as seen in Figure 19.

Figure 19: General Contractor Submittals Search Screen

Throughout the development of the app, our team consistently sought feedback from our advisor, Matt O’Malley, and client Barton Malow. We hosted meetings with both parties and made minor modifications to some features based on their requests and knowledge of the industry.

It is important to note that although our app is quite in depth, it lacks some functionalities due to the limitations of the Figma platform and our own lack of app development experience. Some examples of functions that are missing are the ability to scroll, enter information into prompts, and full third-party app integration (P6, Contractor Safety Apps, Accounting Software).

Another missing ability is having the code infrastructure built out to pull from data bases, security features, and having credential checks.

Below is a view-only link to our Figma prototype. The prototype can be interacted with by pressing the play button (Present) in the upper right corner.

https://www.figma.com/file/tnB7ru6bO8PS3omJ1NldGp/MARKR?t=65HwwNGZbvg7Y2YU-1

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Appendix A: Questions and Notes from Owner Interview (Amy Eichenberger)

Background of Amy

- VT undergrad in architecture
- Straight to licensure
- Engineering with residential areas
- Contracting with consulting
- Followed up with design on west coast (7 years)
- Worked at VMDO architecture (architect on SHWC)
- 15 years ago started at UVA
- Lots of experience with design and managerial roles
- Uva has been demanding, and doesn't require travel

Overall view on SHWC

- Working with many stakeholders
    - Bouncing ideas off each other
    - Being able to understand the needs and engaging with teams well
    - Had a great team relationship
    - Putting the pieces together with receiving stakeholders
    - Amy's job was to facilitate the meeting with all stakeholders and understand their priorities
        - Fitting in UVA's sustainability goals
        - Making decisions for UVA programs
    - Two street layout, unique site
        - Many decisions
        - Parking lot
    - Not involved in the early stages of the project
        - Was disappointed with that decision
        - Important to have the same team throughout the entire process, makes it easier
    - Huge on relationships
    - Had to deal with team approach on design for project
    - Design changed many times
        - Had problems pulling the pieces together
        - 5 departments (multi-functional)
        - Needing to support EACH department very well
        - Focused on simple, open designed building
        - Connecting building to park, green street, and retention pond
        - Wanted to keep it SIMPLE

        - Building was designed to reduce stress and anxiety.
    - The experience behind entering the building
    - Food education L1
    - General medicine L2
    - Student lounge L3
        - Functional exercise space renovation
    - She worked on Link Lab
    - Student's want and needs
- Huge on relationships

What guidelines did UVA enforce on the SHWC project and other UVA projects?

- Told "not to come in", completely remote
- Went to construction sites, less than before
    - Masks were required
        - Contractors had strict policies
        - Screening, temp gauging
    - Different to get subs on site
        - Impacted the schedule

Do you feel that Barton Malow followed these guidelines well? Did other projects follow the guidelines better or worse?

- Yes, for the most part. Owner had to enforce COVID protocols on GC and subs occasionally.
- She believes that Barton Malow did a great job, generally.
    - Language barrier with subs, more spanish speakers

If you could go back, would there be things you would have done differently as far as COVID guidelines go? i.e. what were the lessons learned.

- Retirement of people from industry was huge (OVERLAP WITH CLIFF)
- People moved on during COVID, subs, managers with lots of experience
    - Very difficult to fill in those roles and impacted quality!
- Checks & Balances are effective but there are gaps
- Creating a team charter (New Strategy)
    - Agreeing on the most important goals
        - Quarterly checks
        - Relationship, trust, bringing everything to surface
    - Milestone/decision making, value management efficiency hours
    - Creating the Lean design, avoiding scope creep
    - Brings the team together

        - Positive on team morale
    - Meeting with the key members
        - Biweekly OAC meetings

Were there major quality issues that occurred due to COVID on the project? If so, where? Have they been resolved?

- There were A LOT of quality issues
    - Not due to Covid, on Barton Malow's end
- Very frustrating
    - Budget
    - Commitment issues
- Covid Impacted schedule and cost
    - 1.5 to 2x cost escalation
- Key roles on TEAMS, PEOPLE
    - Had to hold people more accountable
- She needed to depend on people and hold them accountable

What were the expectations following the onset of the pandemic? Material shortages, infections, delays, COVID-19 protocols?

- Electrical switchgear, glass, door sourcing
- Reshuffling, resequencing
- Glass, doors
- Furniture
    - Need to conduct change orders because of the lack

Did students being off Grounds due to COVID help the project progress at all?

Was there any pressure placed on UVA by the Charlottesville community for continuing project work during the pandemic?

How did the project team communicate with the owner prior to and following the pandemic? Do you think the pandemic increased or decreased communication?

- Says people are more adaptable
- Had the initial shock of the pandemic scare
- Impacted all stakeholder
    - Politics (talking about the division in government)
- Movement towards zoom with management
    - Stayed on schedule generally
    - Worked well

Was there a push to finish the project as soon as possible because of the pandemic and the returning of students to Grounds? i.e. did a possible covid surge in students influence/rush the project?

Were there any significant change orders resulting from the pandemic?

- Electrical switchgear, glass, door sourcing
- Circulation wasn't balanced to meet the sustainability goals
- Added scope to fix the negative air pressure in educational pods
    - Mechanical changes, with 5 fans
    - $250,000 of increased cost

Did UVA self perform any work on the building, if so how was it impacted by the pandemic?

Does UVA have plans in place for if/when another event similar to COVID occurs in the future?

- UVa takes life safety very seriously
    - Has been changes in leadership bc of it
    - Security deal
    - Messaging in facilities
        - With signage and plastic dividers
- Always thinking about the future, being AGILE
    - In SWHC was created to avoid the main hospital and go through the stressful process
- Need to keep up with the times
    - With health
    - Having great air quality
    - Open space
    - Environment that promotes water drinking, lights, clear navigation and access
    - Promote diversity and equal equity
        - Signage, furniture
        - Always keeping up
- Security and access committee
    - Making buildings and sites safe for students
    - Being proactive, planning ahead and allowing students
    - Optimization of smells, sizes, light, air quality, other resources
    - Active shooter resources
    - Fire shutters
    - Takes a long time

- Keep up with high standards
    - Codes and guidelines are slow
    - Getting better more rapidly

Closing thoughts

- Project engineer role is very important
    - Managing the packages
    - Need to get out on site
- Good Project Managers are key to a successful project
    - Superintendent needs to be a people person to relate with subs
        - If the subs don't like you, they won't perform
        - Had issues with that on this project
    - Saw, in person, a subcontractor walk off site
        - Caused a lot of problem
            - Subpar quality afterward
            - Retirement of subs due to covid
                - Policies of unemployment contributed
        - Poor relationship with cons. manager and sub
        - Saw first hand
        - Treat everyone better, need to hear people out
- Stay optimistic
- New technologies, sustainability, safety policies
- Everyone has a different perspective

Appendix B: Questions and Notes from Barton Malow Superintendent Interview (Cliff Smith)

How do relationships change during Covid? Com with trades

- The construction industry completely changed during covid
- No one knew the truth
- 15-25% of the workforce got covid
    - Probably a higher percentage since the workers wouldn't get paid on the days they were sick
- 200 people on job
- No deaths
- Firemen with tents and heat
    - Nothing detected from that
    - They experienced sy
- Trades didn't transmit COVID to other trades
    - Only with people who rode today and lived together
- One Sub said no van use
- When students were away and professors worked at home gave more space before
    - University recognized and accommodated
- UVa had its own policies that affected contractors
    - Quarantine
    - UVA campus policy with masks
        - In building usage
    - UVA never checked or enforced
- OSHA regulations
    - Very restrictive
    - Daily QR code
        - Comparing day-to-day
        - Contract tracing
- Had a pre-task plan daily
    - Double-checked who was there
- Workers would leave in the middle of the day (April of 2020 - April 2021)
    - Initially would sent who groups home and get results back before coming to site
    - Policy to get results
    - As more information about Covid came out
    - Same stairs. Same portajohns
- The safety manager was on top with stocking masks and hand sanitizer

Do you think the quality was impacted?

- It was very impacted
- It was functional
    - Paint, flooring issues
- Not the highest quality project
- Rules were constantly changing
- Lots of fear in the beginning
- Media craze with fear
- Lots of delays and inefficiencies were had to track
- Massive project and difficult to finish
- No direction or **flow**
    - **No one wanted to work together**
- Flow is key to finish a job
    - Missing finishes and trims
- Productivity was down but manpower was the same
- Workers had so many excuses
    - Had two major changes
    - Material procurement issue
        - Doors
        - Sealants
        - Paints
        - Supply chain issues
        - Switched products for materials
    - 9 months late with power and getting a switchgear
        - Was more
        - Elevators weren't efficient
- Uva accepting that turnover
- Mechanical sub got massive manpower boom
    - Nothing got done
    - Lack of supervision
    - Lack of plan
    - Became conservative to save money after
    - Too many people to be effective
- Lots of exam rooms
    - Small rooms
- Hazard pay issues with subcontractors
- State of Virginia never stopped construction work
- Logic went out the window when fear took over.
- Corporate said "Keep working"

- Subs workers are paid hourly and wouldn't get paid
- Lots of moving items
    - Worked as a team
- The productivity never fully picked up (even to this day)
- Work ethics have changed
- Used to be work achievement society
- Not as focused with work ethic
- Quality of work is also dropped
    - Didn't
    - Lot of people retired (older workers)
- No more people want to do night shifts
- Short of experience
- Less people in the trades
    - Gap of generation
- Technology has picked up
    - Lazers
    - Auto graders
    - Robots layout for framers
- CM has to prove value to owners
- UVA is huge on the users
    - Will buy for quality
- VMDO is a great architecture firm

Appendix C: Questions and Notes from Barton Malow Scheduler Interview (Tom Carolan)

What is your background?/How did you get into scheduling?

Director of Scheduling. Prior worked for URS bought by AECOM (EPC/Energy). High complexity, project control and management. Cost plus work. They want to be very much informed, and need lots of evidence. Then worked for owners for a while. Then came to Barton Malow, working in the eastern region. Now oversees Builders.

What software is used to create the schedule?

- P6

When creating a schedule how do you account for hundreds, sometimes thousands of tasks that need to be done for a project to be completed?

How do you use productivity data to update the schedule?

Which aspects of the schedule did COVID have the largest impact on?

How has COVID changed the construction scheduling process?

If the schedule was based on previous projects, how did Barton Malow adjust to creating new schedules following the pandemic?

Based on other schedules/projects you have worked on have you found any trends?

- General performance issues, especially in states with higher stimulus checks
- Penn, Maryland that led to people retiring
- Productivity was down
    - Learning curve for new employees
- Workforce was getting pulled away
    - Got drained
- Reallocation of workers

From an inside perspective, were there any industry trends that emerged or were trends unique to specific companies?

How does Barton Malow deal with supply delays? Does the schedule get pushed or is work resequenced?

When it comes to procuring material/products, what was the typical timeframe prior to COVID-19 versus following COVID-19?

- New material tracking
    - Long lead procurement times
- During the onset warehouses and suppliers struggled to make demand
- Calling lots of people
    - Looking for alternatives

Most important lessons learned for the scheduling team?

Words of advice for new industry members such as ourselves?

Forces out of control. Asked owner's for time and money, varied depending on the owner.

- Steven Dempsey UVA facilities
    - sjd2n@virginia.edu

***Most of this interview Tom spent time showing us tips and tricks in P6, there was little time to ask him questions

Appendix D: Questions and Notes from Masonomics Interview (Matt Ferguson and Sal Binundo)

How did the company keep track of project manpower prior to the pandemic?

- Created their own program through access
- Employees enter all their info with job tracking, etc.
- Created their own software to track team
- 2 hour radius
    - Lots of people involved
- 200-300 employees at one time
- 15-20 jobs at one time
- Very useful

How does the company keep track of project manpower now?

- Uses the same program to track manpower
- Keeps notes on each file per employee (safety certification, driver license, etc)
- All on computer
    - Working on tablet capabilities
- Gives location, time start and end
- Change of manpower based on need with information through the system/program
    - All automated
- USER INTERFACE (UI/UX)
    - Make it easy
    - Less features
    - Not complex
    - Simply for the foreman to track
    - Still need the infrastructure
    - 3 year time frame to build

How is manpower reported to the GC?

- GC has their own daily report
    - No more hand writing reports
- GC usually has their own program
    - Autodesk (Barton Malow old)
        - Not user friendly
    - Ricken (Barton Malow new)
        - An app
- GC will require sub to communicate
- ProCore is a software that can communicate with Sub and GC
- Needs to be user friendly

- Everyone uses so many different programs
- "Weekly Work Plan" excel sheet for COMM building
    - Very difficult to use without computer
- PlanGrid (Masonomics uses now)
    - Communicates with Foreman to keep up to date with submittals, change orders, documents, etc from GC
    - Allows for information to be communicated efficiently and effectively
    - Date, weather, location, field reports, materials, manpower
    - Very successful system
- TimeSheets
    - Foreman can input a time or activity where anyone can see

What additional metrics does the company track?

- Materials on-site, with time on delivery
    - Billing purposes
    - Timing
- Issue with vendors with material shortage
    - 15k short of brick
    - Proposing to take a picture to account for materials and amounts
    - Creating issue with billing issues with suppliers
- GC needs to track progress every month (monthly reports)
    - Annotate progress with dates
    - No automated way to mark up finishes
    - Overtime to comparing manpower vs work-in-place
- Cost of job vs billing system
    - Manpower can be identified as shortages
    - Better tool for GC
    - Good for Sub
        - Sub are the workforce
        - Difficult with foremans to account with new technology

Any specific software or tools?

- Cost of job vs billing system
    - Manpower can be identified as shortages
    - Better tool for GC
    - Good for Sub
        - Sub are the workforce
        - Difficult with foremans to account with new technology
- Raken for GC

    - Lots of data to open
    - For Sub
        - Input for manpower and progress questions (much less confusing)
        - Productivity usages
    - Can be used as safety reports
    - Ease-of-use
- Bim360
    - RFIs
    - File storage

Are you satisfied with the software/tools you are using to track manpower? If not, what additional features/functionality do you wish the tool had?

- For Sub
    - Bluebeam Studio best for foremen
    - ProCore not ideal
    - PlanGrid is better
- For GC
    - ProCore
        - Many features
        - Most complicated
        - Most expensive
    - PlanGrid
        - Simpler
        - More industry accepted
    - Autodesk
        - Bim360
        - Build
        - Working with PlanGrid to improve
- Too many programs
    - Wants a standard to make it easier for everyone
    - Wants a centralized app to communicate with other programs

During the onset of the pandemic, did the company institute any specific health and safety measures? If so, how did the team respond?

- When Covid initially hit, no one knew what was happening
    - Followed CDC guidelines
    - Then followed each GC protocol
        - Some had 3 page or 100+ page policy
    - Mercy at GC and CDC

- Wanted to ensure that workforce was safe
    - Everyone was understanding and accommodating

Following mask mandates, did the company see increased accidents or safety issues unrelated to COVID-19?

- Everyone was onboard with masks, safety glasses, gloves
    - Big complaint with the glasses fogging up and can't see
- Safety glasses vs mask problems
    - Barton Malow had the stair policy to take off glasses to see steps
    - Goggles technology to avoid problem
    - Tried 10 different lens cleaning products

How many individuals were infected with COVID-19 while working at the SHWC project from March of 2020 to June of 2020?

- Initially, VSU engineering building got COVID and needed to disinfect everything behind going back to work
- More trades and employees got COVID due to contact
    - **Sharing rides (all got infected)**
        - **Huge problem**
    - Job site never shutdown fully
    - Information across site to
- More safe in the beginning of COVID
- Less safe at the end of COVID as policies relaxed
- Isolated on SWHC with exterior of building, not fully shutdown
- Ride share issue with team
- 05/27/20 and 05/28/20 they were not on site due to COVID (see manpower report)
- 04/27/20 "left from fear of corona" (manpower report)

Of the individuals who were infected, what work were they performing prior to testing positive?

- Exterior brick work during pandemic
    - Good ventilation
    - Spaced out (social distanced)
- Crew was able to be shuffled around as being a huge company
    - Transfer workers between sites
- Wanted to wipe each brick down for disinfection
    - Challenged them
- CDC and hospital had aggressive protocols
    - Needed a face shield with a mask

- Current jobs ask for vaccines (flu and COVID boosters)
- The hammer test with safety glasses
    - Face shields

In your experience on the SHWC project, how successful was social distancing? Were different crews able to stay separated from one another?

- Bricklayers 10 -15 feet apart normally
- Outside, well ventilated, good conditions for Covid spread prevention

Was communication significantly impacted between intertrades and management?

- During COVID time, big challenge with coordination
    - Needed to zoom in to meetings
    - Impacted GC, sub (field and office) communication
    - Zoom/Team option is now beneficial
        - Saves time
        - Problem solving should be hands on
    - People weren't planning attention during online meetings
        - Loses focus
    - Lack of body language
    - Loses that sense of connection
    - Example
        - Zoom classes don't have discussion or response
        - Participation was gone
    - Huge disconnect
    - Tripled in work with emails
    - Losing the personal touch
    - Lack of human interaction
    - People are less able to communicate effectively

In your experience on the SHWC project were the COVID-19 protocols effective?

What type of leave does/did the company offer its employees? Vacation? Sick leave? COVID-19 specific sick leave? Paid or unpaid?

- Depends on employees wage status (hourly/salary), tenure
    - Sick leave

Does the company suspect that some individuals may not have reported symptoms in order to keep working?

Have you seen any changes in productivity after the pandemic, on current jobs?

Do you think the quality of work was impacted by the pandemic?

- Quality control is one of their teams highest requirements
    - Mistakes happen, but does not necessarily think COVID was the reason for quality issues

Say another pandemic were to happen in the near future, what would you want your company to do differently than what they did during COVID-19?

- Hope to never see anything like it again
- At home tools for employees to improve efficiency
- They have a small office and are spread out, able to continue working in office
    - Some were prepared to work from home
    - Wants to see a faster remote process, make working from home more seamless

Did you have any problems with more experienced folks in your workforce retiring and leaving the industry?

- Had a foreman at retirement age leave
- Had other more seasoned people leave
- There's a gap in knowledge between the new people and the seasoned people (~10 years)
- Acknowledged there is a shortage of trade workers
    - Have made programs at trade schools or high schools, trying to rebuild labor force
- Side Note
    - Older Foreman get overwhelmed with emails
        - Email chain increases constantly
        - Questions build on different questions
        - Need quick communication
        - Disconnection with management, owner, and field workers

Appendix E: Questions and Notes from Contemplative Commons Interview (Ryan Byrd and Paul Hahn)

How does the project team currently keep track of labor?
Don't keep track of specific manpower data from subcontractors unless subs get behind schedule. They Meet with subs regularly. Meetings with subs are 1 on 1 and in groups. There are also meetings with the foreman everyday to discuss manpower and productivity.

What software does the team currently use to track the schedule? Are there any issues with it?
Modified version of P6 I think.

What are the current challenges procuring materials (aka lead times)? How has the team combatted these issues?
If a material usually takes longer to get, say for example steel, then the construction team asks for the architect to release the steel early so they can order it to make the schedule.

Communication? How does the project team communicate with subcontractors? Did this change following COVID-19?
Meet once a week with each of the subcontractors individually and as a whole.

Does UVA still have any procedures/guidelines/policies regarding COVID-19?

Past projects during COVID-19?
APEX Plaza. Tracking COVID-19 QR identification, temperature reading, survey. Probably get sent back home.
Masking was helpful during COVID-19 especially for dust. Didn't see any issues with carbon dioxide decision impairment. Currently some workers prefer to continue using masks.

- Major issues?
- Outbreak?
- Company Mitigation Strategies & Policies?
- Quality? Did it suffer?

Contemplative Commons is a tight site, how did the team plan around this?

Appendix F: Detailed Manpower Summary Notable Events

- 03/09/2020
  - Barton Malow Management
  - Walt is sick
- 03/12/2020
  - Barton Malow Management
  - Walts sick
- 04/27/2020
  - ColonialWebb Contractors
  - 14 people left from possible Coronavirus exposure
- 04/27/2020
  - Masonomics
  - Left from fear of corona
- 04/30/2020
  - ColonialWebb Contractors
  - All crew left from possible Coronavirus exposure and regroup Monday
- 05/11/2020
  - Liphart Steel
  - Had worker confirmed with Covid Pulled off job
- 05/12/2020
  - Liphart Steel
  - No work due to Covid
- 05/13/2020
  - Liphart Steel
  - Out with Covid
- 05/14/2020
  - Liphart Steel
  - COVID-19
- 05/18/2020
  - BMC Interiors
  - Off for Coronavirus
- 05/19/2020
  - BMC Interiors
  - Off for Coronavirus
- 05/19/2020
  - ColonialWebb Contractors
  - Duct sent home from Coronavirus
- 05/20/2020
  - BMC Interiors
  - Off for Coronavirus
- 05/20/2020
  - ColonialWebb Contractors
  - Duct L1 L2/home w-Coronavirus
- 05/21/2020
  - BMC Interiors
  - Off for Coronavirus

- 05/21/2020
    - ColonialWebb Contractors
    - Duct L1 L2/5 men home w-Coronavirus
- 05/26/2020
    - IES Electric
    - Worked until they had an employee came in hot. Sent whole crew to be tested
- 05/27/2020
    - IES Electric
    - Out due to Covid 19
- 05/27/2020
    - Masonomics
    - Out due to Covid 19
- 05/28/2020
    - IES Electric
    - Out due to Covid 19
- 05/28/2020
    - Masonomics
    - Out due to Covid 19
- 08/14/2020
    - AG Dillard
    - Crew left sick at 10:45
- 08/17/2020
    - AG Dillard
    - Waiting on covid test
- 08/18/2020
    - AG Dillard
    - Waiting on covid test
- 08/19/2020
    - AG Dillard
    - Waiting on covid test
- 04/21/2021
    - RC
    - Filled out B&M covid sheet

Appendix G: Roles & Responsibilities

Ryan Naddoni (Role: Communication Leader)

- Responsibilities: Reviewing and analyzing monthly reports. Coordinating, scheduling, and leading meetings. Modifying/updating the project schedule. Reviewing and analyzing schedules from the project. Developing the app. Writing the report.

Jackson Quinn (Role: Meeting Agenda Co-Leader)

- Responsibilities: Analyzing manpower report and creating charts for manpower report. Create agendas prior to each weekly capstone meeting. Reviewing and analyzing schedules from the project. Developing the app. Writing the report.

Alexander Maleski (Role: Meeting Scribe)

- Responsibilities: Reviewing and analyzing RFI's. Attentively note-taking during meetings. Assist in modifying the project schedule. Reviewing and analyzing schedules from the project. Developing the app. Writing the report.

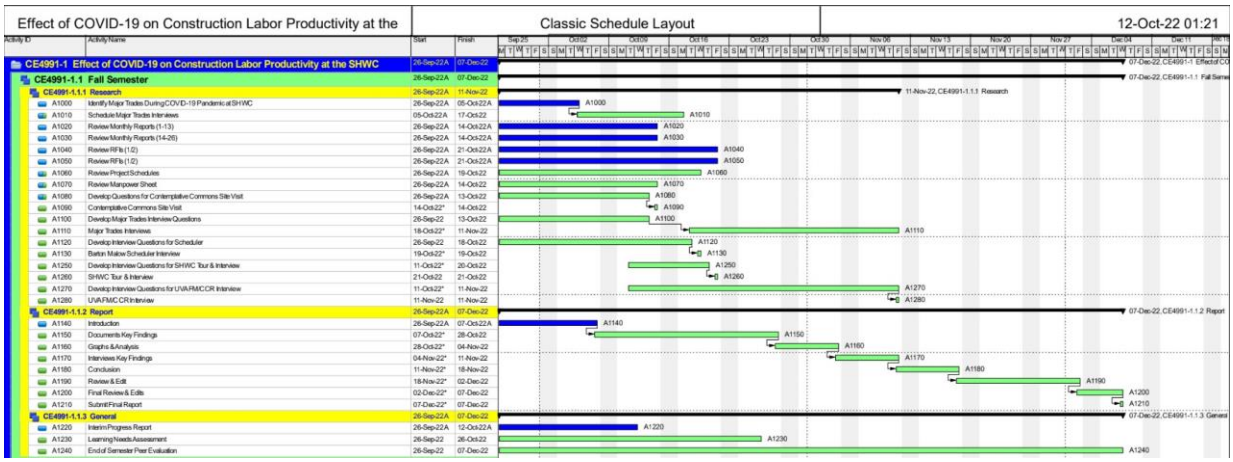
Hayden Hunter (Role: Assistant Meeting Leader)

- Responsibilities: Assist in leading weekly meetings. Reviewing and analyzing monthly reports. Reviewing and analyzing schedules from the project. Developing the app. Writing the report.

Brant Flici (Role: Meeting Agenda Co-Leader)

- Responsibilities: Reviewing and analyzing RFI's. Create agendas prior to each weekly capstone meeting. Reviewing and analyzing schedules from the project. Developing the app. Writing the report.

Appendix H: Fall 2022 Project Schedule



Appendix I: Spring 2023 Project Schedule

Schedule Spring 2023 Layout:

- Update & Expand Preliminary Framework **Due 02/24/23**
    - Draft Design #1 (Capstone Update) **Due 02/28/23**
- Interim Report **Due 02/24/23**
- Third Party Review **Due 03/03/23**
    - Preferably Subcontractor or Barton Malow Team Member Review
- Complexity Assignment **Due 3/31/23**
- Figma Phase #1 **Due 03/24/23**
    - Initial App Setup
        - Develop Individual “Screenshots”
- Figma Phase #2 **Due 04/05/23**
    - Prototyping
        - Linking Up & Checking for Flow
        - Usable Model is End Goal
- Draft Design #2 **Due 4/7/23**
- Figma Phase #3 **Due 04/21/23**
    - Final Formatting & Clean Up
    - Third Party Review **4/21**
        - Preferably a Subcontractor or Barton Malow Team Member Review
    - Adjustments Based on Feedback
- Poster Symposium - **04/27/23**
- Final Project Presentation **(4/24 - 5/10)**
- Final Paper **Due 5/2/23**

How the COVID-19 Pandemic Changed Construction Work Life

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Hayden Hunter

Spring 2023

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

Pedro A. P. Francisco, Department of Engineering and Society

Introduction

In 2020, the emergence of the COVID-19 virus spiraled the world into a global pandemic that interrupted numerous systems. This forced companies of all disciplines to adjust their structures and procedures to accommodate the monumental shifts brought by the virus. Many companies adopted innovative technologies that allowed them to minimize the effects of the pandemic on their businesses. However, these quick changes to industry standards altered the lives of those who worked in them. One industry that was significantly changed was that of construction, so how did the technologies implemented during the pandemic effect the laborers? Many workers left the industry whether by their choice or not. Employment trends changed due to this innovative and regulatory shift in construction, which played a role on workers' well-being and satisfaction with their company's response to the pandemic (Liang et al., 2022). The construction industry is known as being slow to adapt to innovative technologies, however the pandemic changed the course of this growth. These technologies had significant impacts on the daily actions and well-being of workers involved in the industry.

Background and Significance

The world has changed significantly over the past several years. This is largely due to the unprecedented circumstances induced by the COVID-19 pandemic. From the fourth quarter of 2019 to the second quarter of 2020, 21.0 million people in the U.S. were laid off. This raised the unemployment rate to roughly 13% (C, 2021). Although these numbers are staggering, some industries and fields were hit harder than others. By April 2020, almost one million jobs were lost in the construction industry and the unemployment rate within the field rose to 16.6% (*U.S. construction industry employment under Covid-19 pandemic 2020*). The pandemic impacted the

laborers in the construction industry in numerous ways—not simply by employment numbers dropping.. These included health risks, supply chain disruptions, financial strain, and change in work processes. Many construction projects were halted or delayed which resulted in firms letting go of workers. A significant factor in these delays was major supply chain issues. The delivery of materials and equipment prevented companies from being able to complete projects on time and forced them to alter their routine procedures for project completion. Construction laborers are also required to work near one another, which increased their likelihood of contracting the COVID-19 virus. Thus, construction sites implemented safety protocols to mitigate the spread of the virus, technologies that required fewer workers, staggered work schedules, remote work, and virtual meetings. Considering the multitude of these changes in the industry over a short duration of time and the fact that they affect all construction workers in the industry, the lives and well-being of these individuals were changed dramatically.

Research Methods

The impact that new technologies implemented during the pandemic had on construction workers can be analyzed through literature reviews and interviews. The literature reviews provided a general background and baseline for the topic, while the interviews with several construction industry professionals contributed as the primary source of research. Considering the topic of this paper involves the well-being of individuals within the construction industry, interviewing various professionals was a way of gathering data directly from those who lived through the pandemic to better understand how it affected them personally. Consequential data analysis was selected for this research because I was looking to analyze how the change in certain technologies impacted those involved in a construction project, both their daily lives and personal well-being. As technology inherently impacts their users and influence one's actions

and well-being, Actor Network Theory, which emphasizes these relationships, was the framework used.

Results and Discussion

This section focuses on the changes of personal protective equipment (PPE) as a result of the pandemic, the increase in technological adoption in the construction industry, and their connection to actor network theory. PPE was not only adopted by the construction industry, but all in-person industries during the pandemic. This includes face masks, face shields, gloves, and the practice of social distancing. A study was conducted on healthcare workers in the United Kingdom to observe the proportion of individuals who experienced heat stress while wearing PPE. The researchers concluded that wearing PPE had negative impacts on the performance, safety, and well-being of the workers (Davey et al., 2020). Assuming healthcare workers are stationed inside buildings with controlled temperatures, this environment is much different from those of construction laborers who may be either in the heat or the cold of the outdoors. This assumption leads to the extrapolation that if a survey was conducted on construction laborers similar to that mentioned in the study above, the results would be similar to the healthcare workers if not more extreme. Although these technologies and practices negatively impacted the laborers with respect to their productivity and well-being, it significantly decreased the spread of the COVID-19 virus. This improved the well-being and states of mind of both the overhead of the contractors and the owner by saving them nearly $30,000 per week according to one study (Briggs et al., 2022). Considering PPE as some of the technology implemented on construction sites during the pandemic, its impact on the well-being of individuals in the construction industry varied depending on one's role in a project. It negatively affected laborers in the field while positively impacting overhead and owners.

While the construction industry is one that seems behind the times in terms of technological innovation, there have been recent advancements in technology that have altered the traditional methods of construction. The COVID-19 pandemic could have been a catalyst for this shift towards innovation. Considering the multitude of challenges the pandemic brought to the industry, construction firms and third parties increased their focus on research of technologies that attempt to minimize these effects (Alsharef et al., 2021). With the implementation of new technologies in the construction industry, such as modular construction, digital collaborative platforms, autonomous machinery, and BIM, over a relatively short span of time, the actions and procedures of those involved in construction projects have been replaced and changed by these innovations.

This idea that technology plays a role in dictating the extent of human actions is one proposed by Science and Technology Studies (STS) scholars. People have not only given technologies tasks but also ethics, morals, duties, and values. This theory that artifacts can control, limit, reshape, and replace human actions and humans can have this same influence on artifacts is referred to as Actor-Network-Theory (ANT) (Latour, 1992). The main aspect of this framework I will be drawing upon in this section concerns how technological devices and methods dictate individuals' daily actions. A non-engineering example of this was studied by a scholar who suggested that security is related to objects. In his article he refutes and scrutinizes opposing viewpoints of scholars to come to the conclusion that ANT plays a crucial role in securitization theory (Salter, 2019).

A more recent technological example supporting the idea that technology has the capability of restricting the actions of humans can be seen in the sentencing of Punithan Genasan in Singapore. During the pandemic, personal interaction was limited which affected the court of

law in Singapore. Sentences were given out via Zoom rather than in a court room. The use of Zoom video communication increased during global quarantine and changed the traditional methods of human interaction. Punithan Genasan received his death sentence via Zoom while alone and isolated. This likely impacted his mental health and well-being by not being allowed to be comforted by others (Heinsch et al., 2021). This instance is evidence that due to the pandemic, technological innovations that arose changed the actions individuals took. Another study was conducted in two settlements in Freetown, Sierra Leone. The study examined how two Community Based Organizations (CBOs) regarded COVID-19 as a health risk and how they interacted with other entities in the community. The authors employed Actor Network Theory to find that these community-based organizations recognized vulnerabilities within the communities and relied on past experiences and available technology to help design protocols that aided the communities in minimizing the impact of COVID-19. The researchers interviewed members of the CBOs to collect data. They found that the technologies they had at their disposal dictated their response to the pandemic in their respective communities (Frimpong et al., 2022).

This relates to Latour's ANT framework because technologies available to the communities limited their actions. One final source that closely relates ANT to the construction industry and my technical topic examines a commercial office development in central London and the associated networks that emerged during the planning stage. Using actor network theory, the author found the importance of planning policy documents in mediating and defining relationships between planners. He also concluded that the material nature of the development shapes and solidifies network inter-relationships (Rydin, 2012). Over the last several decades, the idea that technology inherently replaces and reshapes human actions has come to light and gained traction among the STS community. The numerous technological solutions that arose

during the COVID-19 pandemic are evidence that those technologies altered traditional human interactions and behaviors.

This background knowledge of humans' influence on technology and technology's influence on humans sheds light on this relationship specifically in the construction industry during the COVID-19 pandemic. In order to gain direct insight into this time period within the construction field, several interviews were conducted with various construction industry professionals. The first individual consulted worked for a large private general contractor in it business development sector. This company primarily does work in vertical construction. They said that their company pivoted to rely significantly on virtual meetings and direct messaging rather than communicating in person. This required a large capacity of connection and bandwidth.

The second professional interviewed held a position as Director of Construction for a small general contractor for transportation projects. This individual also stated that the majority of office employees and other non-labor employees had the option of working remotely. This individual also noted that this strained their workers who did not have access to fast internet and the company as a whole due to its being a small business with a smaller capacity to absorb such a dramatic change. The company also required workers to wear face coverings when within six feet of another individual and limited company vehicles to only one or two individuals. The interviewee noted that this limited interaction between workers forced their company to rely on smaller teams and more technology/equipment. They also encountered issues with the supply chain disruptions, predominantly due to the lack of accessibility to computer chips used for installing traffic signals. Despite the restrictions and inhibitions, the professional interviewed stated that their firm was more productive than prior to the pandemic. Reasons for this included

increased safety of workers, less traffic on roadways, saving money on fuel for vehicles, and offering their employees more free time with family because some no longer had to commute. However, the negative impacts of the pandemic on their workers were excuses for missing meetings due to not being in-person, increased conflicts due to connection issues when working remotely, and difficulties setting up meetings when some workers were in the field and others were remote.

After constructing the interviews, several similarities and differences in responses were noted. This could have been a result of the individuals being involved in different branches of the construction industry. Both individuals noticed that in-person interactions were limited by the virus. This led to both companies facilitating communication by relying on virtual meetings and direct messaging. Given the circumstances of the pandemic, this greatly aided workers' ability to efficiently work by bolstering communication. However, there were certain downfalls of this technological shift in communication. The individual from the large vertical construction general contracted noticed that younger employees began to solely rely on virtual methods of interaction. They followed this observation up with by stating that this negatively impacted their ability to network with others within and outside of their company which slowed some of their career development. The individual from the smaller general contractor stated that virtual communication was difficult and stressful for several of their workers who did not have access to reliable or fast internet remotely.

The next biggest change in technology implemented during the pandemic in the construction industry was the increase of PPE. Some of the research conducted showed that some laborers had issues breathing and overheating while wearing masks on the job site. This is likely to have had a very negative impact on workers especially in warmer climates. However,

the information gathered from the interviews suggests that this may have been the case at the earlier stages of the pandemic, but as time moved on companies began to rely on less physical work and more equipment and machinery, such as the groundbreaking ‘Spot’ which is a robot that can scan and analyze buildings under construction by surveying and inspecting the site.

Building Information Modeling (BIM) has been used in the construction industry for several years now. Although it is not considered a new technology, the pandemic forced companies to rely more heavily on its usage and development. BIM models allowed teams involved in a construction project to meet virtually and discuss the design of a structure before ground was ever broken. Contractors and designers could effectively communicate to identify potential issues that may have arisen during physical construction, which helped both owners and contractors save money and combat schedule impacts.

As mentioned in the literature reviewed above, prefabrication and modular construction significantly increased during the pandemic. Considering the restrictions of social distancing on job sites, modular construction and prefabrication became perfect alternatives to assembling all construction tasks in the field (Assad et al., 2022). This allowed more workers to continue to work on a project at one time, keeping more people employed, and allowing them to work in a controlled environment. It also made the lives of project managers and executives easier by enabling projects to stay on budget and schedule.

One final technology that was of extreme importance in maintaining positive worker well-being was the use of wearable monitoring systems. This includes smart helmets that can track workers’ temperatures, safety vests, and other sensors. These devices, especially the smart helmet, allowed for workers and supervisors to be conscious of their health on the site (Li et al., 2021). Not only did these technologies help workers prevent the spread of the virus and keep

others around them safe, but they also tracked equipment usage and improved work site efficiency.

Conclusion

The COVID-19 pandemic was one of the most impactful events in the world in recent memory. It changed the lives of many people by either creating new opportunities or stripping others of the opportunities they already had before them. The pandemic was a stressful time not only for businesses, but also each individual in the United States. Many industries were affected due to this virus which caused an increase in unemployment and decrease in well-being for many people. Among these industries impacted was that of construction. However, during this unprecedented time the opportunity rose for technological innovation to combat some of the challenges introduced by the pandemic. The technologies that became prevalent in the construction industry during the COVID-19 pandemic had mixed impacts on the well-being of those in the workforce and those who began the pandemic employed in the industry but were laid off. For employees that continued to work in the industry, the technologies that emerged during the pandemic increased their personal well-being by easing their physical workload, allowing them to have spend more time with their significant others, and preventing the spread of the virus as well as other illnesses. However, these newly adopted technologies allowed companies to perform activities with fewer workers which significantly decreased the well-being of those who were let off during this time period. With this in mind, the innovation of new and existing technologies within the construction industry during the COVID-19 pandemic had both positive and negative impacts on the well-being of workers depending on their employment status.

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Impact of COVID-19 on Construction Labor Productivity

Technological Shift in Construction in Response to the COVID-19 Pandemic

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Civil Engineering

By
Hayden Hunter

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Hundreds of construction projects around the U. S. were inhibited by the unprecedented global event of the COVID-19 pandemic. It caused issues with the worldwide supply chain, workers' ability to come to their jobs, and much more. Crews would often have to take off two weeks when one member became exposed or infected with the COVID-19 virus. Medical absences in the construction industry increased 70% from March to April 2020. The pandemic even impacted the employment of construction laborers. During that same month period change in 2020 mentioned above, approximately one million construction workers lost their jobs, 55% of whom were temporarily laid off (Brown et al., 2020). It can be assumed that these drastic increases in percentages were due to the onset and uncertainty of the COVID-19 virus.

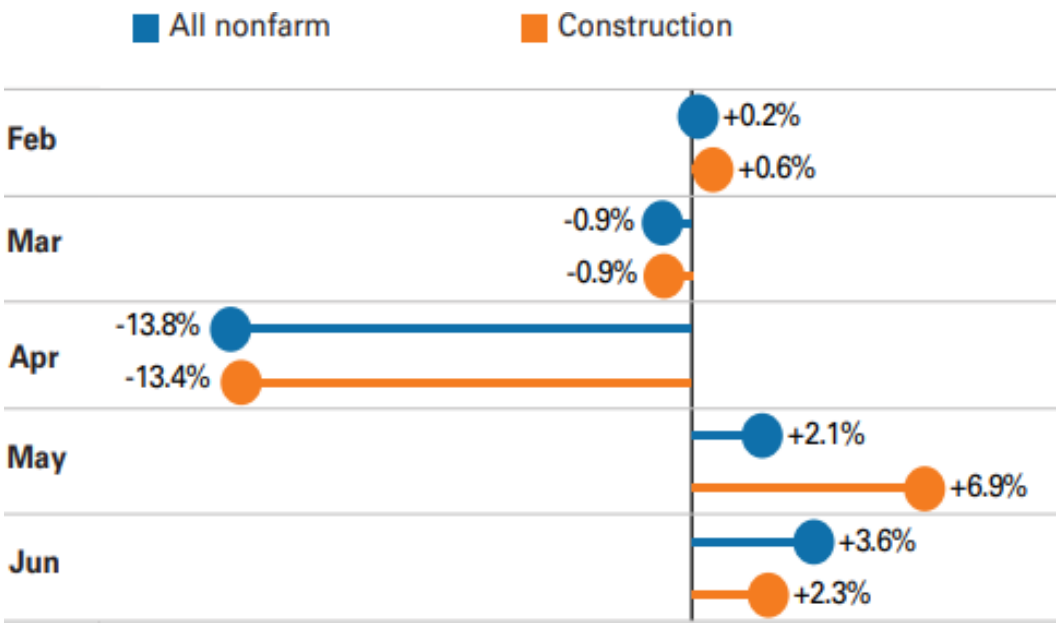

Figure 1. Monthly percentage change of employment for construction versus all non-farm industries (Brown et al., 2020).

Materials that companies would order only several weeks in advance continuously shot up in price and in some cases could take up to a whole year to become available. A 2020 report showed that 71% of contractors had issues acquiring at least one material due to supply chain disruption. Steel mill products increased in cost by nearly 75% (Smith, 2022). These supply chain and worker shortages put certain activities and entire projects behind schedule. A survey conducted during the pandemic emphasized the previously mentioned findings by indicating that construction laborers were nearly five times more likely to have contracted the virus than any other worker. It also found that these construction projects researched by the survey were delayed between 5 to 56 days (Kisi et al., 2022). The pandemic resulted in projects being behind schedule and vastly over budget. This major global event pushed construction firms to look for alternative strategies to mitigate these issues. One alternative to traditional construction methods was offsite construction methods and technologies. This involves the building of certain parts of a structure that can be transported to the site and installed immediately upon arrival. One article inspects two instances where hospitals were constructed using offsite methods during the climax of the pandemic in China and the United Kingdom. The construction timelines for each structure shortened dramatically due to modular offsite construction. This was found to increase worker safety and reduce schedule impacts due to less crew members having to be on site to place each piece and by allowing multiple separate crews to build sections simultaneously (Assad et al., 2022). This is just one example of the technological changes and innovations that took place in response to the global pandemic. The construction industry as a whole had to alter their approach to these new challenges in order to combat the effects of the COVD-19 virus.

Technical Topic

The construction of the Student Health and Wellness Center (SHWC) on Brandon Avenue underwent construction from early 2019 to August of 2021. This building features four stories and 160,000 square feet of space. Barton Malow was the general contractor responsible for managing the construction of the structure. The onset of the COVID-19 virus occurred during this period when Barton Malow began ramping-up field crews and increasing the number of workers on site. The pandemic significantly impacted the project construction and well-being of the laborers. The Barton Malow team attempted to act promptly to keep the project on schedule but failed to properly collect the data that they could use in the future to understand exactly how the pandemic affected the project.

My Capstone group is tasked by Barton Malow with delving into their Request For Information (RFIs), monthly reports, schedules, manpower documents, and submittals to analyze data and find trends that will shed light on how the pandemic impacted the labor productivity of the crews involved in this project. The ultimate goal is not only to determine trends that have gone unnoticed, but ultimately to recommend a solution for preserving project continuity in the face of a similar event in the future.

Our team met with the project executive and project manager assigned to the SHWC who communicated to us that crews would often commute to the job site in groups of up to five workers. This caused issues when one or more members of a crew would test positive for the Coronavirus and be required to quarantine for weeks at a time. Traffic on the job site also led to increased human interaction and effectively the transmission of the virus. In response to these issues, construction firms were encouraged to introduce new technologies and methods of communication to reduce the effects of these challenges on construction sites. Barton Malow

realized this quickly and experimented with different methods of combating these challenges. My capstone group is tasked with taking those changes into account when finding trends of labor productivity and ultimately develop a system/application to mitigate challenges in the future similar to those induced by the COVID-19 pandemic.

STS Topic

While the construction industry is one that seems behind the times in terms of technological innovation, there have been recent advancements in technology that have altered the traditional methods of construction. The COVID-19 pandemic could have been a catalyst for this shift towards innovation. Considering the multitude of challenges the pandemic brought to the industry, construction firms and third parties increased their focus on research of technologies that attempt to minimize these effects (Alsharef et al., 2021). With the implementation of new technologies in the construction industry, such as modular construction, digital collaborative platforms, autonomous machinery, and BIM, over a relatively short span of time, the actions and procedures of those involved in construction projects have been replaced and changed by these innovations.

This idea that technology plays a role in dictating the extent of human actions is one proposed by Science and Technology Studies (STS) scholars. People have not only given technologies tasks but also ethics, morals, duties, and values. This ideology that artifacts can control, limit, reshape, and replace human actions is referred to as Actor-Network-Theory (ANT) (Latour, 1992). The main aspect of this framework I will be drawing upon in this section concerns how technological devices and methods dictate individuals' daily actions. A non-engineering example of this was studied by a scholar who suggested that security is related to

objects. In his article he refutes and scrutinizes opposing viewpoints of scholars to come to the conclusion that ANT plays a crucial role in securitization theory (Salter, 2019).

A more recent technological example supporting the idea that technology has the capability of restricting the actions of humans can be seen in the sentencing of Punithan Genasan in Singapore. During the pandemic, personal interaction was limited which affected the court of law in Singapore. Sentences were given out via Zoom rather than in a court room. The use of Zoom video communication increased during global quarantine and changed the traditional methods of human interaction. Punithan Genasan received his death sentence via Zoom while alone and isolated. This likely impacted his mental health and well-being by not being allowed to be comforted by others (Heinsch et al., 2021). This instance is evidence that due to the pandemic, technological innovations that arose changed the actions individuals took. Another study was conducted in two settlements in Freetown, Sierra Leone. The study examined how two Community Based Organizations (CBOs) regarded COVID-19 as a health risk and how they interacted with other entities in the community. The authors employed Actor Network Theory to find that these community-based organizations recognized vulnerabilities within the communities and relied on past experiences and available technology to help design protocols that aided the communities in minimizing the impact of COVID-19. The researchers interviewed members of the CBOs to collect data. They found that the technologies they had at their disposal dictated their response to the pandemic in their respective communities (Frimpong et al., 2022).

This relates to Latour's ANT framework because technologies available to the communities limited their actions. One final source that closely relates ANT to the construction industry and my technical topic examines a commercial office development in central London and the associated networks that emerged during the planning stage. Using actor network theory,

the author found the importance of planning policy documents in mediating and defining relationships between planners. He also concluded that the material nature of the development shapes and solidifies network inter-relationships (Rydin, 2012). Over the last several decades, the idea that technology inherently replaces and reshapes human actions has come to light and gained traction among the STS community. The numerous technological solutions that arose during the COVID-19 pandemic is evidence that those technologies altered traditional human interactions and behaviors.

Research Question and Methods

In connection to both the technical and STS topics, the research question I will be addressing is how did the technologies implemented in the construction industry during the COVID-19 pandemic shed light on the technologies' effects on construction projects and their laborers? I plan on conducting research on this topic using a variety of methods. I will analyze data and trends from the construction of the SHWC as a case study. I will also be touring current job sites on Grounds and the greater Charlottesville area to ask supervisors and construction workers their experiences during the pandemic. In addition, I will reach out to several project managers for both general and subcontractors that I have connections to both in Charlottesville and in Northern Virginia inquiring about technological and procedural changes they made while working on construction projects during the pandemic. This should provide data on how these new technologies affected laborers and construction during this period. Using this information, I will be able to draw conclusions on how these technologies limited, reshaped, and replaced traditional actions of those involved on a construction project.

Conclusion

The COVID-19 pandemic posed a huge hurdle for industries worldwide, especially the construction industry. Its aftermath impacted project schedules, costs, material supply, labor productivity, worker well-being, and much more. The technical component of my Capstone project aims to find a technological solution for construction management firms to mitigate risks associated with having labor impacts or disruptions in a construction project. The nontechnical component involves researching the effects of COVID-19 that led to the implementation of new technologies that changed the daily actions and decision-making of those involved in a construction project. These two findings will aid in solving similar issues as ensued from the COVID-19 pandemic for construction projects in the future and shed light on the changes that may occur when implementing this new technology.

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