Impacts of COVID-19 on Construction

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Abstract

This research investigates and quantifies the impacts of coronavirus (COVID-19) on the duration and cost of construction projects, focusing specifically on two construction dimensions: supply chain and construction labor productivity. Conclusions on the topic were reached using two methods, namely performing two case studies and using Primavera 6 and Schedule Analyzer software to analyze schedule updates. Each of the case studies utilizes a real-life construction project that was active when the impact of the pandemic was at its peak (April 2020). The data also includes interviews with project managers and progress meeting minutes. Results reveal that COVID-19 has impacted the progress of construction in two ways: 1) delays resulting from the shutdown of the manufacturing facilities and suppliers that state officials deemed non-essential; 2) labor disruptions resulting from restrictions on gatherings, as well as absenteeism of workers who were either sick with COVID-19 or who were avoiding construction sites and preferred to stay home in response to state officials' recommendations. The results suggest that contractors should request compensable time extensions, as they establish the basis for a

legitimate claim that will lead to modifications of the contract time and/or total dollar amount. Future work may investigate the integration of tools and methods during the bidding and construction process that would mitigate the future impact of similar potential situations due to a pandemic or any other force majeure event. Future work may also investigate impacts of COVID-19 on construction sites outside the United States.

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Introduction

The novel COVID-19 pandemic has had a significant effect on numerous industries. Despite many states and countries worldwide deeming it an essential service, the construction industry was among those that were impacted. This research will investigate the ways in which, and the extent to which, construction has been affected by the pandemic by examining two of the industry's core components: supply chain and construction labor productivity. Construction contains many dimensions and aspects. A construction project requires a design, material supply, and labor. If one of these areas is impacted, this in turn disrupts the progress of the entire project; consequently, the contract's time and/or total costs would have to be modified. The powerful and unforeseeable nature of COVID-19 made it difficult for most countries to control it. As one of these countries, the United States consequently experienced widespread disruption to the progress of most, if not all, ongoing construction projects. With annual expenditures exceeding USD 1,293 billion, the construction industry is one of the country's largest industries.[1] When asked if COVID-19 has impacted construction, all the project managers interviewed in the two case studies answered that it has; however, they are uncertain as to how and to what extent. Moreover, these participants had no definite answer as to whether they planned to submit a time extension request or claim costs, due to their unawareness of whether they were impacted enough to submit a claim and if they consequently deserved compensation. The pandemic has caused disruption and delays to many working in construction sites. Although these groups were nevertheless able to overcome them and continue working on the project, this does not exclude the fact that they were impacted, that the project was delayed even further behind its contractual completion date, and that

extra overhead costs would consequently ensue. Project managers are more likely to realize the importance of proving their eligibility for a time extension towards the end of the project, by which point they are obligated to deliver the project by the agreed-upon time. The subsequent outcomes include negotiations, arbitration, and the funneling of additional costs toward hiring expert witnesses. This research is therefore of great importance to all stakeholders involved in construction projects that were active during the pandemic. This list of stakeholders includes, but is not limited to, the projects' owners and developers; contractors; suppliers; and the public that would be impacted by the delayed delivery of the relevant projects, such as the public transportation users currently anticipating the activation of the bus routes in Montgomery County (see first case study). Moreover, a delay in a public transportation-related project forces the public to use other transportation means, such as cars, until bus routes are reopened; this produces additional costs and increases carbon emissions. The public also includes residents around the roadway segment that is under reconstruction (see second case study). Therefore, depending on the type of the project, each will have a set of stakeholders who will be impacted by delays to its delivery. Moreover, this research is of importance to all owners, suppliers, and contractors who will be working on future projects. All upper management staff in construction-related work will now be forced to accommodate and prepare for further waves of COVID-19 or another pandemic that may be similarly accompanied by stay-home orders, restrictions on gatherings, and shutdowns. The COVID-19 era has fundamentally shaped the construction industry, and this research will discuss how certain dimensions were molded by this impact. Going forward, decision makers in the construction industry will take different measures to prepare for similar situations in which suppliers may be deemed non-essential and

thus prevented from delivering materials on schedule. Moreover, decision makers will also take into consideration the added costs, which include but are not limited to costs for PPE; the absenteeism of sick employees; loss of productivity; idle equipment; delays; and changes to means and methods. This research will offer future construction-industry stakeholders an insight into the possible consequences of another wave of COVID-19, if they fail to take the following measures in preparation for it: 1) financially preparing by allocating additional money in contractors' bids for extra costs; 2) contractually preparing by including provisions for pandemics; 3) preparing through means and methods by including different plans and options to amend for possible disruption to the progress.

Literature Review

Most previous papers on the impact of COVID-19 on economy and business focus on the monetary impacts on small business owners, the stock market, oil prices, gold prices, technology, the travel industry, and consumer purchasing patterns, and examine the economic relief packages granted by the government. Meanwhile, other works discuss the legal implications of COVID-19 on construction such as Force Majeure clauses, insurances, worker's compensation, and impacts on design sector. These predominantly take the form of short articles and industry webinars. However, no research has been published that quantifies the impact of COVID-19 on construction, specifically on supply chain and labor productivity.

Available Literature on COVID-19 Impacts on Construction

The CDC has classified COVID-19 as an airborne illness, due to its transmission via respiratory air droplets that carry the virus. [2] As a result, engineering research is currently focusing predominantly on how HVAC systems can be modified to reduce the spread of COVID-19. For instance, ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) has created an "Epidemic Task Force" of experts to study the relationship between the spread of COVID-19 and HVAC systems (ASHRAE, 2020).[3] In the first half of 2020, ASHRAE released statements on COVID-19 indicating that changes to building operations, including the HVAC system, can attenuate airborne exposure. In a webinar titled "Four Ways to Adapt Building Design for Safety Following COVID-19" by Autodesk, engineers discussed how to utilize computer tools to track the flow of air in a

confined office space and modify the mechanical systems accordingly (Bayer, Graves, Herrera, & Schmehl, 2020).[4]

Other literature on COVID-19 and construction also focused on the decrease of architecture billings due to the postponement of numerous construction projects.[5] As indicated by the Architecture Billings Index (ABI), architecture billings have been severely impacted during the months in which the virus has spread. According to AIA (2020), this index is an economic indicator that represents non-residential construction activity.[6] For over 20 years, AIA has been gathering billings data from architectural firms' leaders to produce a monthly report on ABI, which design and construction firms can then use to track and predict the market. The benchmark for ABI is 50. A score above 50 indicates an increase in billings, while a score below 50 indicates a decrease.

In March 2020,[7] the ABI's billings score declined by 20.1 points from 53.4 to 33.3. AIA indicates this as the largest single monthly decline in the past 25 years, exceeding those of both the Great Recession and the 2001 recession. The ABI dropped again in April to 29.5,[8] an all-time lowest score.

Meanwhile, The Associated General Contractors of America (AGC) has conducted regular surveys examining the impact of COVID-19 on construction jobs. The construction market suffered a loss of 975,000 construction jobs in April, constituting 13% of the industry's employment (AGC, 2020).[9] AGC continued tracking construction employment and releasing reports describing the status of construction jobs recovery. A study released by AGC on November 6, 2020 indicates the creation of an additional 85,000 construction jobs across the

US.[10] However, AGC also warns that the construction job market will shrink with the further cancellation or postponement of projects,[11] which 75% of contractors participating in the survey stated that they have already experienced.

Meanwhile, much research has focused on the impact of COVID-19 on construction contracts. Most articles discuss Force Majeure clause, insurances, and worker's compensation. Even when delays are discussed, these publications do not present fully detailed real-life projects that have been impacted by COVID-19. For instance, three papers presented an identical problem, questioning whether COVID-19 is a force majeure event (Mugisha, 2020) (Otieno,2020) (Jassat, 2020).[12] [13] [14] Before addressing this topic, the distinction should be made between a force majeure and an act of God. A French term that translates to "superior force",[15] a force majeure can refer to a clause in a contractual agreement between parties used upon the occurrence of a sudden and irresistible event that prevents a party from fulfilling their contractual obligations. Force majeure and act of God are interchangeable terms in the construction industry, and can be used to refer to the same interpretation of an event. However, as stated by Waide and Eikhhoff (2020), the two terms differ.[16] Force majeure is a broader term that covers different events including acts of God; therefore, while not all force majeures are acts of God, all acts of God are referred to as one of the events that can invoke a force majeure argument. Merriam-Webster Dictionary defines an act of God as "an extraordinary interruption by a natural cause (such as a flood or earthquake) of the usual course of events that experience, prescience, or care cannot reasonably foresee or prevent".[17] For example, war, political turmoil, a strike, or an economic crisis, are not acts of God; however,

they may be instances of a force majeure, depending on the context and the magnitude of their impact.

The authors of the three separate papers all discuss how to classify an event as a force majeure, and agree that in order for an event to be generally considered a force majeure, it should satisfy the three conditions:

1. It must be unforeseeable. This means that there was no way anyone could predict the occurrence of the event, or when and how it would occur.
2. It must be external. An event should not be the result of the action, or lack thereof, of the party.
3. It must be irresistible. This condition mainly focuses on the extent to which a party can control the event. In other words, for an event to be considered a force majeure, it must be uncontrollable, with no countermeasures that could have been taken to control its severity.

Research on this subject concludes that COVID-19 satisfies these three conditions that define an event as a force majeure: it is unforeseeable, external, and irresistible. Every scholar and expert on contractual law agrees that COVID-19 has emphasized the importance of a force majeure clause in the contract to protect the contractor from monetary consequences (e.g., liquidated damages and costs of loss of productivity) as a result of their inability to meet the contractual dates.

Moreover, webinars held by professionals and experts on construction management and contract law discuss ways to recover losses resulting from COVID-19.[18] [19] These webinars

conclude that there are three ways one could possibly recover losses: 1) the contract, 2) common law doctrine, 3) insurance claims. Relief through contracts must be supported by clauses such as force majeure/act of God clauses; time extensions; delays; change orders and claims; termination and suspension; and differing site conditions.

Research Gap

While a significant number of publications and webinars have discussed COVID-19 since its initial emergence, these focus predominantly on disparate aspects of COVID-19's impact; these include small businesses, the healthcare sector, commodities, and supplies, as well as the psychological impact experienced by much of the general population. As it was deemed essential in most US states, few researchers focused on the subject of construction due to the general assumption that the construction industry was among the least impacted. Contrary to this assumption, construction has been considerably affected by COVID-19. As the construction industry is extremely broad and encompasses various dimensions and fields, different projects may experience the impact in different forms depending on their location, type, and magnitude. Many engineering professionals discussed COVID-19 in the context of construction (especially in the context of contract law). However, none have concluded to what extent and how the industry has been impacted by the pandemic, nor have they discussed how a similar situation might be avoided or mitigated in the future. There is also a substantial gap in the research regarding the impact of COVID-19 on procurement and labor productivity in civil construction projects, and no case studies have been provided to demonstrate and quantify the impact of COVID-19 on ongoing construction. This research will therefore investigate how

COVID-19 has impacted different aspects of construction and include case studies from real-life projects.

Methodology

This research was conducted using several methods. One was the use of industry webinars and publications discussing the impact of COVID-19 on construction. The webinars used included *Four Ways to Adapt Building Design for Safety Following COVID-19* (2020); *COVID-19 & Construction Insurance* (2020); *Pricing COVID-19 Lost Productivity Claims (2020)*; *Construction Claims and Change Order Management* (2020); *Claim Preservation, Documentation, and Contract Interpretation* (2020); *DSC's, Delays, Acceleration & Mitigation* (2020); and *Pricing: Putting Dollars To The Damages* (2020). [4] [18] [19] [20] [64] [65] [66] Excluding the webinar on the design, all webinars discussed the legal implications of COVID-19 as well as ways to provide financial relief. This study also conducted interviews with recruiters in the construction industry and project managers involved in ongoing and impacted construction projects, among others. These interviews were held either in person or via telephone, email, or video call.

However, the primary method used to quantify the impact of COVID was the presentation and investigation of two case studies. These case studies involve two active and real-life projects that were in progress during the peak of COVID-19's impact on the construction sector in April 2020, one of which was used to investigate the impact on supply chain in construction. This unique project was situated in the DC-Maryland-Virginia (DMV), was ongoing during the peak of the impact, and procured material from various sources; these factors made it a highly suitable candidate to represent this research, particularly due to the insight it provides into the implications of out-of-state procurement (Michigan and Canada). As it was not required to shut down but was affected nonetheless, this project illustrates how construction work has been impacted despite having been deemed essential. This case represents the conclusion that

construction projects generally follow a domino effect; if one aspect (in this case, the procurement of materials) is impacted, the entire construction process will most likely be impacted. As recommended by AACEI 52R-06,[21] the method used in this project to quantify the delays due to procurement was that of prospective time impact analysis. Meanwhile, the second case study involves a civil project that illustrates the impact of the pandemic on labor productivity. This project was active during the height of COVID-19 in the DMV area, and presents a case in which absenteeism (caused by either social-distancing regulations or COVID-19 infection) has led to substantial labor disruption. This project's inclusion contains the limitation of its lack of documentation provided by the contractor regarding on-site productivity (output/input). This prevented the use of the measured-mile study, thus necessitating the use of other methods to quantify the loss of productivity. This quantification of the loss of productivity was performed using a combination of two methods recommended by AACEI 25R-03,[22] namely Earned Value Analysis (EVA) and Productivity Impact on Schedule.

Other data used in this research to quantify the impact of COVID-19 on construction include drawings, minutes from progress meetings, agreements, specifications, monthly reports on schedule status, and schedule updates for both of the aforementioned projects. Note that the schedule of the second project (used in the productivity loss case study) was both cost and resource loaded. Finally, the tools used to assist in the review and analysis of the collected data include Primavera P6 software and Schedule Analyzer software.

Impacts of COVID-19 on construction:

The construction industry was one of many impacted by COVID-19. Undertaking a construction project requires a significant amount of planning: beginning with a conceptual plan and ending with a detailed design, it is necessary to make thorough preparations regarding labor; the allocation of costs and resources; and the procurement of materials and equipment. To examine the impact of COVID-19 on construction projects, the following two dimensions will be considered:

1. Supply chain
2. Labor productivity

This research will not investigate impacts on design since the projects under discussion are active design-bid-build projects that were in the construction phase by the time of COVID-19's entry to the region. As the design phase of these projects had already been completed, it was not impacted by COVID-19.

To understand the impact of COVID-19 on the construction industry overall in the US, an interview was conducted with Heba Saeb, a recruitment consultant at Hays Construction and Property.[23] Saeb, who predominantly recruits estimators in construction projects mostly in Atlanta, Georgia, indicated that COVID-19 impacted different sectors of the construction industry in different ways. For instance, the interior, retail, and hospitality sectors were impacted most severely, while hiring in the civil, multifamily housing, and industrial sectors was the least affected. Saeb indicates that many construction companies implemented hiring freezes, resulting in decreased hiring. For instance, she previously had a client who acted as

owner's representative and construction manager for a company involved in the hotel business, working with major American hotel brands such as Marriot and Hilton. This company, which was Saeb's client immediately prior to the COVID-19 outbreak, had requested that she recruit two estimators at senior and junior level for an upcoming hotel project. After COVID-19 entered the US, the company informed Saeb that their project had been cancelled for the year and that they had implemented a hire freeze until January 1, 2021, with the possibility of further extensions of this deadline. Saeb commented that she understood their decision to cancel this project alongside many other hotel projects, since "who would want to build hotels when people aren't even going to travel?" She added that another heavily impacted sector of construction was that of interiors, mentioning how the impact of COVID-19 forced another client, which focused solely on interior work, to create 600 redundancies out of a workforce of 1,000 employees. Saeb attributed this to a decline in the company's number of clients per month from 15-20 to 3-5, pre- to post-pandemic.

This research will examine the impact of COVID-19 on civil construction projects in the US overall and on projects in the DMV area specifically.

Material Supply Chain

The supply chain is a dimension of construction that has been impacted by COVID-19. Material procurement is a major component in planning each project: if not well planned and integrated into the construction schedule, material procurement may lead to delays in completion and delivery of the project. In the US, the procurement of building materials was impacted by not only the country's own stay-home orders but also the occurrence of lockdowns elsewhere.

China supplies approximately 30% of all imports of building materials to the US,[24] despite the imposed tariffs on Chinese imports having caused a decline in these imports in 2019 (Diduch, 2020). However, the US is still dependent on China, both for these direct imports and for the importation of products manufactured using Chinese materials. The Chinese government responded to the initial outbreak of COVID-19 by imposing strict lockdowns in affected areas. In January 23, 2020, all transportation services in Wuhan city were closed, and all residents were ordered to stay home;[25] surrounding cities and provinces also entered lockdown. Hubei Province, in which Wuhan city is situated, ordered 56 million people to quarantine (Somerville 2020). Consequently, the production and manufacturing of material in this area was put on hold. A statistical study performed by Trading Economics in June 2020[26] revealed a decline in Chinese imports of 16.7% year-over-year in May 2020, the most significant decline since 2016, due to decreased domestic demand. This number represents all imports from China. However, in the specific context of raw construction materials, the market has experienced substantial drops in copper, aluminum, and iron ore imports.

Nevertheless, China was not the only country whose struggle against the virus led to disruptions in material supply to the US. For instance, Italy is a major source of stone, glass, and marble for US construction projects. The founder of New York-based construction law firm LePatner & Associates reported that one of their projects was missing half of the stone required for flooring, as the stone was sourced in Italy.[24] This shortage was due to Italian Prime Minister Giuseppe Conte imposing a national lockdown on March 9, 2020 (2020). In response to the continued surge in cases and deaths, Conte ordered a full shutdown on March 12, 2020 with the exception of pharmacies and grocery stores.[27] Other US companies reported delays in the

procurement of lighting fixtures, LED strips, and drivers from China, as well as glass office fronts from Italy.[25]

The supply of materials within the US experienced similar nationwide disruption due to COVID-19. Although construction was deemed essential in most affected states, many manufacturing plants were deemed non-essential and consequently experienced shutdowns or a partial loss of productivity. In a survey released by AGC between March 17 and 19, 2020, 22% of the 901 respondents indicated that they have been notified by their suppliers/subcontractors that the project will be experiencing delivery delays or cancellations.[28] [29] Moreover, owners that have not been notified of delays specific to supply chains may still be experiencing material disruptions that do not necessarily impact the project's critical path. Confident of their ability to control disruptions to material supplies, contractors may decide against informing the owners. Likewise, manufacturing plants may choose not to inform the contractor of any delays or loss of productivity if they have already planned and allocated additional resources and shifts that would enable them to meet the schedule.

Some projects may have been fortunate to have stockpiled necessary materials on site ahead of their requirement for them, meaning that some projects proceeding during the pandemic may not experience delays related to supply chain. However, this is typically a rare occurrence, especially since the unforeseeable nature of the pandemic meant that most companies were unable to prepare accordingly.

Moreover, another report by AGC indicates that 45% of US-based contractors are experiencing delays as a result of COVID-19.[30] These delays primarily stem from disruptions in the supply of

materials, equipment, and personal protective equipment (PPE). Active projects that began prior to the pandemic still require these necessary materials and equipment to be manufactured and delivered. However, many projects whose scheduled start dates collided with the initial spread of COVID-19 were postponed, with commercial projects most heavily impacted. According to law firm Berger Singerman, project delays will eventually cause a softening in demands with higher inventory alongside a decline in prices, two major blows to material and equipment suppliers (Chaissan, 2020).[31]

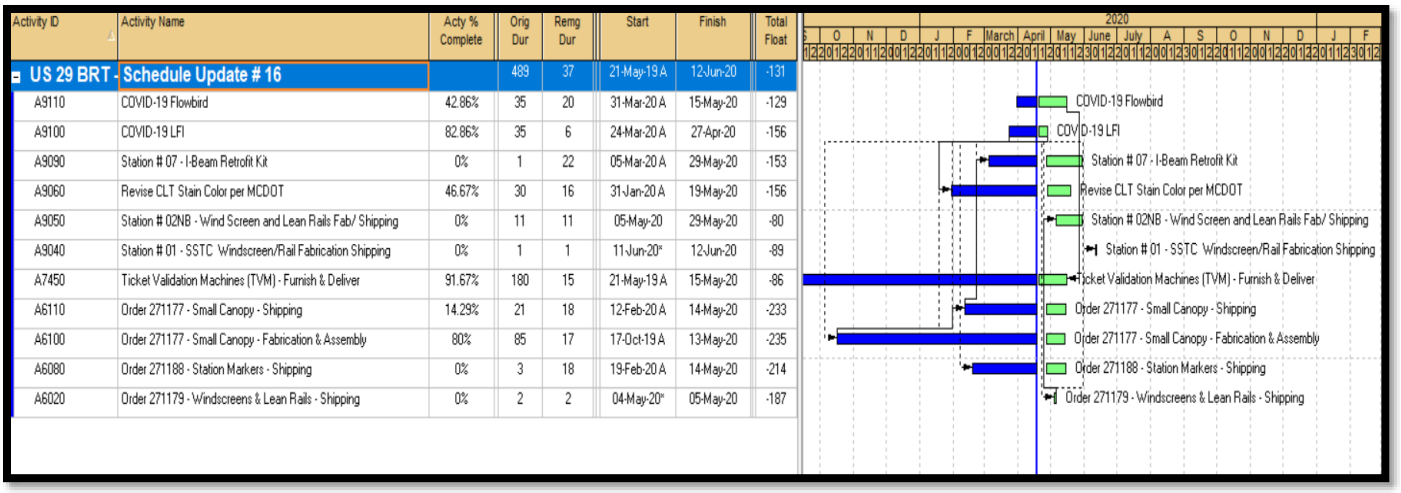
One of the projects impacted by COVID-19 is a bus route project in Maryland, wherein the contractor was required to construct bus stations and do some roadway work. When COVID-19 entered the US, especially the DMV area, the project was in its final stages of constructing the stations; this phase was to be followed by the installation of architectural items and Ticket Vending Machines (TVMs). Architectural items included windscreens, lean rails, and canopies. The owner received two Notices of Delay: one was for overall delays to the project due to COVID-19 that were not fully realized at the time the letter was sent (see **Figure 29** in Appendix A), and the second was specific to the TVMs' sourcing (see **Figure 28** in Appendix A). The manufacturer for the architectural items is Landscape Forms, Inc. (LFI), a manufacturing plant in Michigan, while the TVM manufacturer is Flowbird.

Two activities that were added to the schedule update for April 2020 are shown to impact the manufacture and delivery of many of these items to a near-critical degree. **Figure 1** illustrates the "COVID-19 activities" incorporated in the schedule update along with their successors, i.e., those activities that cannot be undertaken prior to the completion of the former. The eventual completion of the two COVID-19 activities represents the end of COVID-19's impact on the

manufacturing plants. This could refer to the plants' reopening or to the resumption of their normal productivity rate, which would then place the contractor's orders back in production.

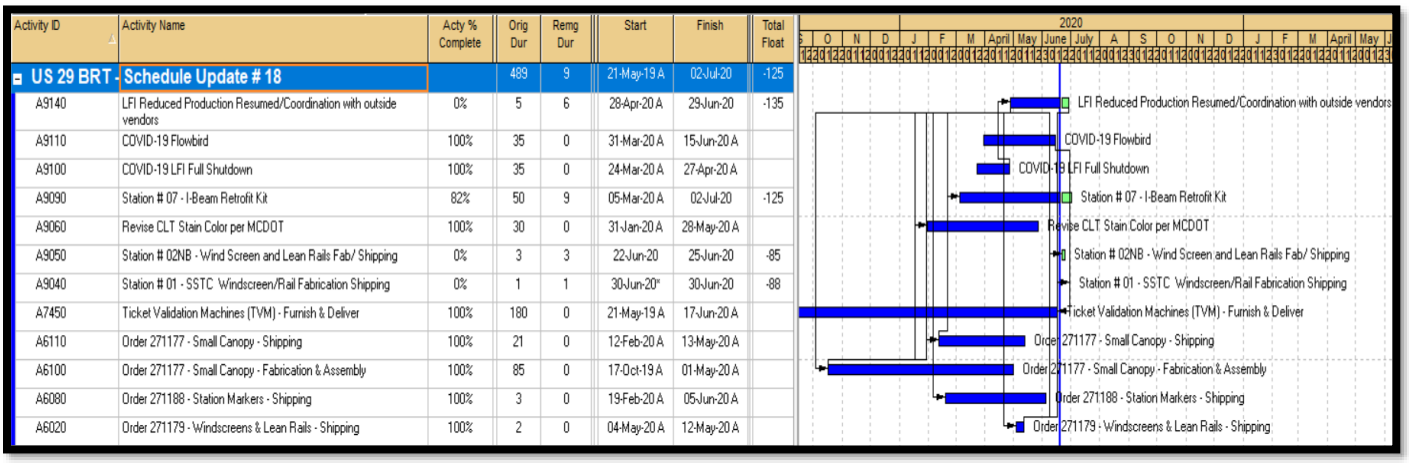
The projected finish dates of the COVID-19 activities in this project's schedule were later updated in May and June 2020. As shown in **Figure 2**, the delay in Flowbird's facility ended a month later than originally predicted. On the other hand, LFI's facility reopened in April 27, 2020 after a month-long closure. However, as the facility did not return to its normal production due to the enforcement of social distancing restrictions, LFI experienced productivity loss despite having reopened. The facility consequently required additional time to resume normal production and coordinate with outside vendors, causing further delays to the procurement process related to architectural items. LFI introduced additional activities to illustrate and track their loss of productivity after reopening, as shown in **Figure 2.**

Figure 1-: Newly Added COVID-19 Activities during the Month of April 2020 – Bus Route Project in MD



Activity ID	Activity Name	Acty % Complete	Orig Dur	Remg Dur	Start	Finish	Total Float
US 29 BRT -	Schedule Update # 16		489	37	21-May-19 A	12-Jun-20	-131
A9110	COVID-19 Flowbird	42.86%	35	20	31-Mar-20 A	15-May-20	-129
A9100	COVID-19 LFI	82.86%	35	6	24-Mar-20 A	27-Apr-20	-156
A9090	Station # 07 - I-Beam Retrofit Kit	0%	1	22	05-Mar-20 A	29-May-20	-153
A9060	Revise CLT Stain Color per MCDOT	46.67%	30	16	31-Jan-20 A	19-May-20	-156
A9050	Station # 02NB - Wind Screen and Lean Rails Fab/ Shipping	0%	11	11	05-May-20	29-May-20	-80
A9040	Station # 01 - SSTC Windscreen/Rail Fabrication Shipping	0%	1	1	11-Jun-20*	12-Jun-20	-89
A7450	Ticket Validation Machines (TVM) - Furnish & Deliver	91.67%	180	15	21-May-19 A	15-May-20	-86
A6110	Order 271177 - Small Canopy - Shipping	14.29%	21	18	12-Feb-20 A	14-May-20	-233
A6100	Order 271177 - Small Canopy - Fabrication & Assembly	80%	85	17	17-Oct-19 A	13-May-20	-235
A6080	Order 271188 - Station Markers - Shipping	0%	3	18	19-Feb-20 A	14-May-20	-214
A6020	Order 271179 - Windscreens & Lean Rails - Shipping	0%	2	2	04-May-20*	05-May-20	-187

Figure 2: Updated COVID-19 Activities during the Month of June 2020 – Bus Route Project in MD



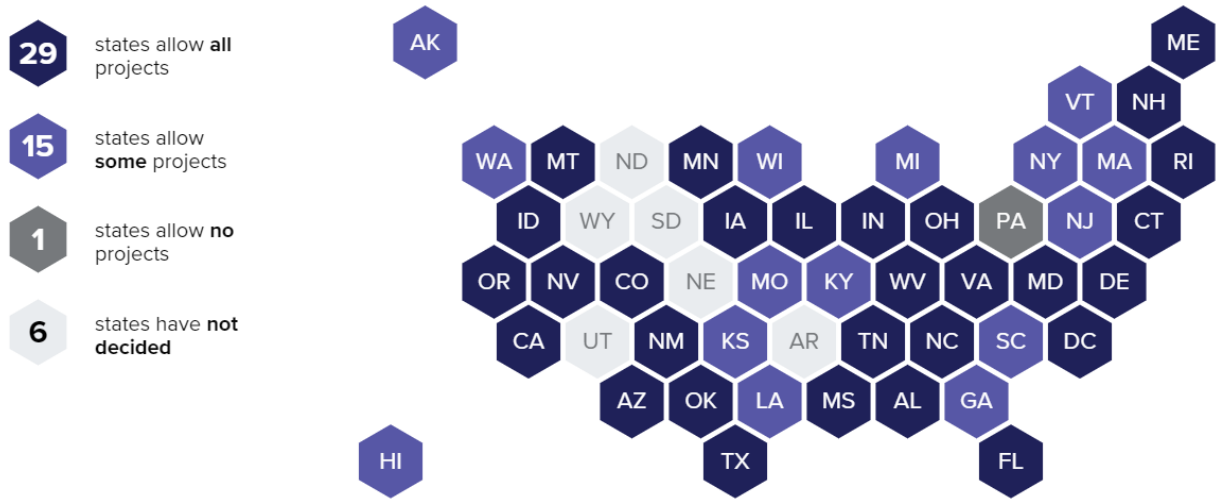
Activity ID	Activity Name	Acty % Complete	Orig Dur	Remg Dur	Start	Finish	Total Float
US 29 BRT -	Schedule Update # 18		489	9	21-May-19 A	02-Jul-20	-125
A9140	LFI Reduced Production Resumed/Coordination with outside vendors	0%	5	6	28-Apr-20 A	29-Jun-20	-135
A9110	COVID-19 Flowbird	100%	35	0	31-Mar-20 A	15-Jun-20 A	
A9100	COVID-19 LFI Full Shutdown	100%	35	0	24-Mar-20 A	27-Apr-20 A	
A9090	Station # 07 - I-Beam Retrofit Kit	82%	50	9	05-Mar-20 A	02-Jul-20	-125
A9060	Revise CLT Stain Color per MCDOT	100%	30	0	31-Jan-20 A	28-May-20 A	
A9050	Station # 02NB - Wind Screen and Lean Rails Fab/ Shipping	0%	3	3	22-Jun-20	25-Jun-20	-85
A9040	Station # 01 - SSTC Windscreen/Rail Fabrication Shipping	0%	1	1	30-Jun-20*	30-Jun-20	-88
A7450	Ticket Validation Machines (TVM) - Furnish & Deliver	100%	180	0	21-May-19 A	17-Jun-20 A	
A6110	Order 271177 - Small Canopy - Shipping	100%	21	0	12-Feb-20 A	13-May-20 A	
A6100	Order 271177 - Small Canopy - Fabrication & Assembly	100%	85	0	17-Oct-19 A	01-May-20 A	
A6080	Order 271188 - Station Markers - Shipping	100%	3	0	19-Feb-20 A	05-Jun-20 A	
A6020	Order 271179 - Windscreens & Lean Rails - Shipping	100%	2	0	04-May-20 A	12-May-20 A	

Another project impacted by COVID-19 is a roadway reconstruction project in Washington DC. Due to the pandemic, this project's contractor not only experienced delays in material procurement but also suffered labor shortages and additional disruptions, and eventually requested a partial suspension of operations (see **Figure 30** in Appendix A).

Labor Productivity at Construction Sites

Whether a full, partial, or no shutdown was imposed, every construction site's progress was impacted to some extent. States affected by COVID-19 began issuing stay-home orders in March and April 2020, resulting in the closure of numerous non-essential businesses such as gyms; restaurants; hair and nail salons; and malls. While construction was deemed essential in most states, some construction projects were nevertheless prevented from continuing. For example, Phil Murphy, governor of New Jersey, signed an executive order mandating the postponement of all non-essential construction from April 10, 2020.[32] Deemed essential, transportation, healthcare, schooling, and utility construction projects were exempt from this order. On the other hand, the state of Maryland deemed all construction projects essential. **Figure 3** provides a map of the US that explains the guidance on construction projects in each region.

Figure 3: States' Guidance on Construction Projects Shutdown due to COVID-19[32]



1

The economy, and particularly the construction industry, were more impacted in states with executive orders halting non-essential construction. For instance, major retail, residential, and commercial projects were deemed non-essential under New Jersey's stay-home orders, resulting in shutdowns and delays (Rubin & Cubarrubia, 2020).[33] New Jersey's largest retail project, the $5 Billion American Dream mall and entertainment venue in the northern area of the state, exemplifies this particularly effectively. Prior to COVID-19, the project had been nearing completion, and the retail section was open to the public, before Governor Murphy mandated its closure. The executive order also postponed construction of the indoor water park, which has yet to be completed.

[32] Retrieved from https://www.constructiondive.com/news/mapping-high-impact-construction-across-the-us/551042/

The impact of COVID-19 on any given construction project does not cease simultaneously with the end of a lockdown, and may extend far beyond it. In other words, projects that were permitted to continue after stay-home orders were relaxed or lifted also faced on-site losses of productivity; this includes those caused by demobilizing during the lockdown, remobilizing after reopening, and applying new safety guidelines. Loss of productivity in projects that experienced temporary closure may be caused by the following factors:

- Demobilization of crews, materials, and equipment
- Time expended on reassigning and/or redirecting crews prior to shutdown (Schwartzkopf & Halligan, 2020)[20]
- Measuring and documenting progress immediately before shutdown
- Preparing to restart after shutdown
- Remobilization
- Assembly of new crews due to either the unavailability of previous crews or an increase in shifts and the deployment of larger crews
- Creation of a new construction plan or schedule
- Learning Curve
- Implementation of new safety guidelines (discussed further in the paragraph below)
- Cooperation with suppliers to restart delivery of material and equipment[20]

Projects in the DMV area will exemplify those upon which no shutdown was imposed. By late May 2020, 95,000 COVID-19 cases and 4,000 related deaths had been reported in the area (Portnoy, & Amenabar, 2020).[34] State officials issued stay-home orders in response, shutting

down non-essential businesses but deeming construction essential. Temporary stay-home orders went into effect in the DMV area on the following dates:[35]

- Governor Larry Hogan of Maryland: March 23, 2020
- Mayor Muriel Bowser of Washington District of Columbia: March 24, 2020
- Governor Ralph Northam of Virginia: March 30, 2020

Although the labeling of construction as essential allowed projects in these regions to continue, the strict guidelines imposed by health officials on construction work significantly affected the progress of these projects.

Firstly, many contractors have reported labor shortages and disruptions to field crews and operators. Personnel are either infected or prefer to stay home, thereby adhering to health officials' recommendations for avoiding exposure to infection (**Figure 30**). However, in many cases, the consequences of personnel contracting COVID-19 extend beyond the loss of productivity; it could lead to the temporary shutdown of the project. For example, during the construction of the Marriott International world headquarters and hotel in Bethesda, Maryland,[36] two on-site employees tested positive and construction was forced to cease (Hull, 2020). This project had been highly celebrated and publicized, especially following Marriott's decision to base their headquarters in Maryland (Arcieri,2018).[37] The $600 million complex was expected to bring about $2.3 billion in business activity in the first year following completion, and around $1.8 billion in the local tax district over the next two decades. This was by no means the only construction project that faced delays after employees tested positive for

the coronavirus, with at least six other construction sites in Montgomery County alone having experienced temporary shutdowns for the same reason (Lewis, 2020).[38]

However, even if labor is not disrupted, most fields of construction have experienced other forms of productivity loss. The different dimensions that accompany the loss of productivity, including delays as the project falls behind schedule and exceeds its budget, make it a highly expensive issue. Sources of productivity loss in construction sites may include the following:

- Gatherings of over ten people prohibited. For example, Maryland's stay-home order, issued on March 23 and amended on March 30, 2020, prohibited gatherings of more than ten people[39]
- Social distancing of six feet enforced, as recommended by CDC
- Physical separation of staff introduced, such as for engineering and consulting firms that previously seated employees in close proximity to each other[40]
- Work shifts staggered by hours and days
- Face masks provided, with employees required to wear them (Rygiel-Boyd, 2020)[41]
- Non-essential visitors prevented from entering work sites
- Frequent sanitization of high-touch areas (e.g., kitchen, break rooms, restrooms, meeting rooms, copy/print rooms, etc.) required
- Body temperature of employees screened before entry to sites is permitted (Rosenfeld,2020)[42]
- Sanitization of equipment and areas allotted for screening employees' temperatures required

- Limitations imposed on the sharing of tools and equipment[43]
- Re-assignment undertaken for older employees, employees with underlying conditions, and employees who have been exposed to COVID-19 patients but show no symptoms, to different tasks or departments that could use their expertise and that offer limited or no contact between staff
- Hygiene promoted via the provision of water, soap, and hand-sanitizer stations
- Training provided to ensure that employees adhere to new health guidelines and modify their tasks and responsibilities accordingly
- Policies regarding sick leave implemented or modified, and supportive practices provided

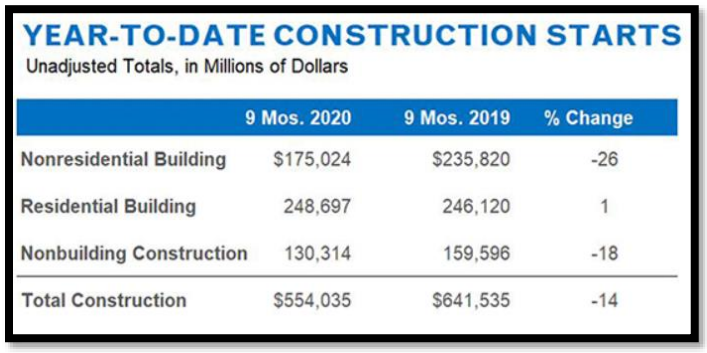
Many companies experienced some of the above sources of loss of productivity only at the early stages of the pandemic and immediately after governors declared a state of emergency; for example, modifying employees' tasks to comply with health guidelines. On the other hand, many sources of productivity loss endure throughout a project's lifetime, while the state of emergency remains in effect (e.g. screening temperatures and sanitizing common areas daily).

Some of the new changes implemented may require hiring and training additional staff. Many of the above sources of productivity loss can be categorized as preventative measures and administrative work (National Electrical Contractors Association, 2020).[44] The direct costs associated with productivity loss involve direct work productivity, such as changes in the productivity rate in laying pipelines in roadway projects or wall rough-ins in commercial projects. Social distancing and staggering shifts and hours could lead to loss of productivity,

thus causing the duration of completion to exceed the task's initial prediction and plans. Later sections will provide a more in-depth discussion regarding the quantification of productivity loss in claims and change orders.

Meanwhile, not all categories of construction have been identically affected by the pandemic. Many home and business owners (such as restaurants) have viewed the shutdown as a chance to undertake renovation projects that had been shelved indeterminately. Moreover, Dodge Data and Analytics indicate that despite the decline in construction work in March and April 2020, residential projects increased considerably in the first nine months of 2020 compared to the same period in 2019 (**Figure 4**).[45] This suggests that residential projects that were put on hold also continued.

Figure 4: Number of construction projects started in the first nine months of 2019 vs. first nine months of 2020 per Dodge Analytics [45]



YEAR-TO-DATE CONSTRUCTION STARTS

Unadjusted Totals, in Millions of Dollars

	9 Mos. 2020	9 Mos. 2019	% Change
Nonresidential Building	$175,024	$235,820	-26
Residential Building	248,697	246,120	1
Nonbuilding Construction	130,314	159,596	-18
Total Construction	$554,035	$641,535	-14

Quantification of impacts of COVID-19 on construction

This section will assess in greater depth the impacts on labor productivity in the field as well as the supply chain. These two aspects of construction will be the focus of the two case studies.

Firstly, each issue or case will fall under one of two categories: delays and disruptions. Although these terms are occasionally used interchangeably, they can be differentiated mainly by the method used to quantify the impact of a certain event on the project.

Two projects will be used as case studies: a bus route construction project in the state of Maryland and a project involving the reconstruction of a roadway segment in Washington DC.

As mentioned previously, delays and disruptions are sometimes considered to be synonymous. However, each term pertains to a certain type of event, and thus requires a specific way to quantify and prove the basis for its costs. According to Excell Consulting (2019), delays are singular and specific events or conditions that impact the critical path of a project and cause it to begin or be completed later than originally planned and agreed to contractually.[46] Meanwhile, disruptions include the effects produced by a delaying event (or multiple events) as well as changes to the planned method and sequence of construction or changes to the allotted original duration.

Costs associated with delays include extended project management, engineering, and administrative support, as well as other overhead costs such as home office and general conditions (e.g., insurances, bonds, warranties). Direct costs might include idle equipment costs (e.g., idle cranes and equipment rentals) as well as costs associated with changes made to work due to the delay. The contractor would submit a time extension for the owner's review, for the

purpose of recovering costs caused by a delay. Delays are either excusable or non-excusable. Excusable delays are delays for which an owner agrees to grant a time extension; if a delay is excusable, the owner will decide whether it is also compensable. A compensable delay results from unforeseeable conditions or events for which the contractor is also entitled compensation in addition to the granted time extension. To measure the impacts of a delay on a project, the contractor uses the Critical Path Method (CPM). CPM is used to illustrate the delay and its impact on the project's schedule.

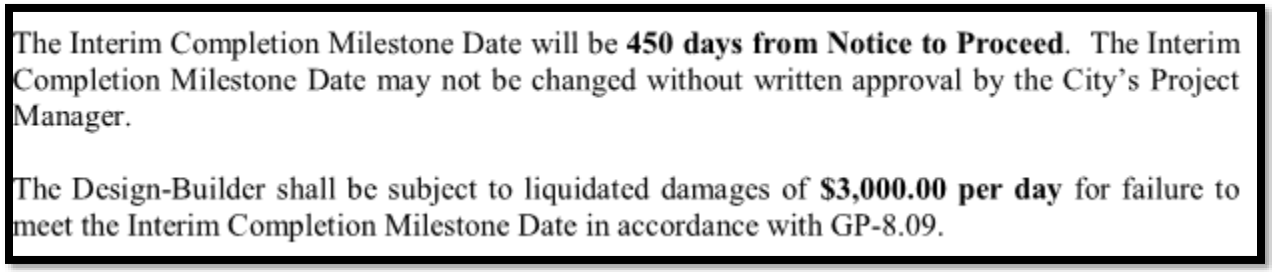
Costs of disruptions, on the other hand, are associated with the effort to re-sequence work, inefficiencies, reduced performance in adverse weather, overcrowding trades, and less skilled crews. To illustrate the impact of a disruption, contractors measure the loss of labor productivity, which can be achieved by employing the "measured mile study" method. However, many other methods can be used to fulfill the same purpose, as will be detailed in later sections.

Quantifying Delays on Supply Chain

As mentioned earlier, impacts of delays are typically measured using the CPM method. It is important to quantify these delays for two reasons: 1) to prove the eligibility for a time extension and possibly recover overhead costs (compensable delay); 2) to learn by how many days the project was behind the contractual completion date due to the event, and to investigate methods to mitigate these delays and recover the time lost. This section quantifies delays on procurement schedules for both reasons stated. This section will also discuss how mitigation options during this pandemic differ to those existing in normal circumstances. The research will analyze these points by presenting the case study of a real-life project that was impacted by COVID-19.

Before introducing the project and analyzing how it was impacted by COVID-19, the research will briefly discuss the consequences of an unplanned and unforeseeable event. In summary, most contractors are required to submit a baseline CPM schedule at the time of being awarded the contract. The CPM schedule should detail how the contractor plans to construct the project (for example, building a bridge) by the contracted completion date, which the owner will generally have specified in the contract documents by requiring the contractor to complete the project in *"x"* number of days from the Notice to Proceed (NTP). Examples of specified completion dates are below:

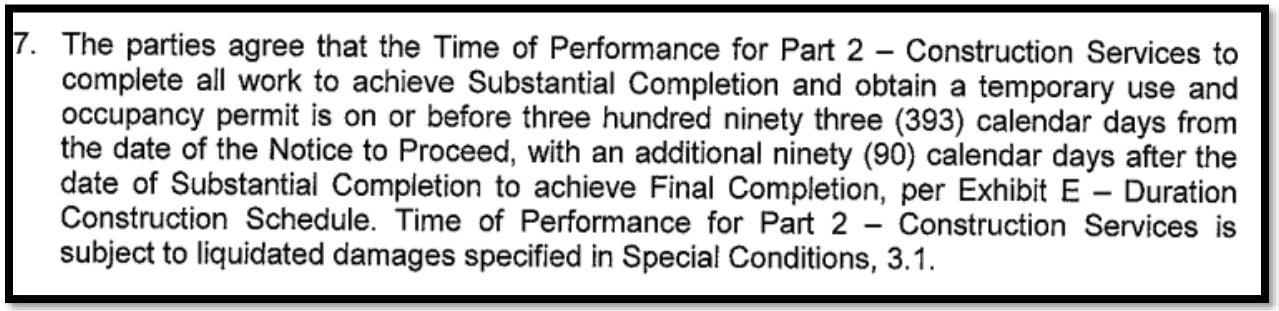
Figure 5: Provisions from a construction project in MD



The Interim Completion Milestone Date will be **450 days from Notice to Proceed**. The Interim Completion Milestone Date may not be changed without written approval by the City's Project Manager.

The Design-Builder shall be subject to liquidated damages of **$3,000.00 per day** for failure to meet the Interim Completion Milestone Date in accordance with GP-8.09.

Figure 6 : Provisions from a commercial project in MD



7. The parties agree that the Time of Performance for Part 2 – Construction Services to complete all work to achieve Substantial Completion and obtain a temporary use and occupancy permit is on or before three hundred ninety three (393) calendar days from the date of the Notice to Proceed, with an additional ninety (90) calendar days after the date of Substantial Completion to achieve Final Completion, per Exhibit E – Duration Construction Schedule. Time of Performance for Part 2 – Construction Services is subject to liquidated damages specified in Special Conditions, 3.1.

Most of the projects will include a specification indicating that "time is of the essence", and that the contractor will be subject to liquidated damages ($amount/day) for each day the project is late beyond the contractual completion date without an approved time extension. The contractual completion date will be set by the baseline CPM schedule and must be in accordance with and within the allotted time by contract. After it is approved, the baseline CPM schedule will then become the benchmark for the following schedule updates to track and measure any changes and deviations from the original plan. Most contracts require the contractor to submit a monthly schedule update reflecting the work performed during that month (adding actual dates) and the plan for further development, based on that month's

progress. Changes can be made to a schedule and reflected in a schedule update (for example, changes in the sequence) without significant deviation from the original plan. If an unforeseeable event were to occur and subsequently impact the project, the contractor would make the following actions:

- Submit a Notice of Delay to the owner to reserve their right to claims related to the event. The contract documents will specify the due dates for submitting a Notice of Delay from when the event takes place. For example, the contractor may be required to notify the owner of the delay within 14 calendar days.
- Prepare a Time Impacts Analysis (TIA). The details, format, deadline, and requirements of a TIA submission will be dictated by the specifications and contract documents. This will generally include a narrative on the delaying event and its impact on the schedule. More importantly, the TIA submission will also include a schedule submission that will model the event's impacts (delay) in the schedule update by inserting activities into the schedule using the appropriate logic ties and activity durations. The TIA is a CPM method and can be performed in different ways, such as prospectively or retrospectively. TIA will be explained in further detail in upcoming sections focusing on prospective TIA. The purpose of the TIA is to prove that the event in question has impacted the critical path of the project and delayed its overall completion. The TIA may also include overhead costs, in which case the owner will study it to determine whether the delay is both excusable and compensable, or solely excusable.
- If the owner approves the TIA, the contractual completion date will be adjusted to reflect the newly granted time extension. Moreover, if the owner determines that the

delay is not a result of the contractor's actions, then the owner may decide to compensate the contractor for the additional overhead costs.

- If the owner determines that the contractor has caused the delay, then they may choose to reject the TIA request and inform the contractor that they are liable for all consequences including liquidated damages. The contractor would then act in accordance with the process of claims resolution as set forth by the contract documents.
- Regardless of who may be at fault, the owner may require the contractor to recover the delays and return the project to schedule. This may require additional resources; rescheduling of activities; or any new means and methods by which to accelerate the project, all of which contain further costs. In this case, the TIA submission may also include a mitigation plan indicating the number of days that can be recovered, a time extension request for the days that will still be unrecovered, and the resultant costs.

When experiencing delays, most projects generally undergo this process.

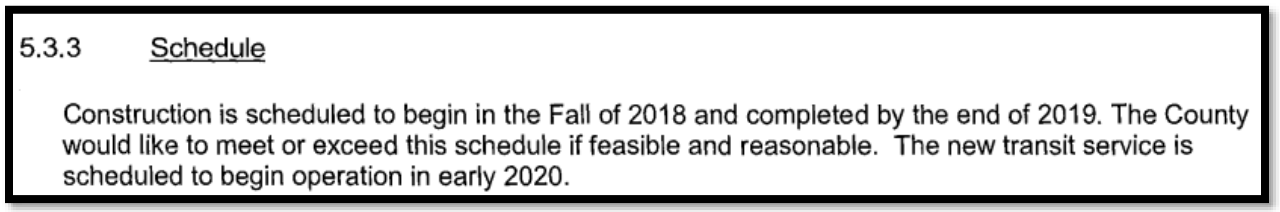
History of the Project

This discussion will focus on the public project of US 29 BRT Improvement Silver Spring Transit Center to Burtonsville Park and Ride in Montgomery County, Maryland. The project includes two service pattern routes to follow the proposed 14-mile BRT corridor from the Silver Spring Transit Center (SSTC) to the Burtonsville Park and Ride, and along Lockwood Drive to the Briggs Chaney Park and Ride. The project includes new frequent all-day BRT service operating in existing travel lanes and shoulders; the construction of 17 architecturally designed stations along the corridor; the purchase and installation of off-board fare collection equipment; and

improvements to landscapes, sidewalks, and cycling facilities to facilitate station access, including new Capital Bikeshare docking stations. The owner is Montgomery County DOT (the County) and the contractor is Concrete General, Inc. (CGI), which is the Construction Manager at Risk (CMAR).

The contract documents set the completion date and project delivery as follows:

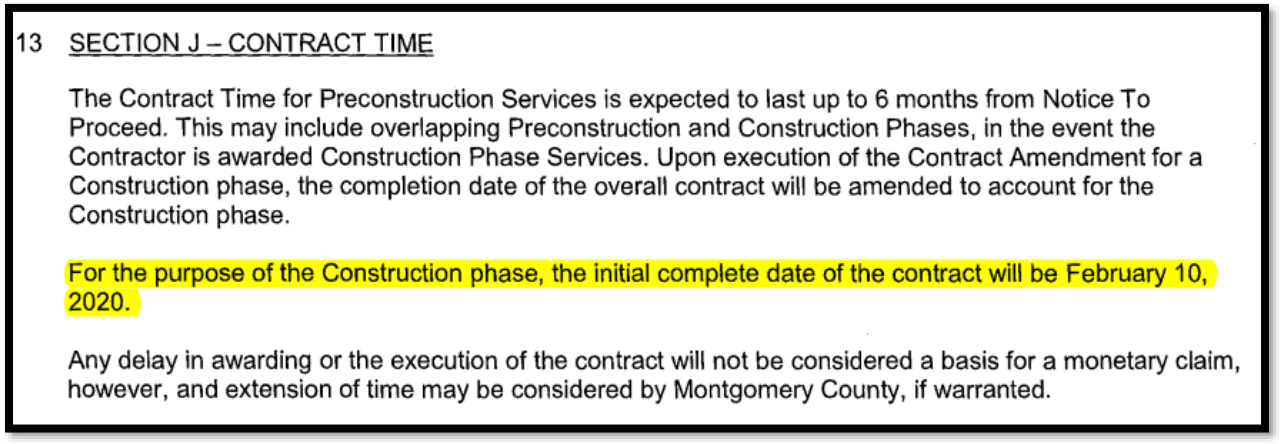
Figure 7: Specification on project schedule – Bus Route Project in MD



5.3.3 Schedule

Construction is scheduled to begin in the Fall of 2018 and completed by the end of 2019. The County would like to meet or exceed this schedule if feasible and reasonable. The new transit service is scheduled to begin operation in early 2020.

Figure 8: Specification on contract time – Bus Route Project in MD



13 SECTION J – CONTRACT TIME

The Contract Time for Preconstruction Services is expected to last up to 6 months from Notice To Proceed. This may include overlapping Preconstruction and Construction Phases, in the event the Contractor is awarded Construction Phase Services. Upon execution of the Contract Amendment for a Construction phase, the completion date of the overall contract will be amended to account for the Construction phase.

For the purpose of the Construction phase, the initial complete date of the contract will be February 10, 2020.

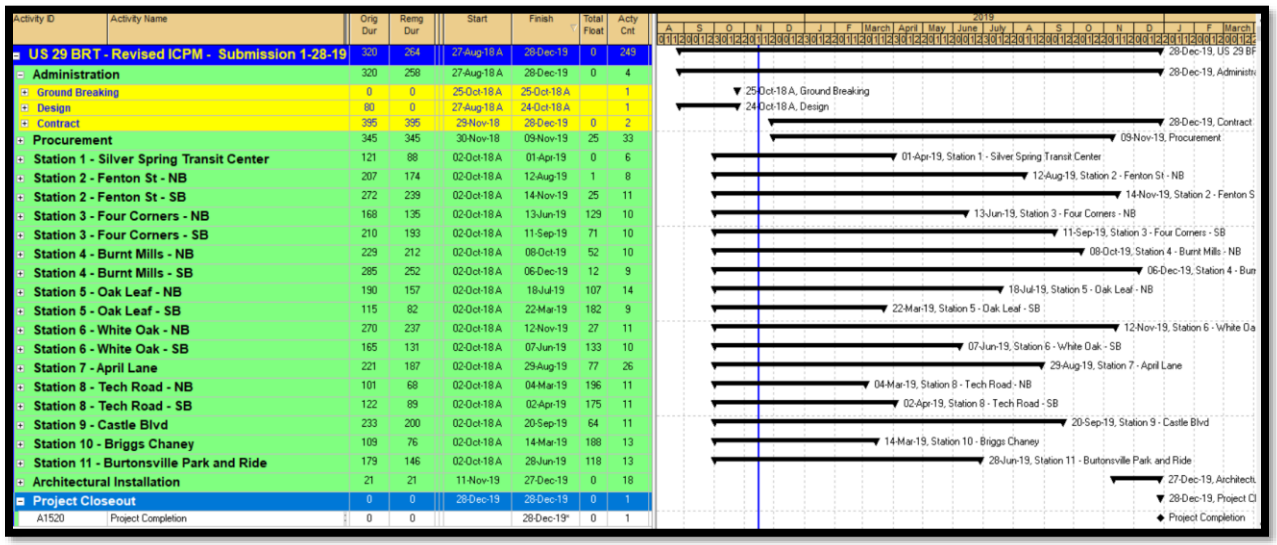
Any delay in awarding or the execution of the contract will not be considered a basis for a monetary claim, however, and extension of time may be considered by Montgomery County, if warranted.

After CGI was awarded the contract, it submitted the baseline CPM schedule indicating the final completion date of the project as December 28, 2019. **Figure 9** provides a summary of the Baseline Schedule. As shown in **Figure 24**, construction began in fall 2018 and was completed

by the end of 2019. The Baseline Schedule is compliant with the project's specification on the timeline of the construction, as **Figures 7 and 8** illustrate.

CGI's general plan is to complete station construction before undertaking the architectural installation.

Figure 9: CPM Baseline Schedule Summary – Bus Route Project in MD



Activity ID	Activity Name	Orig Dur	Remg Dur	Start	Finish	Total Float	Acty Cnt
US 29 BRT - Revised ICPM - Submission 1-28-19		320	264	27-Aug-18 A	28-Dec-19	0	249
Administration		320	258	27-Aug-18 A	28-Dec-19	0	4
Ground Breaking		0	0	25-Oct-18 A	25-Oct-18 A		1
Design		80	0	27-Aug-18 A	24-Oct-18 A		1
Contract		395	395	29-Nov-18	28-Dec-19	0	2
Procurement		345	345	30-Nov-18	09-Nov-19	25	33
Station 1 - Silver Spring Transit Center		121	88	02-Oct-18 A	01-Apr-19	0	6
Station 2 - Fenton St - NB		207	174	02-Oct-18 A	12-Aug-19	1	8
Station 2 - Fenton St - SB		272	239	02-Oct-18 A	14-Nov-19	25	11
Station 3 - Four Corners - NB		168	135	02-Oct-18 A	13-Jun-19	129	10
Station 3 - Four Corners - SB		210	193	02-Oct-18 A	11-Sep-19	71	10
Station 4 - Burnt Mills - NB		229	212	02-Oct-18 A	08-Oct-19	52	10
Station 4 - Burnt Mills - SB		285	252	02-Oct-18 A	06-Dec-19	12	9
Station 5 - Oak Leaf - NB		190	157	02-Oct-18 A	18-Jul-19	107	14
Station 5 - Oak Leaf - SB		115	82	02-Oct-18 A	22-Mar-19	182	9
Station 6 - White Oak - NB		270	237	02-Oct-18 A	12-Nov-19	27	11
Station 6 - White Oak - SB		165	131	02-Oct-18 A	07-Jun-19	133	10
Station 7 - April Lane		221	187	02-Oct-18 A	29-Aug-19	77	26
Station 8 - Tech Road - NB		101	68	02-Oct-18 A	04-Mar-19	196	11
Station 8 - Tech Road - SB		122	89	02-Oct-18 A	02-Apr-19	175	11
Station 9 - Castle Blvd		233	200	02-Oct-18 A	20-Sep-19	64	11
Station 10 - Briggs Chaney		109	76	02-Oct-18 A	14-Mar-19	188	13
Station 11 - Burtonsville Park and Ride		179	146	02-Oct-18 A	28-Jun-19	118	13
Architectural Installation		21	21	11-Nov-19	27-Dec-19	0	18
Project Closeout		0	0	28-Dec-19	28-Dec-19	0	1
A1520	Project Completion	0	0		28-Dec-19*	0	1

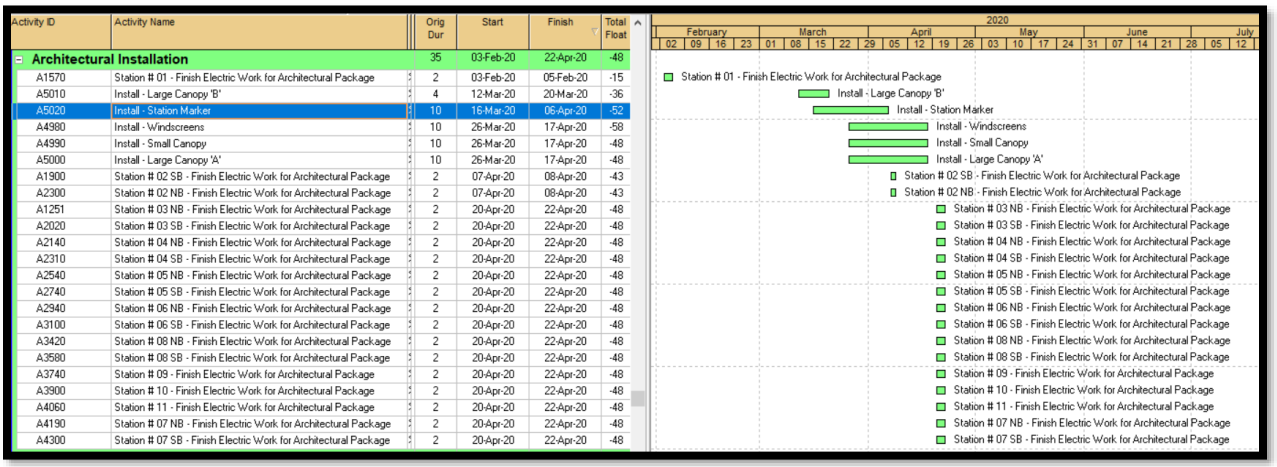
CGI's architectural installation plans include the installation of architectural items in each station, as shown in **Figure 10**. These architectural items include windscreens, lean rails, canopies, station markers, and other non-architectural items such as ticket validation machines (TVMs), tap pole validators, and additional equipment including CCTV cameras and push-button speakers. A large number of items consequently had to be procured. During the baseline schedule, the contractor generally presented the procurement of architectural items without specifying or breaking down the procurement and installation of these items on an item-by-item basis; instead, the procurement and installation of these items were represented by activities broken down station by station.

Figure 10: Architectural Installation Plan per Baseline Schedule – Bus Route Project in MD

Activity ID	Activity Name	Orig Dur	Remg Dur	Start	Finish	Total Float	Acty Cnt
Architectural Installation		21	21	11-Nov-19	27-Dec-19	0	18
A1570	Station # 01 - Installation of Architectural Package	10	10	11-Nov-19	02-Dec-19	11	1
A1900	Station # 02 SB - Installation of Architectural Package	10	10	11-Nov-19	02-Dec-19	1	1
A1251	Station # 03 NB - Installation of Architectural Package	10	10	11-Nov-19	02-Dec-19	1	1
A2140	Station # 04 NB - Installation of Architectural Pachage	10	10	11-Nov-19	02-Dec-19	1	1
A2540	Station # 05 NB - Installation of Architectural Package	10	10	11-Nov-19	02-Dec-19	1	1
A3420	Station # 08 NB - Installation of Architectural Pachage	10	10	11-Nov-19	02-Dec-19	1	1
A3740	Station # 09 - Installation of Architechtural Package	10	10	11-Nov-19	02-Dec-19	11	1
A3900	Station # 10 - Installation of Architectural Package	10	10	11-Nov-19	02-Dec-19	11	1
A4060	Station # 11 - Installation of Architectural Package	10	10	11-Nov-19	02-Dec-19	11	1
A4190	Station # 07 NB - Installation of Architectural Package	10	10	11-Nov-19	02-Dec-19	1	1
A2940	Station # 06 NB - Installation of Architectural Package	10	10	12-Nov-19	04-Dec-19	0	1
A2020	Station # 03 SB - Installation of Architectural Pachage	10	10	04-Dec-19	26-Dec-19	1	1
A2740	Station # 05 SB - Installation of Architectural Package	10	10	04-Dec-19	26-Dec-19	1	1
A3580	Station # 08 SB - Installation of Architectural Package	10	10	04-Dec-19	26-Dec-19	1	1
A4300	Station # 07 SB - Installation of Architectural Package	10	10	04-Dec-19	26-Dec-19	1	1
A2300	Station # 02 NB - Installation of Architectural Package	10	10	04-Dec-19	26-Dec-19	1	1
A2310	Station # 04 SB - Installation of Architectural Package	10	10	06-Dec-19	27-Dec-19	0	1
A3100	Station # 06 SB - Installation of Architectural Package	10	10	06-Dec-19	27-Dec-19	0	1
Project Closeout		0	0	28-Dec-19	28-Dec-19	0	1

The baseline schedule demonstrates the progress of concurrent architectural work at most stations. More specifically, each station was assigned generic activity described as "Station XX – Installation of Architectural Package" for performing architectural installations. **Figure 10** demonstrates that eleven of these stations scheduled for concurrent architectural work were followed by seven stations also scheduled for concurrent work. However, from *Schedule Update No. 03* (March 2019) onward, CGI decided to change its architectural installation sequence and install each component concurrently at all stations. For example, *Install Canopy A* at all stations and *Install Windscreens* at all stations. Until *Update No. 13,* CGI had planned the concurrent installation of many of these components (**Figure 11**). *Update No. 13* reflects the plan as of January 18, 2020 (data date).

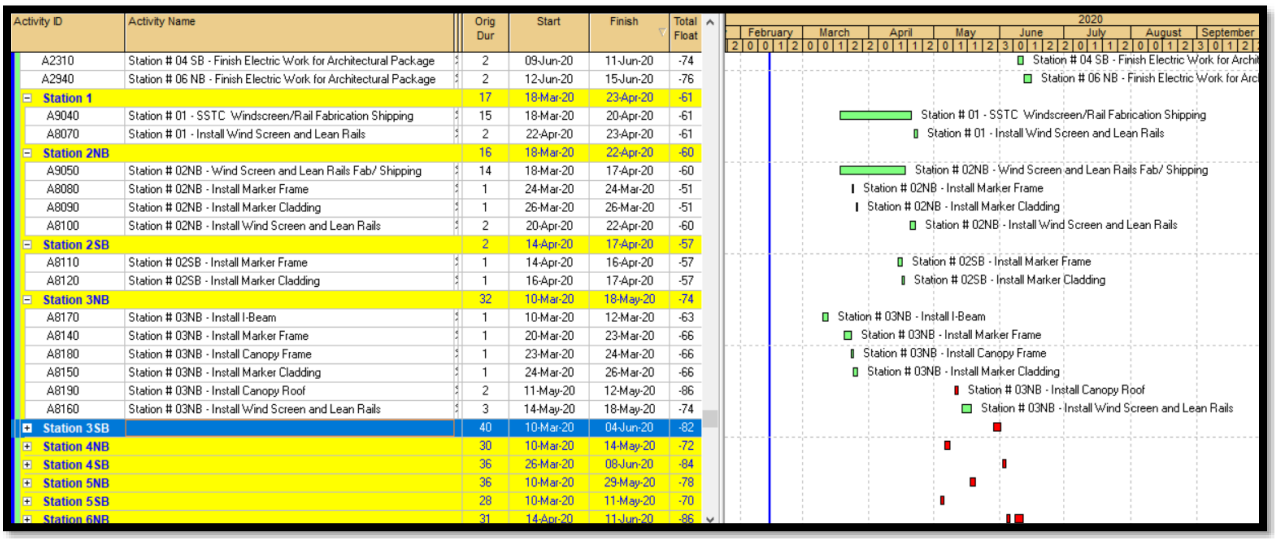
Figure 11: Architectural Installation Plan per Update No. 13 – Bus Route Project in MD



Activity ID	Activity Name	Orig Dur	Start	Finish	Total Float
Architectural Installation		35	03-Feb-20	22-Apr-20	-48
A1570	Station # 01 - Finish Electric Work for Architectural Package	2	03-Feb-20	05-Feb-20	-15
A5010	Install - Large Canopy 'B'	4	12-Mar-20	20-Mar-20	-36
A5020	Install - Station Marker	10	16-Mar-20	06-Apr-20	-52
A4980	Install - Windscreens	10	26-Mar-20	17-Apr-20	-58
A4990	Install - Small Canopy	10	26-Mar-20	17-Apr-20	-48
A5000	Install - Large Canopy 'A'	10	26-Mar-20	17-Apr-20	-48
A1900	Station # 02 SB - Finish Electric Work for Architectural Package	2	07-Apr-20	08-Apr-20	-43
A2300	Station # 02 NB - Finish Electric Work for Architectural Package	2	07-Apr-20	08-Apr-20	-43
A1251	Station # 03 NB - Finish Electric Work for Architectural Package	2	20-Apr-20	22-Apr-20	-48
A2020	Station # 03 SB - Finish Electric Work for Architectural Package	2	20-Apr-20	22-Apr-20	-48
A2140	Station # 04 NB - Finish Electric Work for Architectural Package	2	20-Apr-20	22-Apr-20	-48
A2310	Station # 04 SB - Finish Electric Work for Architectural Package	2	20-Apr-20	22-Apr-20	-48
A2540	Station # 05 NB - Finish Electric Work for Architectural Package	2	20-Apr-20	22-Apr-20	-48
A2740	Station # 05 SB - Finish Electric Work for Architectural Package	2	20-Apr-20	22-Apr-20	-48
A2940	Station # 06 NB - Finish Electric Work for Architectural Package	2	20-Apr-20	22-Apr-20	-48
A3100	Station # 06 SB - Finish Electric Work for Architectural Package	2	20-Apr-20	22-Apr-20	-48
A3420	Station # 08 NB - Finish Electric Work for Architectural Package	2	20-Apr-20	22-Apr-20	-48
A3580	Station # 08 SB - Finish Electric Work for Architectural Package	2	20-Apr-20	22-Apr-20	-48
A3740	Station # 09 - Finish Electric Work for Architectural Package	2	20-Apr-20	22-Apr-20	-48
A3900	Station # 10 - Finish Electric Work for Architectural Package	2	20-Apr-20	22-Apr-20	-48
A4060	Station # 11 - Finish Electric Work for Architectural Package	2	20-Apr-20	22-Apr-20	-48
A4190	Station # 07 NB - Finish Electric Work for Architectural Package	2	20-Apr-20	22-Apr-20	-48
A4300	Station # 07 SB - Finish Electric Work for Architectural Package	2	20-Apr-20	22-Apr-20	-48

Nevertheless, not all stations contain identical architectural items and features. For instance, the plan indicates that Station 1 had only windscreens and lean rails, whereas Station 2SB had only station markers. However, most stations, such as Station 3NB, contain canopies. Each station was planned to have one of three types of canopies: Large Canopy A, Large Canopy B, or Small Canopy. Due to the requirement of most stations, canopies were one of the major architectural items to be procured. In *Update No. 14*, CGI broke down the architectural installation process to provide more detailed activities for each station. **Figure 12** exemplifies the different architectural items intended for installation in each station. *Update No. 14*'s period of performance spans from January 18 to February 14, 2020; in other words, this was the period in which actual, material progress occurred.

Figure 12: Architectural Installation Plan per Update No. 14 – Bus Route Project in MD



Activity ID	Activity Name	Orig Dur	Start	Finish	Total Float
A2310	Station # 04 SB - Finish Electric Work for Architectural Package	2	09-Jun-20	11-Jun-20	-74
A2940	Station # 06 NB - Finish Electric Work for Architectural Package	2	12-Jun-20	15-Jun-20	-76
Station 1		17	18-Mar-20	23-Apr-20	-61
A9040	Station # 01 - SSTC Windscreen/Rail Fabrication Shipping	15	18-Mar-20	20-Apr-20	-61
A8070	Station # 01 - Install Wind Screen and Lean Rails	2	22-Apr-20	23-Apr-20	-61
Station 2NB		16	18-Mar-20	22-Apr-20	-60
A9050	Station # 02NB - Wind Screen and Lean Rails Fab/ Shipping	14	18-Mar-20	17-Apr-20	-60
A8080	Station # 02NB - Install Marker Frame	1	24-Mar-20	24-Mar-20	-51
A8090	Station # 02NB - Install Marker Cladding	1	26-Mar-20	26-Mar-20	-51
A8100	Station # 02NB - Install Wind Screen and Lean Rails	2	20-Apr-20	22-Apr-20	-60
Station 2SB		2	14-Apr-20	17-Apr-20	-57
A8110	Station # 02SB - Install Marker Frame	1	14-Apr-20	16-Apr-20	-57
A8120	Station # 02SB - Install Marker Cladding	1	16-Apr-20	17-Apr-20	-57
Station 3NB		32	10-Mar-20	18-May-20	-74
A8170	Station # 03NB - Install I-Beam	1	10-Mar-20	12-Mar-20	-63
A8140	Station # 03NB - Install Marker Frame	1	20-Mar-20	23-Mar-20	-66
A8180	Station # 03NB - Install Canopy Frame	1	23-Mar-20	24-Mar-20	-66
A8150	Station # 03NB - Install Marker Cladding	1	24-Mar-20	26-Mar-20	-66
A8190	Station # 03NB - Install Canopy Roof	2	11-May-20	12-May-20	-86
A8160	Station # 03NB - Install Wind Screen and Lean Rails	3	14-May-20	18-May-20	-74
Station 3SB		40	10-Mar-20	04-Jun-20	-82
Station 4NB		30	10-Mar-20	14-May-20	-72
Station 4SB		36	26-Mar-20	08-Jun-20	-84
Station 5NB		36	10-Mar-20	29-May-20	-78
Station 5SB		28	10-Mar-20	11-May-20	-70
Station 6NB		31	14-Apr-20	11-Jun-20	-86

By default, the installation schedule regarding the architectural items depended predominantly on their procurement. As the manufacturer of these items, LFI was consequently responsible for manufacturing and delivering the canopies, station markers, windscreens, and lean rails. LFI is a manufacturing plant that specializes in landscaping items including adaptive outdoor structures, shelters, signage, litters, bike racks, and LED lights.[47] An interview was conducted with Chris Kirsch, the contractor's Project Manager, in which he provided further information about LFI's role and performance in the schedule.[48] Kirsch noted that LFI was one of three plants in North America that was able to manufacture these custom-made items, as the types of the canopies limited the number of candidates and bidders who were able to fulfill this task. He also indicated that following the submission of bids from three manufacturers, only two bids were responsive, and only LFI was ultimately able to meet the deadlines.

Figure 13 provides a rendering of a bus station with a completed canopy.

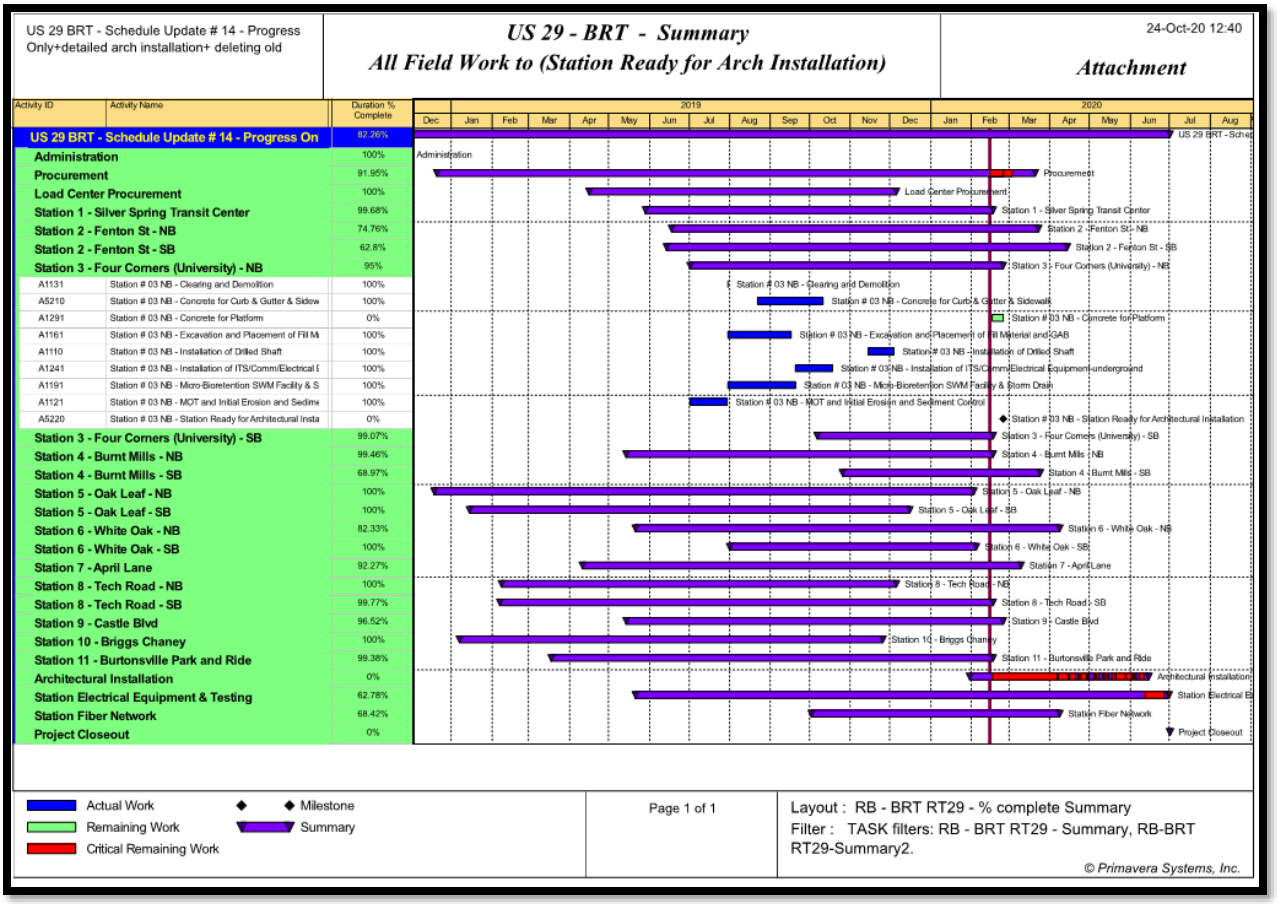
Figure 13: Rendering of one of the bus stations under construction – Bus Route Project in MD

To assist in the time impact analysis related to COVID-19, this paper will first discuss the progress of the project and its performance in terms of schedule prior to the shutdowns imposed by state officials. The last update before COVID-19 began to impact the industry will become the baseline update into which the Fragnet will be inserted. This section will discuss the status of the schedule and the progress of the project, starting from January 18, 2020.

Update No. 14's period of performance spans from January 18, 2020 to February 14, 2020, with a data date of February 15, 2020. As of the data date, the project has consumed 112% of the time allotted by the contract for its completion. Most of the progress made involved activities specific to station construction, including maintenance of traffic (MOT); demolition; curb and gutter work; concrete platform work; and the installation of storm water management facilities. Once construction is complete, the crews will typically perform landscaping, power drops, and architectural installation. As per *Update No. 14,* the overall construction of the stations is

82.26% complete. **Figure 14** summarizes the distance of each station from completion. The latest scheduled completions for station civil construction are Station 2SB (A5100 – Station #02 SB – Station Ready for Architectural Installation) and Station 6NB (A5420 – Station #06 NB – Station Ready for Architectural Installation). Station 2SB is due for completion on April 14, 2020, 28 calendar days later than *Update No. 13*; meanwhile, Station 6NB finishes on April 8, 2020, 15 days later than *Update No. 13*.

Figure 14: Station Construction %Complete Per Update No. 14 – Bus Route Project in MD



Of particular importance to this research is the procurement process of the architectural items, specifically canopies, manufactured and shipped by LFI. The procurement of architectural items

begins by preparing and submitting the shop drawings; reviewing and approving the submission; and fabricating and shipping the items. Although there have been delays in the production of most architectural items, the procurement of canopies is of particular concern. The procurement of canopies was impacted during this update by the owner's request to make changes to the stain color of the CLT roof component. According to Kirsch, each canopy was comprised of three components: the structural frame, the wooden CLT roof, and the metal roof material. Whereas the structural frame and metal roof material were manufactured in LFI's Michigan plant, the wooden CLT roof was manufactured in LFI's plant in Quebec, Canada, intended for completion in New Hampshire, US, before shipping the final product to Maryland. Therefore, the change would impact both the manufacturing progress in the Quebec plant and the overall process of procuring the canopies. The change in CLT stain color is represented by activity *A9060-Revise CLT Stain Color per MCDOT*. The manufacturing of the rest of the components has also progressed during this update, although their completion dates have been somewhat delayed.

The complicated nature of *Update No. 14* stems from the procurement process, starting with the change in the CLT canopy roof stain color and moving to the installation of the canopy roofs at each station. The installation of canopy roofs depends upon the completion of the CLT component procurement activity, scheduled for April 6, 2020; from April 7, 2020 onward, the installation of the canopy roofs is critical. The contractor has chosen to sequence the roof installation in a fully consecutive manner.

Having been delayed by 46 calendar days, the project's final completion date is now 186 calendar days behind schedule. According to *Update No. 14*, the final completion date is July 1, 2020.

Update No. 15's period of performance spans from February 15, 2020 to March 13, 2020, with a data date of March 14, 2020. As of the data date, the project has consumed 119.2% of the time allotted by the contract for its completion. Most of the progress made involved activities specific to station construction. According to *Update No. 15*, the stations' overall construction is 84.41% complete. The construction process was partially interrupted due to utility conflicts at Stations 2NB and 6NB. The latest scheduled completions for station construction are Stations 2NB (delayed during this update by 38 days during this update), 2SB (delayed by 22 days), and 6NB.

Procurement of architectural items, specifically the canopy roofs, has been delayed during this update. Note that CGI uses the schedule provided by LFI to update their own schedule. The procurement and installation of canopy roofs is on the close-to-critical path (the second-longest path) and was deemed by the project's consultant, Ronald Bard, to be on the primary and most critical path. With a three-week delay in the completion of the canopies' procurement process during this update, delivery of the canopies (small, large A, and large B) to the site is now projected for March 31, 2020. The revision of the CLT component activity, however, is now projected for completion on April 17, 2020. This activity is assumed to represent the revision direction by the county, the suspension of work on the CLT manufacturing, the color selection of the CLT stain Color, the official direction to resume fabrication, the fabrication itself, and the delivery of the component to the project site in Maryland. As mentioned previously, the CLT

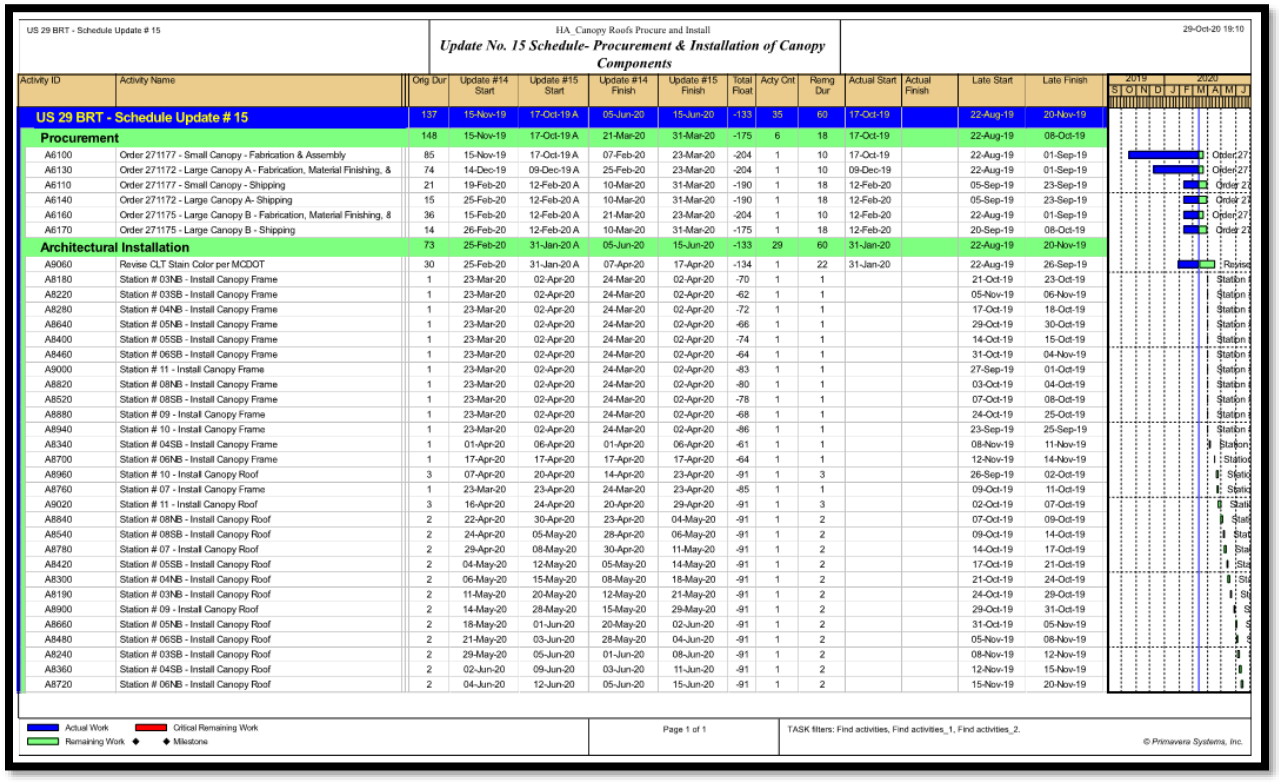
roof component is manufactured in Quebec, Canada, and will be shipped to New Hampshire for completion before its delivery to Maryland. The completion of the CLT stain color revision activity is critical for starting the installation of the canopy roofs. **Figure 15** outlines the procurement and installation schedule of the architectural items. The first canopy roof is scheduled for installation at Station 10 on April 20, 2020. The crew is then scheduled to proceed to Station 11, Station 8NB, and all consecutive stations until installing the final canopy roof at Station 6NB on June 12, 2020. The process of installing the canopies at all stations (as scheduled and planned by CGI in *Update No. 15*) spans the period from April 20, 2020 to June 15, 2020, although most canopy installations would require two work days per station. Consequently, if CGI chooses to install the canopies concurrently on all stations, the installation process would be complete by April 2020. However, CGI instead planned the installations to occur in a fully consecutive manner, thereby putting the installation on the near-critical path. CGI's reasons for doing so will be discussed later.

During this update, the final completion date was delayed by 15 calendar days and is now 201 days behind the contractual completion date. *Update No. 15* presents July 16, 2020 as the final completion date.

Update No. 15 was submitted on April 6, 2020, alongside two Notices of Delay regarding procurement. Both notices were dated later than the update period. The first Notice of Delay, dated March 31, 2020, is specific to the procurement of Ticket Vending Machines (TVMs). CGI states that the supplier is experiencing material procurement delays due to the COVID-19 outbreak. The second Notice of Delay, dated April 3, 2020, is a general notice of delay under Supplemental General Conditions Article 11.6 and refers to delays experienced by LFI plants

that will prevent an on-time delivery of some materials manufactured by LFI. This research will analyze the impacts of COVID-19 on the procurement process involving LFI. The delays in the procurement of the TVMs did not significantly impact the overall schedule, especially when compared to LFI's items, by which the schedule was driven. Moreover, both the contractor and the county state that the TVMs were "sole sourced"; in other words, the required material was available to the contractor from only one supplier or provider, which was in this case, as in most, the supplier that the owner required to be used. Therefore, even if the schedule was driven by the TVMs' delay, the county would most likely take responsibility. As result, this paper will focus on more complex analyses of the delays created by LFI.

Figure 15: Procurement and Installation Schedule of Balance Canopy Components per Update No. 15 – Bus Route Project in MD



US 29 BRT - Schedule Update # 15 | HA_Canopy Roofs Procure and Install | 29-Oct-20 19:10

Update No. 15 Schedule- Procurement & Installation of Canopy Components

Activity ID	Activity Name	Orig Dur	Update #14 Start	Update #15 Start	Update #14 Finish	Update #15 Finish	Total Float	Acty Cnt	Remg Dur	Actual Start	Actual Finish	Late Start	Late Finish
US 29 BRT - Schedule Update # 15		137	15-Nov-19	17-Oct-19 A	05-Jun-20	15-Jun-20	-133	35	60	17-Oct-19		22-Aug-19	20-Nov-19
Procurement		148	15-Nov-19	17-Oct-19 A	21-Mar-20	31-Mar-20	-175	6	18	17-Oct-19		22-Aug-19	08-Oct-19
A6100	Order 271177 - Small Canopy - Fabrication & Assembly	85	15-Nov-19	17-Oct-19 A	07-Feb-20	23-Mar-20	-204	1	10	17-Oct-19		22-Aug-19	01-Sep-19
A6130	Order 271172 - Large Canopy A - Fabrication, Material Finishing, &	74	14-Dec-19	09-Dec-19 A	25-Feb-20	23-Mar-20	-204	1	10	09-Dec-19		22-Aug-19	01-Sep-19
A6110	Order 271177 - Small Canopy - Shipping	21	19-Feb-20	12-Feb-20 A	10-Mar-20	31-Mar-20	-190	1	18	12-Feb-20		05-Sep-19	23-Sep-19
A6140	Order 271172 - Large Canopy A- Shipping	15	25-Feb-20	12-Feb-20 A	10-Mar-20	31-Mar-20	-190	1	18	12-Feb-20		05-Sep-19	23-Sep-19
A6160	Order 271175 - Large Canopy B - Fabrication, Material Finishing, &	36	15-Feb-20	12-Feb-20 A	21-Mar-20	23-Mar-20	-204	1	10	12-Feb-20		22-Aug-19	01-Sep-19
A6170	Order 271175 - Large Canopy B - Shipping	14	26-Feb-20	12-Feb-20 A	10-Mar-20	31-Mar-20	-175	1	18	12-Feb-20		20-Sep-19	08-Oct-19
Architectural Installation		73	25-Feb-20	31-Jan-20 A	05-Jun-20	15-Jun-20	-133	29	60	31-Jan-20		22-Aug-19	20-Nov-19
A9060	Revise CLT Stain Color per MCDOT	30	25-Feb-20	31-Jan-20 A	07-Apr-20	17-Apr-20	-134	1	22	31-Jan-20		22-Aug-19	26-Sep-19
A8180	Station # 03NB - Install Canopy Frame	1	23-Mar-20	02-Apr-20	24-Mar-20	02-Apr-20	-70	1	1			21-Oct-19	23-Oct-19
A8220	Station # 03SB - Install Canopy Frame	1	23-Mar-20	02-Apr-20	24-Mar-20	02-Apr-20	-62	1	1			05-Nov-19	06-Nov-19
A8280	Station # 04NB - Install Canopy Frame	1	23-Mar-20	02-Apr-20	24-Mar-20	02-Apr-20	-72	1	1			17-Oct-19	18-Oct-19
A8640	Station # 05NB - Install Canopy Frame	1	23-Mar-20	02-Apr-20	24-Mar-20	02-Apr-20	-66	1	1			29-Oct-19	30-Oct-19
A8400	Station # 05SB - Install Canopy Frame	1	23-Mar-20	02-Apr-20	24-Mar-20	02-Apr-20	-74	1	1			14-Oct-19	15-Oct-19
A8460	Station # 06SB - Install Canopy Frame	1	23-Mar-20	02-Apr-20	24-Mar-20	02-Apr-20	-64	1	1			31-Oct-19	04-Nov-19
A9000	Station # 11 - Install Canopy Frame	1	23-Mar-20	02-Apr-20	24-Mar-20	02-Apr-20	-83	1	1			27-Sep-19	01-Oct-19
A8820	Station # 08NB - Install Canopy Frame	1	23-Mar-20	02-Apr-20	24-Mar-20	02-Apr-20	-80	1	1			03-Oct-19	04-Oct-19
A8520	Station # 08SB - Install Canopy Frame	1	23-Mar-20	02-Apr-20	24-Mar-20	02-Apr-20	-78	1	1			07-Oct-19	08-Oct-19
A8880	Station # 09 - Install Canopy Frame	1	23-Mar-20	02-Apr-20	24-Mar-20	02-Apr-20	-68	1	1			24-Oct-19	25-Oct-19
A8940	Station # 10 - Install Canopy Frame	1	23-Mar-20	02-Apr-20	24-Mar-20	02-Apr-20	-86	1	1			23-Sep-19	25-Sep-19
A8340	Station # 04SB - Install Canopy Frame	1	01-Apr-20	06-Apr-20	01-Apr-20	06-Apr-20	-61	1	1			08-Nov-19	11-Nov-19
A8700	Station # 06NB - Install Canopy Frame	1	17-Apr-20	17-Apr-20	17-Apr-20	17-Apr-20	-64	1	1			12-Nov-19	14-Nov-19
A8960	Station # 10 - Install Canopy Roof	3	07-Apr-20	20-Apr-20	14-Apr-20	23-Apr-20	-91	1	3			26-Sep-19	02-Oct-19
A8760	Station # 07 - Install Canopy Frame	1	23-Mar-20	23-Apr-20	24-Mar-20	23-Apr-20	-85	1	1			09-Oct-19	11-Oct-19
A9020	Station # 11 - Install Canopy Roof	3	16-Apr-20	24-Apr-20	20-Apr-20	29-Apr-20	-91	1	3			02-Oct-19	07-Oct-19
A8840	Station # 08NB - Install Canopy Roof	2	22-Apr-20	30-Apr-20	23-Apr-20	04-May-20	-91	1	2			07-Oct-19	09-Oct-19
A8540	Station # 08SB - Install Canopy Roof	2	24-Apr-20	05-May-20	28-Apr-20	06-May-20	-91	1	2			09-Oct-19	14-Oct-19
A8780	Station # 07 - Install Canopy Roof	2	29-Apr-20	08-May-20	30-Apr-20	11-May-20	-91	1	2			14-Oct-19	17-Oct-19
A8420	Station # 05SB - Install Canopy Roof	2	04-May-20	12-May-20	05-May-20	14-May-20	-91	1	2			17-Oct-19	21-Oct-19
A8300	Station # 04NB - Install Canopy Roof	2	06-May-20	15-May-20	08-May-20	18-May-20	-91	1	2			21-Oct-19	24-Oct-19
A8180	Station # 03NB - Install Canopy Roof	2	11-May-20	20-May-20	12-May-20	21-May-20	-91	1	2			24-Oct-19	29-Oct-19
A8900	Station # 09 - Install Canopy Roof	2	14-May-20	28-May-20	15-May-20	29-May-20	-91	1	2			29-Oct-19	31-Oct-19
A8660	Station # 05NB - Install Canopy Roof	2	18-May-20	01-Jun-20	20-May-20	02-Jun-20	-91	1	2			31-Oct-19	05-Nov-19
A8480	Station # 06SB - Install Canopy Roof	2	21-May-20	03-Jun-20	28-May-20	04-Jun-20	-91	1	2			05-Nov-19	08-Nov-19
A8240	Station # 03SB - Install Canopy Roof	2	29-May-20	05-Jun-20	01-Jun-20	08-Jun-20	-91	1	2			08-Nov-19	12-Nov-19
A8360	Station # 04SB - Install Canopy Roof	2	02-Jun-20	09-Jun-20	03-Jun-20	11-Jun-20	-91	1	2			12-Nov-19	15-Nov-19
A8720	Station # 06NB - Install Canopy Roof	2	04-Jun-20	12-Jun-20	05-Jun-20	15-Jun-20	-91	1	2			15-Nov-19	20-Nov-19

2019 2020 S O N D J F M A M J

Actual Work | Remaining Work | Critical Remaining Work | Milestone

Page 1 of 1

TASK filters: Find activities, Find activities_1, Find activities_2.

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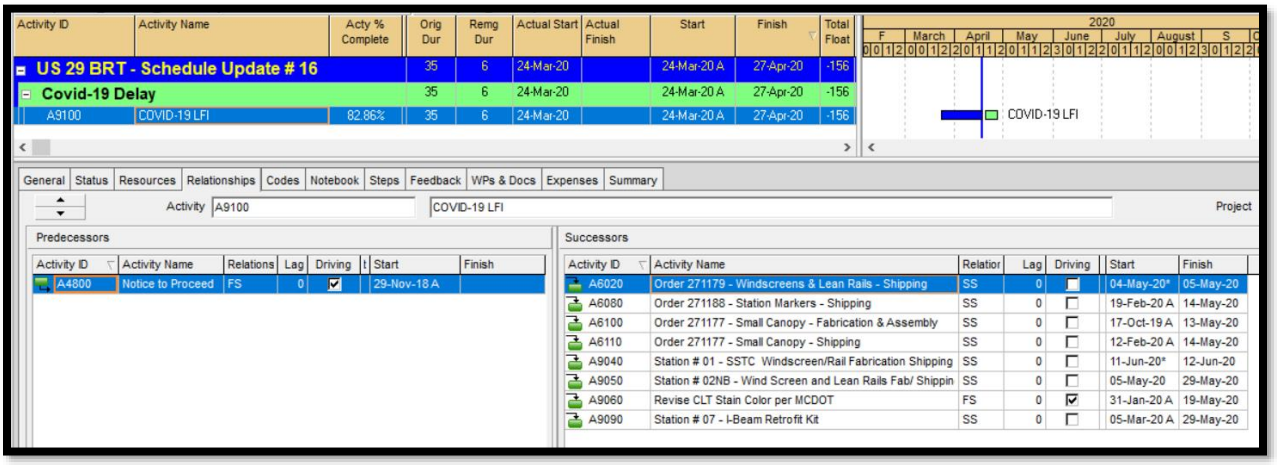
Update No. 16 contains a data date of April 18, 2020 and a period of performance spanning from March 14 to April 17, 2020. During this update, CGI added an activity to model the delay at LFI's facilities. Labeled *A9100-COVID-19 LFI*, this activity contains a starting date of March 24, 2020 and an anticipated finishing date of April 27, 2020. **Figure 16** presents the activity and logic ties. During *Update No. 16,* the longest critical path was driven by the procurement and installation of the Tap Pole Validators with a total float of -113. However, the primary critical path (and the second-longest path) was driven by the procurement and installation of the canopies, with a total float of -107. Calculations indicate that if the procurement and installation of canopies is delayed by six days (113-107), the canopies will be driving the longest path. Therefore, the procurement of the canopies contributes to the overall delay of the project's completion, and may easily drive the longest path in subsequent updates if allowed to slip further. The final completion date, as per *Update No. 16,* is scheduled for August 14, 2020.

Figure 16: the newly added activity (by the contractor) to model LFI's shutdown – Bus Route Project in MD



Time Impact Analysis

Although the contractor has added an activity to model the delay in LFI's schedule, their effort is not sufficient to establish basis for a time extension request. An adequate time impact analysis should be performed to accurately and separately assess the delays on the project due to COVID-19's impacts on LFI's progress. To do so, this research will use the prospective time impact analysis as recommended by AACEI 52R-06.[21] AACEI describes prospective time impact analysis as a forward-looking technique that incorporates one or more event into an unimpacted schedule to determine its potential impact on the project's overall schedule. The prospective TIA technique is performed as the project is ongoing, whereas the retrospective TIA procedure is performed after it has been executed. As of the date of this report, the project is still ongoing but is in its final stages. Also, aside from the Notice of Delay reserving the contractor's right to request a time extension, the contractor has not submitted a TIA request in relation to COVID-19.

The time impact analysis will be conducted in accordance with:

1. General Conditions of Construction Contracts – Montgomery County, ARTICLE 11 Time[49]
2. AACEI Recommended Practice: 52R-06: Prospective Time Impact Analysis – As Applied in Construction
3. *Prospective and Retrospective Time Impact Analysis* construction briefing by Evans Barba (2005)[50]

The first stage in the analytic process is to determine the Fragnet that will model the event; in this case, the event is the state-mandated shutdown of the LFI facility. To model the event and create a Fragnet (as per industry standard practice and as supplemented by AACEI 52R-06), the following actions will be taken:

- Create an activity or set of activities to model the event
- List the activities in the existing project schedule that will be affected by the delay
- If necessary, break down each of the existing and impacted activities into two activities: one representing the work performed before the delay, and one representing the work performed after the start of the delay. The broken down durations of these activities should total the original duration of the original activity
- Add logic ties between the modeled event activity and the impacted existing activities
- Add the projected start and finish dates based on the available information
- Select the correct schedule update
- Run the schedule
- Study the critical path and completion milestones

The activity in this case will be “LFI facility shutdown” due to COVID-19. The activity can be further broken down into three activities in accordance with each facility’s location. As mentioned previously, materials procured through LFI were manufactured at two different LFI facilities, located in Michigan, US and Quebec, Canada. Only the CLT wood roof component was to be manufactured in Canada and shipped to New Hampshire for final modifications, such as

sanding and painting, before its delivery to the Maryland site. The remaining architectural items (provided by LFI), including other parts of the canopy such as the metal roof materials and the structural frame, were to be manufactured in Michigan. Progress Meeting #34, which was held on April 13, 2020, states that LFI facilities were shut down on March 24, 2020.[51] The start and finish dates of the delay will be discussed later in more detail. During the progress meeting, CGI indicated that some components were already shipped and on site. However, remaining items that were to be shipped and manufactured included windscreen posts, lean rails, small canopy frame balances, station marker doors, and (most importantly) the CLT wood roof component. Therefore, to summarize the status of the three roof components:

1. Structural frame: manufacturing was not complete as of the date of the delay, and faced further obstruction due to the shutdown in Michigan
2. Metal roof material: manufacturing was complete and items were shipped. Project manager Chris Kirsch also confirmed in the interview that metal roof material was not a concern when the delay occurred.
3. CLT wood roof component: was manufactured in Canada and was delayed due to the shutdown of non-essential businesses in Quebec. According to Progress Meeting #34, the procurement of this item was critical. Kirsch stated in the interview that although the facility in Quebec did not fully shut down, its capacity and productivity were reduced by 75%, resulting in the facility's inability to continue manufacturing items on this scale. The procurement of this component will also depend upon the reopening of the LFI facility in New Hampshire, where the manufacture of the CLT wood roof component will be completed prior to their delivery to Maryland.

Note: this research will not investigate delays in the procurement of other LFI items such as the windscreen posts; as these items were not on the critical path of the schedule, they do not impact the final completion date or other milestones compared to the canopies procurement. Moreover, the contractor indicated in the progress meeting that to avoid damaging the windscreens, their installation would be undertaken after that of the canopy roof.

Therefore, the Fragnet will include the following activities:

Figure 17: New activities to model the COVID-19 event – Bus Route project in MD

Activity ID	Activity Name
Z1000	LFI Facility Shutdown in Michigan
Z1010	LFI Facility Shutdown in Canada
Z1020	LFI Facility Shutdown in New Hampshire
Z1030	Manufacturing of Remaining CLT Canopy Roof + Shipping to NH + Finishing + Shipping to MD

These activities will be assigned to a new grouping (referred to in P6 as work breakdown structure or WBS) labeled “COVID Delays at LFI”.

In addition, the description of the current existing activity of A9060, “Revise CLT Stain Color per MCDOT”, will be changed to “Revise CLT Stain Color per MCDOT + Manufacturing of CLT Roof First Batch Before COVID”. The duration of the activity will be reduced to eight workdays (WD) and the activity will be 100% complete; meanwhile, the remaining duration of 22 WD (30-8) will

be assigned to the new activity that represents the manufacturing of the remaining canopy roofs.

The related existing activities that will be impacted by this event are listed below, alongside their IDs.

Figure 18: Activities impacted by the COVD-19 delay

Procurement	
A6100	Order 271177 - Small Canopy - Fabrication & Assembly
A6130	Order 271172 - Large Canopy A - Fabrication, Material Finishing, & Assembly
A6110	Order 271177 - Small Canopy - Shipping
A6140	Order 271172 - Large Canopy A- Shipping
A6160	Order 271175 - Large Canopy B - Fabrication, Material Finishing, & Assembly
A6170	Order 271175 - Large Canopy B - Shipping
Architectural Installation	
A9060	Revise CLT Stain Color per MCDOT
A8180	Station # 03NB - Install Canopy Frame
A8220	Station # 03SB - Install Canopy Frame
A8280	Station # 04NB - Install Canopy Frame
A8640	Station # 05NB - Install Canopy Frame
A8400	Station # 05SB - Install Canopy Frame
A8460	Station # 06SB - Install Canopy Frame
A9000	Station # 11 - Install Canopy Frame
A8820	Station # 08NB - Install Canopy Frame
A8520	Station # 08SB - Install Canopy Frame
A8880	Station # 09 - Install Canopy Frame
A8940	Station # 10 - Install Canopy Frame
A8340	Station # 04SB - Install Canopy Frame
A8700	Station # 06NB - Install Canopy Frame
A8960	Station # 10 - Install Canopy Roof
A8760	Station # 07 - Install Canopy Frame
A9020	Station # 11 - Install Canopy Roof
A8840	Station # 08NB - Install Canopy Roof
A8540	Station # 08SB - Install Canopy Roof
A8780	Station # 07 - Install Canopy Roof
A8420	Station # 05SB - Install Canopy Roof
A8300	Station # 04NB - Install Canopy Roof
A8190	Station # 03NB - Install Canopy Roof
A8900	Station # 09 - Install Canopy Roof
A8660	Station # 05NB - Install Canopy Roof
A8480	Station # 06SB - Install Canopy Roof
A8240	Station # 03SB - Install Canopy Roof
A8360	Station # 04SB - Install Canopy Roof
A8720	Station # 06NB - Install Canopy Roof

Logic will be modified as follows:

- Finish-Start relationships added between shipping of canopies and the canopy frames installation at each station

- Finish-Start relationships added between "Z1000 – LFI Facility Shutdown in Michigan" and both the fabrication and shipping of each of the three canopy types
- Relationships deleted between the "A9060 – Revise CLT Stain Color per MCDOT + Manufacturing of CLT Roof First Batch Before COVID" and the Install Canopy Roof activities at each station
- Finish-Start relationships added between "A9060 – Revise CLT Stain Color per MCDOT + Manufacturing of CLT Roof First Batch Before COVID" and "Z1030 – Manufacturing of Remaining CLT Canopy Roof + Shipping to NH + Finishing + Shipping to MD"
- Finish-Start relationships added between each of "Z1010 – LFI Facility Shutdown in Canada" and "Z1020 – LFI Facility Shutdown in New Hampshire", and "Z1030 – Manufacturing of Remaining CLT Canopy Roof + Shipping to NH + Finishing + Shipping to MD" to make the completion of the CLT Roof Procurement dependent on the opening of the facilities in both Canada and New Hampshire
- Finish-Start relationships added between "Z1030 – Manufacturing of Remaining CLT Canopy Roof + Shipping to NH + Finishing + Shipping to MD" and Install Canopy Roof activities at each station

The following start and finish dates for the newly added activities were assigned:

Z1000 – LFI Facility Shutdown in Michigan: This activity's start date, March 24, 2020, is the day upon which LFI's production ceased to comply with Michigan's executive shelter-in-home order,[52] as indicated by both Progress Meeting #34 and the Notice of Delay dated April 3, 2020. Executive Order 2020-59 became effective on March 24, 2020 and was later extended

from its original expiry date of April 13 to April 30, 2020. According to Chris Kirsch, although many businesses remained closed past this date, LFI's facility resumed work with a reduced production rate due to capacity restrictions. Kirsch also added that as LFI was deemed a non-essential business, both CGI and LFI worked to gain the state's approval for the company to resume operations on April 30, 2020; after reopening, it returned to a capacity of 20%-30%. Consequently, the start and finish dates of activity Z1000 are March 24 and April 30, 2020.

Z1010 – LFI Facility Shutdown in Canada: This activity's start date of March 24, 2020 is the day upon which the Quebec Premier François Legault issued stay-home orders in Quebec, Canada.[53] Although the shutdown was originally scheduled to last for three weeks, it was later extended to May 4, 2020.[54] Almost 50% of the CLT roofs manufactured in this facility were not yet completed at the time of the shutdown. Kirsch also revealed that the requirement for social distancing reduced the facility's productivity and capacity by approximately 75%, thereby preventing it from producing the CLT roofs due to the nature of the work required. Therefore, the start and the finish dates of activity Z1010 are March 24 and May 4, 2020.

Z1020 – LFI Facility Shutdown in New Hampshire: The start date of the non-essential businesses' mandated shutdown was extended from March 27 to May 4, 2020. Therefore, the start and the finish dates of the LFI Facility Shutdown in NH are March 27 and May 4, 2020.[55]

Z1030 – Manufacturing of Remaining CLT Canopy Roof + Shipping to NH + Finishing + Shipping to MD: Due to the logic ties, the start of this activity is dependent on the end of the shutdowns in Canada and New Hampshire; the start date will therefore be determined by the schedule after it is run. On the other hand, the finish date would normally be determined by the start

date, with an additional duration of approximately 22 workdays. However, since this research was conducted months after the shutdown event, the CLT roofs have already been shipped and the activity is complete; this activity's finish date has consequently been determined. According to Schedule *Update No. 18*, the CLT roofs were delivered to the site in Maryland on May 28, 2020. Ideally, this activity would be broken down into different activities. However, due to the lack of data and the inability to acquire further information on individual parts of the process such as dates and percentage of completion prior to the shutdown, all the activities were represented by one activity. The data on activity Z1030 were acquired from the schedule updates submitted by CGI to the county, as well as from the interview with Chris Kirsch.

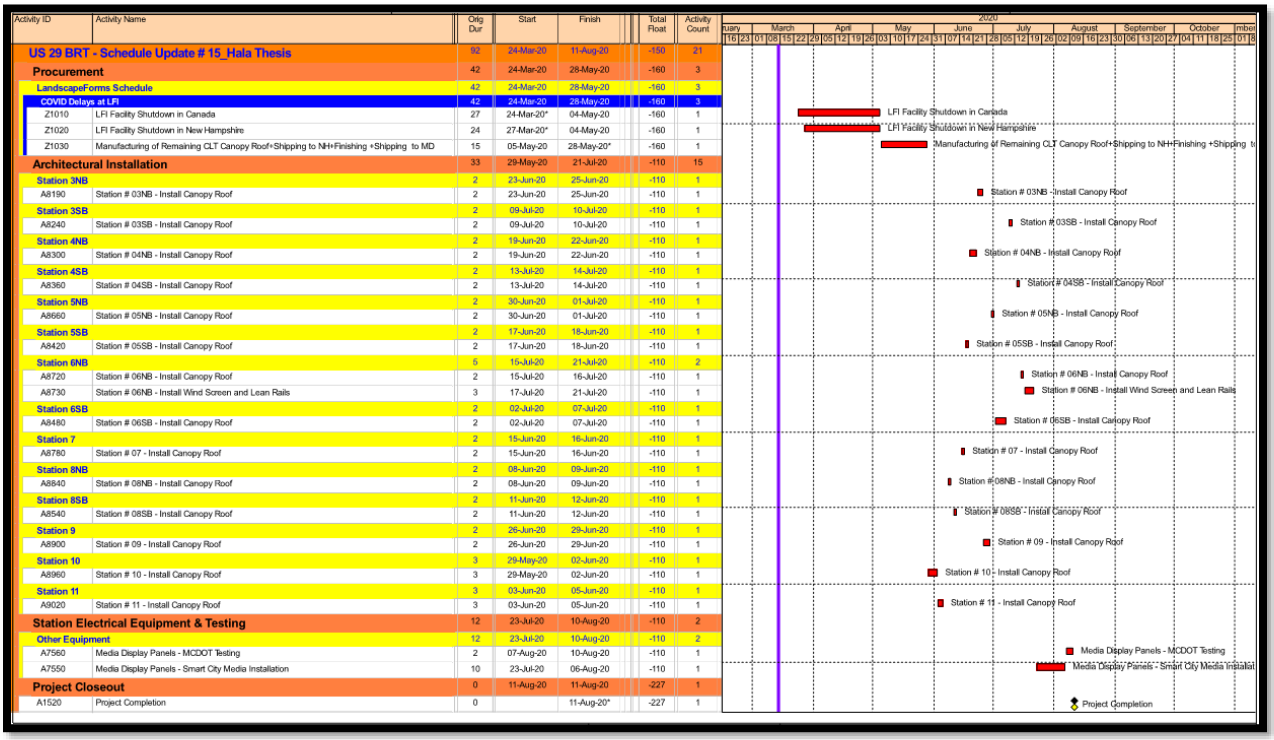
After determining the new activities; their start and finish dates; and their logic ties, the next phase is to choose the schedule update effective as of the start of the delay. In this case, the last schedule update that can be utilized in the TIA, and that was in effect as of the occurrence of the delay, is *Update No. 15*. With a data date of March 14, 2020, this is the closest schedule update to the time of the impact. This update's period of performance spans from February 15 to March 13, 2020. *Update No. 15* will become the "baseline" into which the Fragnet will be inserted to measure the impact of procurement delays caused by COVID-19.

Next, the Fragnet must be incorporated into the baseline, after which the schedule will be run. This new schedule, which will be referred to as "the impacted schedule", will be used to draw conclusions on how the delays produced by COVID-19 impacted the progress of the project. This will be achieved by examining the impacted schedule's critical and longest path.

According to **Figure 19**, the critical path of the impacted schedule is driven by LFI's facility shutdowns in both Canada and New Hampshire, followed by the manufacturing of the remaining CLT roofs and their shipping to Maryland after the facilities open. The critical path then moves to the architectural installations, where it is driven by each station's installation of the canopy roofs, followed by the installation of windscreen and lean rails at Station 6NB. The critical path finally moves to station electrical equipment and testing, wherein the media display panels are installed and tested before the project's final completion date is achieved. Although the installation of canopy frames at each station was not on the critical path, it was still impacted by the COVID-19 event as more float was consumed, resulting in the further delay of the start and finish dates (**Figure 20**). Additionally, **Figure 20** demonstrates the extent to which the finish dates of shipping and fabrication activities for the canopies have been delayed by the shutdowns.

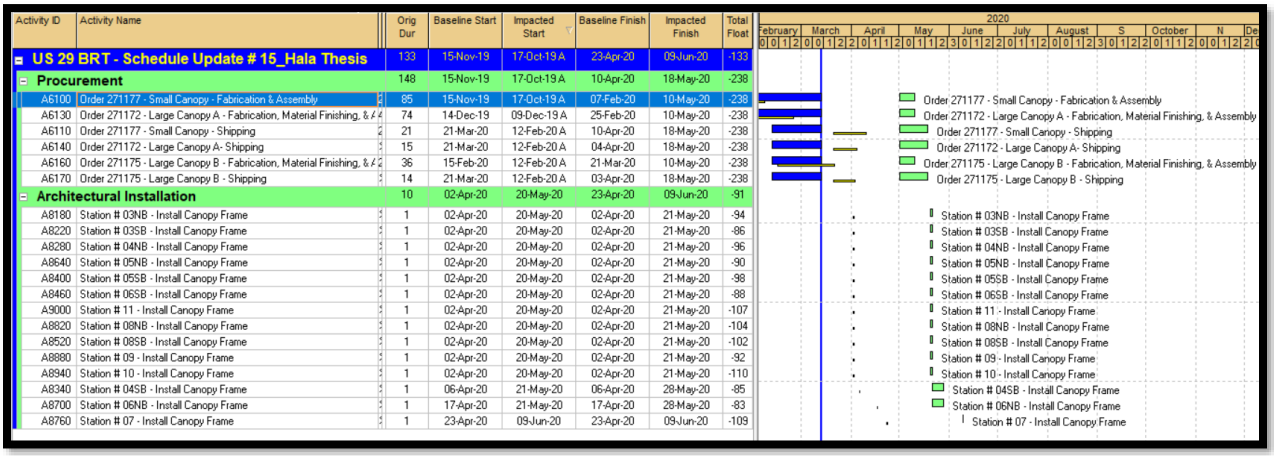
Moreover, the project completion milestone (A1520) has experienced further displacement during LFI's shutdown; having been pushed back by 26 calendar days, the project's final completion date is now 227 calendar days behind the contractual completion. However, the negative float of -227 cannot be fully attributed to LFI's pandemic-induced closure. As demonstrated in *Update No. 15*, which was used as the baseline in this TIA, the project was already 201 calendar days behind schedule before COVID-19 had begun to affect construction work. The contractor is responsible for this 201-day delay, unless they submit claims and time extension requests to the county that prove otherwise.

Figure 19: Longest critical path in impacted schedule – Bus Route Project in MD



Activity ID	Activity Name	Orig Dur	Start	Finish	Total Float	Activity Count
US 29 BRT - Schedule Update # 15_Hala Thesis		92	24-Mar-20	11-Aug-20	-150	21
Procurement		42	24-Mar-20	28-May-20	-160	3
LandscapeForms Schedule		42	24-Mar-20	28-May-20	-160	3
COVID Delays at LFI		42	24-Mar-20	28-May-20	-160	3
Z1010	LFI Facility Shutdown in Canada	27	24-Mar-20*	04-May-20	-160	1
Z1020	LFI Facility Shutdown in New Hampshire	24	27-Mar-20*	04-May-20	-160	1
Z1030	Manufacturing of Remaining CLT Canopy Roof+Shipping to NH+Finishing +Shipping to MD	15	05-May-20	28-May-20*	-160	1
Architectural Installation		33	29-May-20	21-Jul-20	-110	15
Station 3NB		2	23-Jun-20	25-Jun-20	-110	1
A8190	Station # 03NB - Install Canopy Roof	2	23-Jun-20	25-Jun-20	-110	1
Station 3SB		2	09-Jul-20	10-Jul-20	-110	1
A8240	Station # 03SB - Install Canopy Roof	2	09-Jul-20	10-Jul-20	-110	1
Station 4NB		2	19-Jun-20	22-Jun-20	-110	1
A8300	Station # 04NB - Install Canopy Roof	2	19-Jun-20	22-Jun-20	-110	1
Station 4SB		2	13-Jul-20	14-Jul-20	-110	1
A8360	Station # 04SB - Install Canopy Roof	2	13-Jul-20	14-Jul-20	-110	1
Station 5NB		2	30-Jun-20	01-Jul-20	-110	1
A8660	Station # 05NB - Install Canopy Roof	2	30-Jun-20	01-Jul-20	-110	1
Station 5SB		2	17-Jun-20	18-Jun-20	-110	1
A8420	Station # 05SB - Install Canopy Roof	2	17-Jun-20	18-Jun-20	-110	1
Station 6NB		5	15-Jul-20	21-Jul-20	-110	2
A8720	Station # 06NB - Install Canopy Roof	2	15-Jul-20	16-Jul-20	-110	1
A8730	Station # 06NB - Install Wind Screen and Lean Rails	3	17-Jul-20	21-Jul-20	-110	1
Station 6SB		2	02-Jul-20	07-Jul-20	-110	1
A8480	Station # 06SB - Install Canopy Roof	2	02-Jul-20	07-Jul-20	-110	1
Station 7		2	15-Jun-20	16-Jun-20	-110	1
A8780	Station # 07 - Install Canopy Roof	2	15-Jun-20	16-Jun-20	-110	1
Station 8NB		2	08-Jun-20	09-Jun-20	-110	1
A8840	Station # 08NB - Install Canopy Roof	2	08-Jun-20	09-Jun-20	-110	1
Station 8SB		2	11-Jun-20	12-Jun-20	-110	1
A8540	Station # 08SB - Install Canopy Roof	2	11-Jun-20	12-Jun-20	-110	1
Station 9		2	26-Jun-20	29-Jun-20	-110	1
A8900	Station # 09 - Install Canopy Roof	2	26-Jun-20	29-Jun-20	-110	1
Station 10		3	29-May-20	02-Jun-20	-110	1
A8960	Station # 10 - Install Canopy Roof	3	29-May-20	02-Jun-20	-110	1
Station 11		3	03-Jun-20	05-Jun-20	-110	1
A9020	Station # 11 - Install Canopy Roof	3	03-Jun-20	05-Jun-20	-110	1
Station Electrical Equipment & Testing		12	23-Jul-20	10-Aug-20	-110	2
Other Equipment		12	23-Jul-20	10-Aug-20	-110	2
A7560	Media Display Panels - MCDOT Testing	2	07-Aug-20	10-Aug-20	-110	1
A7550	Media Display Panels - Smart City Media Installation	10	23-Jul-20	06-Aug-20	-110	1
Project Closeout		0	11-Aug-20	11-Aug-20	-227	1
A1520	Project Completion	0		11-Aug-20*	-227	1

Figure 20: Canopy frames installation schedule per Impacted Schedule – Bus Route Project in MD



Activity ID	Activity Name	Orig Dur	Baseline Start	Impacted Start	Baseline Finish	Impacted Finish	Total Float
US 29 BRT - Schedule Update # 15_Hala Thesis		133	15-Nov-19	17-Oct-19 A	23-Apr-20	09-Jun-20	-133
Procurement		148	15-Nov-19	17-Oct-19 A	10-Apr-20	18-May-20	-238
A6100	Order 271177 - Small Canopy - Fabrication & Assembly	85	15-Nov-19	17-Oct-19 A	07-Feb-20	10-May-20	-238
A6130	Order 271172 - Large Canopy A - Fabrication, Material Finishing, & A	74	14-Dec-19	09-Dec-19 A	25-Feb-20	10-May-20	-238
A6110	Order 271177 - Small Canopy - Shipping	21	21-Mar-20	12-Feb-20 A	10-Apr-20	18-May-20	-238
A6140	Order 271172 - Large Canopy A- Shipping	15	21-Mar-20	12-Feb-20 A	04-Apr-20	18-May-20	-238
A6160	Order 271175 - Large Canopy B - Fabrication, Material Finishing, & A	36	15-Feb-20	12-Feb-20 A	21-Mar-20	10-May-20	-238
A6170	Order 271175 - Large Canopy B - Shipping	14	21-Mar-20	12-Feb-20 A	03-Apr-20	18-May-20	-238
Architectural Installation		10	02-Apr-20	20-May-20	23-Apr-20	09-Jun-20	-91
A8180	Station # 03NB - Install Canopy Frame	1	02-Apr-20	20-May-20	02-Apr-20	21-May-20	-94
A8220	Station # 03SB - Install Canopy Frame	1	02-Apr-20	20-May-20	02-Apr-20	21-May-20	-86
A8280	Station # 04NB - Install Canopy Frame	1	02-Apr-20	20-May-20	02-Apr-20	21-May-20	-96
A8640	Station # 05NB - Install Canopy Frame	1	02-Apr-20	20-May-20	02-Apr-20	21-May-20	-90
A8400	Station # 05SB - Install Canopy Frame	1	02-Apr-20	20-May-20	02-Apr-20	21-May-20	-98
A8460	Station # 06SB - Install Canopy Frame	1	02-Apr-20	20-May-20	02-Apr-20	21-May-20	-88
A9000	Station # 11 - Install Canopy Frame	1	02-Apr-20	20-May-20	02-Apr-20	21-May-20	-107
A8820	Station # 08NB - Install Canopy Frame	1	02-Apr-20	20-May-20	02-Apr-20	21-May-20	-104
A8520	Station # 08SB - Install Canopy Frame	1	02-Apr-20	20-May-20	02-Apr-20	21-May-20	-102
A8880	Station # 09 - Install Canopy Frame	1	02-Apr-20	20-May-20	02-Apr-20	21-May-20	-92
A8940	Station # 10 - Install Canopy Frame	1	02-Apr-20	20-May-20	02-Apr-20	21-May-20	-110
A8340	Station # 04SB - Install Canopy Frame	1	06-Apr-20	21-May-20	06-Apr-20	28-May-20	-85
A8700	Station # 06NB - Install Canopy Frame	1	17-Apr-20	21-May-20	17-Apr-20	28-May-20	-83
A8760	Station # 07 - Install Canopy Frame	1	23-Apr-20	09-Jun-20	23-Apr-20	09-Jun-20	-109

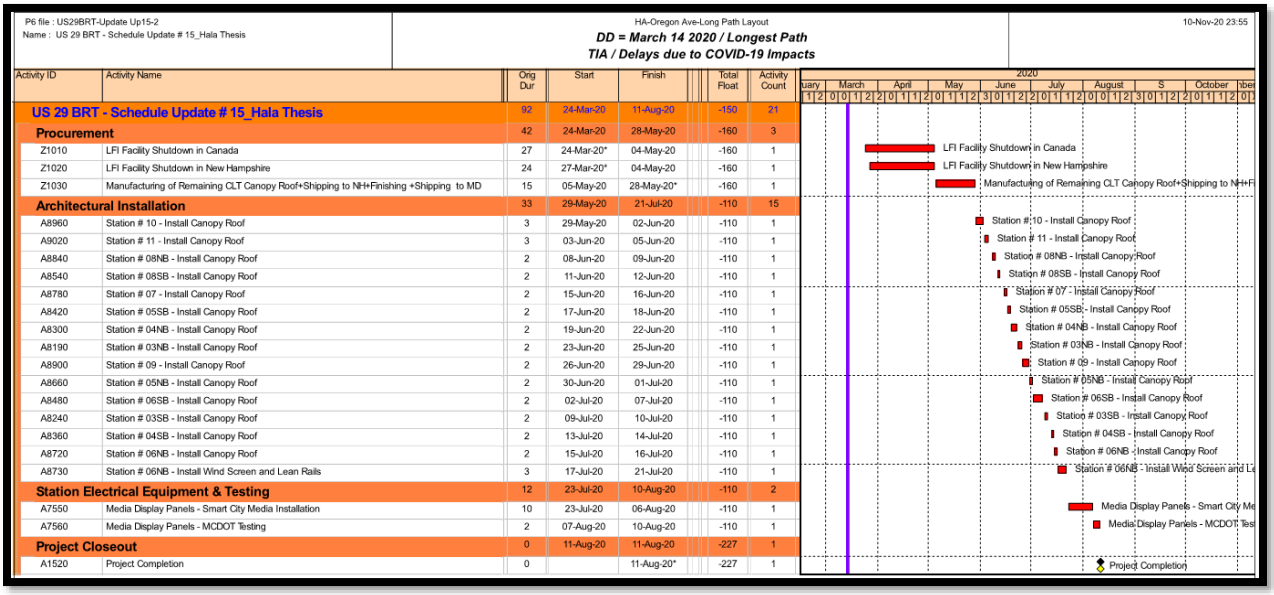
<u>Available Options to mitigate the delays:</u> Having conducted a TIA and quantified the delay caused by COVID-19, standard practice recommends exploring the available mitigation methods. This case contains two possibilities. Firstly, the materials could be procured from a

different manufacturer; this would require the contractor to locate a manufacturer in a state where (at the time of the impact) no stay-home order was issued by its governor, such as Iowa. As Iowa was not under any stay-home orders at the time of the impact, all businesses stayed open during the peak of the shutdown (NASHP, 2020) (Sostaric,2020).[56] [57] One option would be to transport the material and unfinished architectural items to a manufacturer in Iowa and contract with them to complete the assignment and maintain the schedule. However, this process would be costly, given the need to procure a new manufacturer; transport materials and unfinished components from Canada to the facility in Iowa; and research the suitability of various materials and the need to repurchase certain products. Furthermore, as it is costly in terms of time as well as finances, if the impact were to end before this process is complete, all efforts to relocate to a new facility may be moot. Moreover, these items were in the final stages of production, thus complicating and lengthening the process of another manufacturer resuming where another manufacturer stopped. Finally, when asked for input on this option, Kirsch indicated that under normal circumstances featuring a different type of project (e.g., procurement of steel), this may have been possible. However, these architectural items are custom-made and are manufactured by only three suppliers in North America, out of whom LFI alone would have been able to meet the deadline. Therefore, procurement from another manufacturer was not an option.

The second option would be to shorten the overall time allocated to the installation of the canopy roofs that are on the critical path. As shown in **Figure 21**, the first canopy installation began on May 29, 2020. From that date onward, the contractor continued to install the canopy roofs at each station in turn in a fully consecutive manner, as opposed to concurrently, until the

final roof was installed at Station 6NB on July 16, 2020. The contractor was unable to perform the installations concurrently due to the specific architectural components involved, for which special training at the LFI facility was required. Therefore, the contractor did not have enough trained crews to “squeeze” the installation of the canopy roofs. The crew responsible for the canopy installation was sent to LFI facility in January 2020 for training. Had the canopy installation not required special training, CGI could have increased the resources and performed concurrent installations at all stations to mitigate the delay caused by the shutdown of the supplier’s facilities. However, adding more crews and resequencing work would result in additional costs due to the need for increased resources.

Figure 21: Contractor's sequencing of canopy roof installation in a fully consecutive manner



Quantifying COVID-19 Impacts on Labor Productivity:

In the last section, a case study was used to illustrate the impact of COVID-19 on supply chain. This section will examine another effect of COVID-19 on construction: loss of labor productivity at construction sites.

Loss of productivity is another impact that is projected by professionals but not fully studied, especially in relation to civil projects. According to William Schwartzkopf, CEO of Sage Consulting Group, COVID-19 had a particularly severe impact on commercial and interior projects that require employees to work in close proximity to one another.[20] This research will gain new insight on the impacts of COVID-19 on civil projects.

Firstly, the construction industry is wide-ranging in nature; projects are unique and varied. Each project should adopt a set of safety measures that satisfy the requirements imposed by its specific characteristics. For example, an upcoming project on tunneling in northern Virginia was still in the bidding phase at the time of the first COVID-19 outbreak in March 2020. To investigate the impacts of COVID-19 on this project, an interview was conducted with Ray Hashimee (2020), resident engineer of the consulting company that oversaw the bidding process and that will be assisting in managing this project.[58] Hashimee stated that the owner responded to COVID-19's entry into the area by issuing an addendum that required the bidders to include and allot money in their bid towards the additional costs anticipated to result from inefficiencies due to COVID-19. Taking the pandemic into account in this project was especially critical as the nature of the project necessitated certain precautions to prevent infection. On-site workers are usually taken down as a group to the tunnel in an elevator. As this project

involves digging deep into the ground to collect storm water and store it until it can be pumped up and treated at a water plant, the elevator travels a long distance underground. It is essential that the number of the workers riding the elevator is significantly limited, due to the airborne nature of the virus, thereby increasing the number of journeys required to transport them; this in turn creates additional costs.

This section will investigate the loss of productivity in civil projects using a project located in Washington DC. This project involves the reconstruction of a roadway segment, and the scope of work includes but is not limited to utility work; the construction of curbs, gutters, islands, sidewalks, driveways, and accessible ramps; the demolition of a box culvert; and the replacement of a bridge structure that runs over a small creek. Participants' real names will be withheld, to maintain the project's confidentiality.

The Notice to Proceed (NTP) was given on December 19, 2019, and the contractual completion date was scheduled on December 5, 2021. The project is divided into three phases, each of which is then divided into different sub-phases such as Phase 1 B-1, Phase 1 B-2, and Phase 1C. The project's limits are each end of a long segment of a roadway, which is surrounded by residential areas. The contractor must therefore work separately on each part of the roadway separately before moving to the next; due to the need to maintain traffic, it would not be possible to work concurrently on different phases. Consequently, the critical path comprises approximately 53% of the total scheduled activities, and remains unchanged throughout most of the project. As the contractor cannot mobilize to the next phase before the previous phase is complete, delay in one phase would therefore most probably affect the start and completion of other phases.

On April 27, 2020, the contractor submitted a partial suspension request indicating labor disruptions and delays in the procurement of necessary materials such as sewer manholes and pipes (**Figure 30**).The labor disruptions described are related to the field crews and heavy equipment operators, with numerous workers having decided to adhere to CDC guidelines by staying home and avoiding large group gatherings. For this reason, the contractor put in a request to partially suspend the work. The contractor's letter also indicated that the mayor of DC had declared a state of emergency on March 15, 2020. A stay-home order was issued on March 30 and effected on April 1, 2020, mandating the shutdown of all non-essential businesses; infrastructure, however, was deemed essential.[59] The contractor claimed that the loss of productivity caused by the pandemic has impacted the progress of the work.

In an interview with the project manager (2020), he indicated that the timeframe of the impact at its peak spanned from April to the end of May 2020.[60] In April, when public vigilance was at its highest, approximately 50% of the crews attended work. When asked how working at an open-air construction site would pose a risk of infection, he answered that many activities, such as those related to constructing the curb and gutter, involved collective work. Moreover, all crews working with this contractor (even on different projects) were required to gather every morning in an area referred to as the "yard", in which the contractor holds meetings and stores equipment and material. One of the workers at the yard had tested positive for COVID-19. The resultant risk of infection subsequently compelled workers to avoid the yard, thereby contributing to the loss of productivity.

Labor disruptions require a different quantification method than delays. Firstly, it is important to define the loss of productivity. According to "AACEI Recommended Practice Estimating Lost

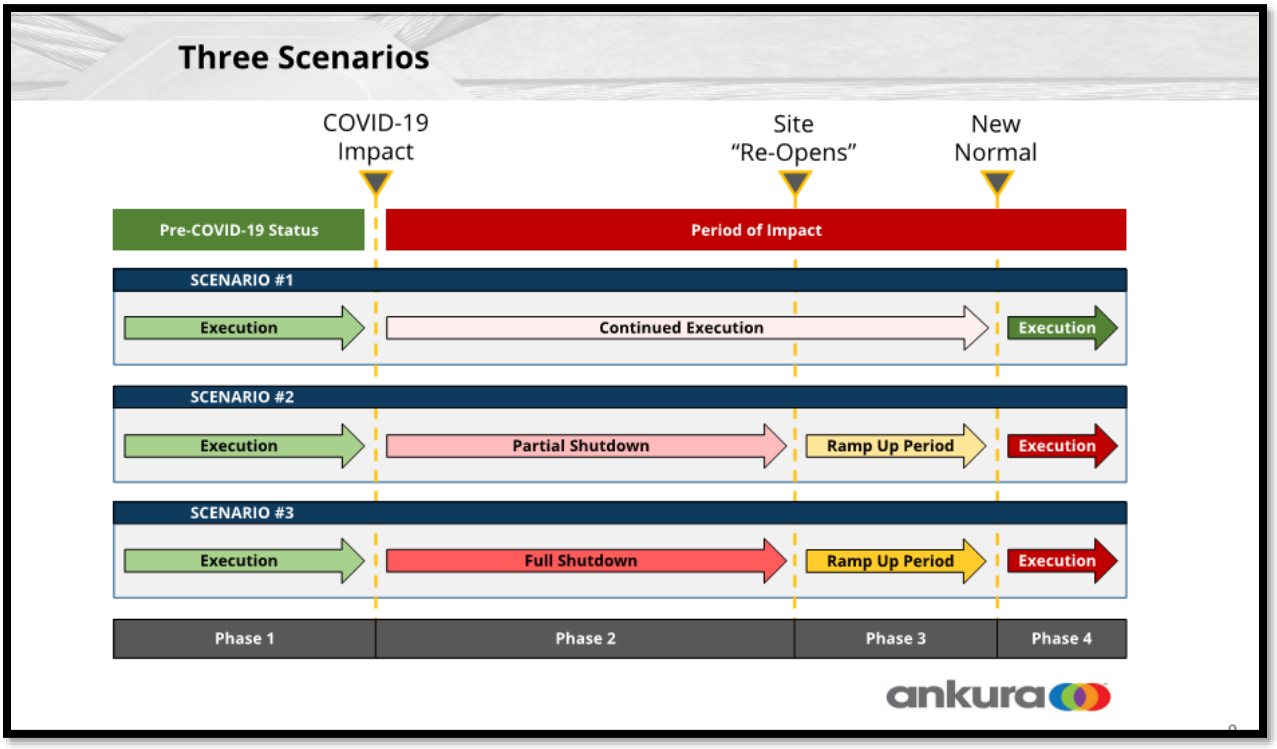
Labor Productivity in Construction Claims (25R-03)",[22] productivity is defined as a relative measure of the efficiency of labor when compared to baseline that is determined by people of experience in the field and in the project. It is defined as the output divided by input or the units (or quantities) produced for each labor hour. Therefore, if a contractor fails to achieve the planned or anticipated productivity rate, they experience loss of productivity. According to AACEI 25R-03, tracking loss of productivity and attributing it to a specific causation can be challenging. Contractors do not typically track their productivity, apart from at the end of project or during the time spent assembling a claim, and the only option that they have in this case is to approximate the numbers. The loss of productivity can be attributed to different causes, with those of absenteeism and shortages of material and equipment most prevalent in this research.

AACEI 25R-03 recommends several methods for calculating the extent of the productivity loss, with no preferred methodology. Most commonly used is the "measured mile", which compares a set of identical activities in the pre- and post-impact periods. The measured mile study would ideally be used to compare the quantities produced per employee hour before and after impact. This type of analysis requires much documentation during the impact as well as access to payments and invoices evidencing the installed quantity and its corresponding payment, neither of which are readily available for use in this research. Lecturers featured in the Loss of Productivity Webinar urge all contractors to document productivity during the pandemic, to establish a strong claim on any potential productivity loss. Nonetheless, AACEI 25R-03 provides different methods to calculate the extent of productivity loss in the event of insufficient documentation. This research will approach this issue using a combination of two

recommended methods, namely earned value analysis and productivity impact on schedule, both of which are utilized when there is insufficient information regarding the physical units installed. As the schedule is cost and resource loaded, both methods will be used to extract (from the CPM schedule) the allocated budgeted labor hours for April 2020, the budgeted costs, and the planned activities for that month. These data will then be compared to those produced during the impact using schedule updates from different months.

Firstly, there are three different scenarios for how the productivity was impacted by the stay-home orders. Dr. Dave Halligan from Ankura Consulting summarizes these scenarios as follows:

Figure 22: Scenarios for COVID-19's impact on construction as per Ankura Consulting [48]



Since infrastructure in Washington DC was deemed essential, the project under discussion was not shut down and can therefore be categorized in the first scenario. Other projects must

account for the ramp-up period which will be accompanied with different measures and productivities as the project management attempts to return the project to normality. However, it is important to note that although many states deemed construction as essential, construction was still impacted in a way or another.

The first stage of analysis will involve examining the status of the project prior to COVID-19 using *Update No. 04* for March 2020. This will illustrate how the project was doing pre-impact, and identify which issues affecting the progress are independent from COVID-19 impacts. April 1, 2020 will mark the first day of the period of impact. Therefore, this study will focus on and compare the months of March and April 2020.

The project was behind schedule by 12 calendar days in March 2020, with a calculated final completion of December 17, 2021. The contractor attributes this delay to issues related to the relocation of poles. This was the only reported issue as of March 31, 2020, with no other issues pertaining to productivity. Schedule *Update No. 04* reported the progress during March with a data date of March 31, 2020 and a period of performance spanning from February 29 to March 30, 2020.

Update No. 04 will be used to plot the cost curve that demonstrates the monthly budgeted costs for construction as of March 31, 2020.

Figure 23: Cost curve per Update No. 04 (March Update) – Roadway Reconstruction Project in DC

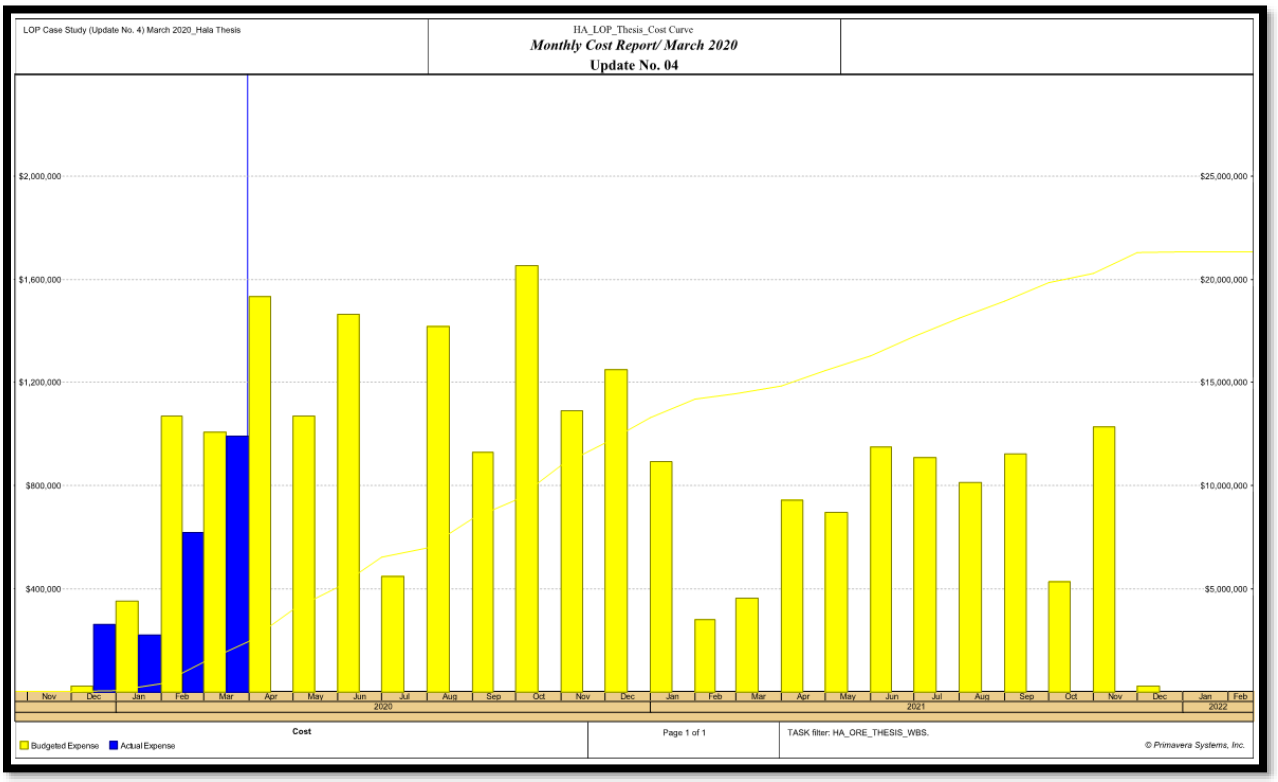
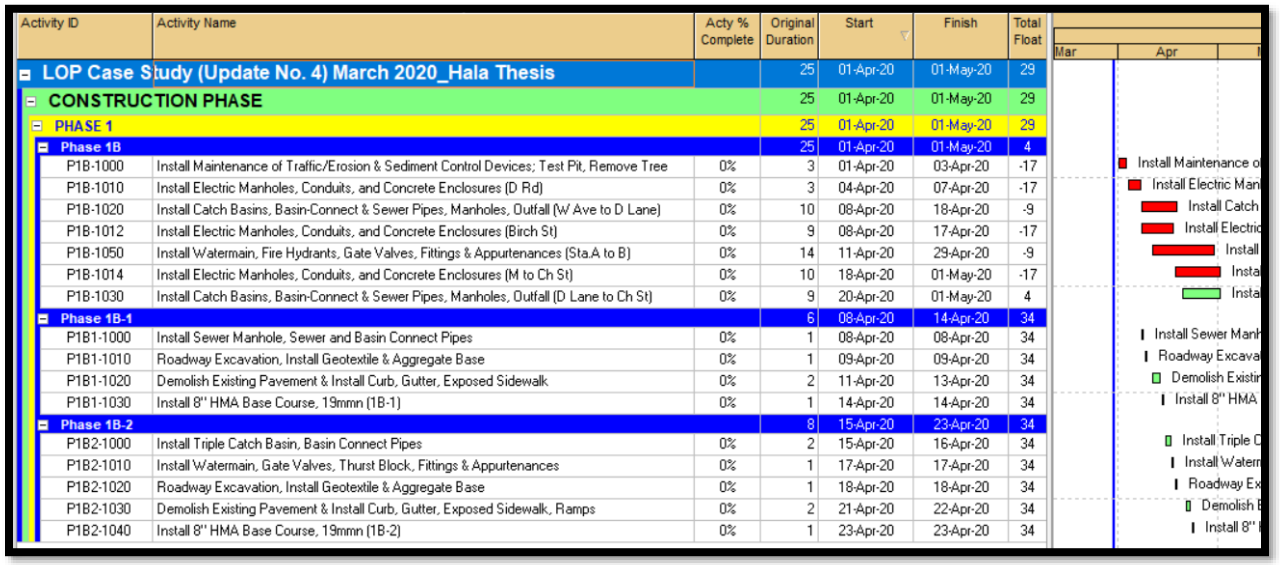


Figure 23 shows the budgeted costs solely for construction without taking into account the overhead costs normally added by the contractor to the invoice submitted to the owner. As shown in **Figure 23**, the contractor has budgeted $1,533,533 for the activities that he plans to perform in April. The list of the activities scheduled for the month is as follows:

Figure 24: one month lookahead schedule as per Update No. 04 – roadway reconstruction project in DC

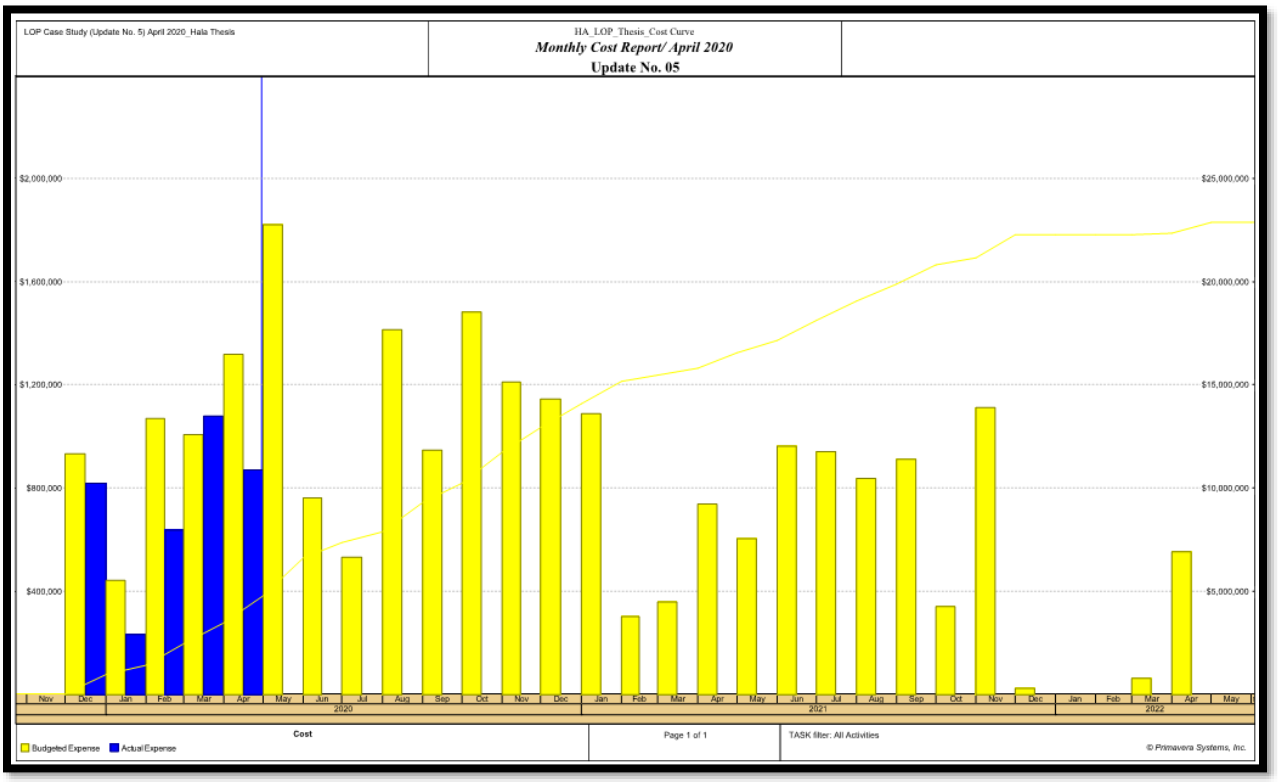


Activity ID	Activity Name	Acty % Complete	Original Duration	Start	Finish	Total Float
LOP Case Study (Update No. 4) March 2020_Hala Thesis			25	01-Apr-20	01-May-20	29
CONSTRUCTION PHASE			25	01-Apr-20	01-May-20	29
PHASE 1			25	01-Apr-20	01-May-20	29
Phase 1B			25	01-Apr-20	01-May-20	4
P1B-1000	Install Maintenance of Traffic/Erosion & Sediment Control Devices; Test Pit, Remove Tree	0%	3	01-Apr-20	03-Apr-20	-17
P1B-1010	Install Electric Manholes, Conduits, and Concrete Enclosures (D Rd)	0%	3	04-Apr-20	07-Apr-20	-17
P1B-1020	Install Catch Basins, Basin-Connect & Sewer Pipes, Manholes, Outfall (W Ave to D Lane)	0%	10	08-Apr-20	18-Apr-20	-9
P1B-1012	Install Electric Manholes, Conduits, and Concrete Enclosures (Birch St)	0%	9	08-Apr-20	17-Apr-20	-17
P1B-1050	Install Watermain, Fire Hydrants, Gate Valves, Fittings & Appurtenances (Sta.A to B)	0%	14	11-Apr-20	29-Apr-20	-9
P1B-1014	Install Electric Manholes, Conduits, and Concrete Enclosures (M to Ch St)	0%	10	18-Apr-20	01-May-20	-17
P1B-1030	Install Catch Basins, Basin-Connect & Sewer Pipes, Manholes, Outfall (D Lane to Ch St)	0%	9	20-Apr-20	01-May-20	4
Phase 1B-1			6	08-Apr-20	14-Apr-20	34
P1B1-1000	Install Sewer Manhole, Sewer and Basin Connect Pipes	0%	1	08-Apr-20	08-Apr-20	34
P1B1-1010	Roadway Excavation, Install Geotextile & Aggregate Base	0%	1	09-Apr-20	09-Apr-20	34
P1B1-1020	Demolish Existing Pavement & Install Curb, Gutter, Exposed Sidewalk	0%	2	11-Apr-20	13-Apr-20	34
P1B1-1030	Install 8" HMA Base Course, 19mmn (1B-1)	0%	1	14-Apr-20	14-Apr-20	34
Phase 1B-2			8	15-Apr-20	23-Apr-20	34
P1B2-1000	Install Triple Catch Basin, Basin Connect Pipes	0%	2	15-Apr-20	16-Apr-20	34
P1B2-1010	Install Watermain, Gate Valves, Thurst Block, Fittings & Appurtenances	0%	1	17-Apr-20	17-Apr-20	34
P1B2-1020	Roadway Excavation, Install Geotextile & Aggregate Base	0%	1	18-Apr-20	18-Apr-20	34
P1B2-1030	Demolish Existing Pavement & Install Curb, Gutter, Exposed Sidewalk, Ramps	0%	2	21-Apr-20	22-Apr-20	34
P1B2-1040	Install 8" HMA Base Course, 19mmn (1B-2)	0%	1	23-Apr-20	23-Apr-20	34

Figure 24 reflects how the contractor planned to perform the job before learning about the inefficiencies inflicted upon the project by the impact of the pandemic.

Meanwhile, *Update No. 05* represented the work achieved during April 2020. The cost report as of April 30, 2020 showed the following budgeted monthly costs:

Figure 25: Cost curve as per Update No. 05 (April Update) – Roadway Reconstruction Project in DC



The following table summarizes the data and compares the budgeted and actual costs and labor hours for the month of April:

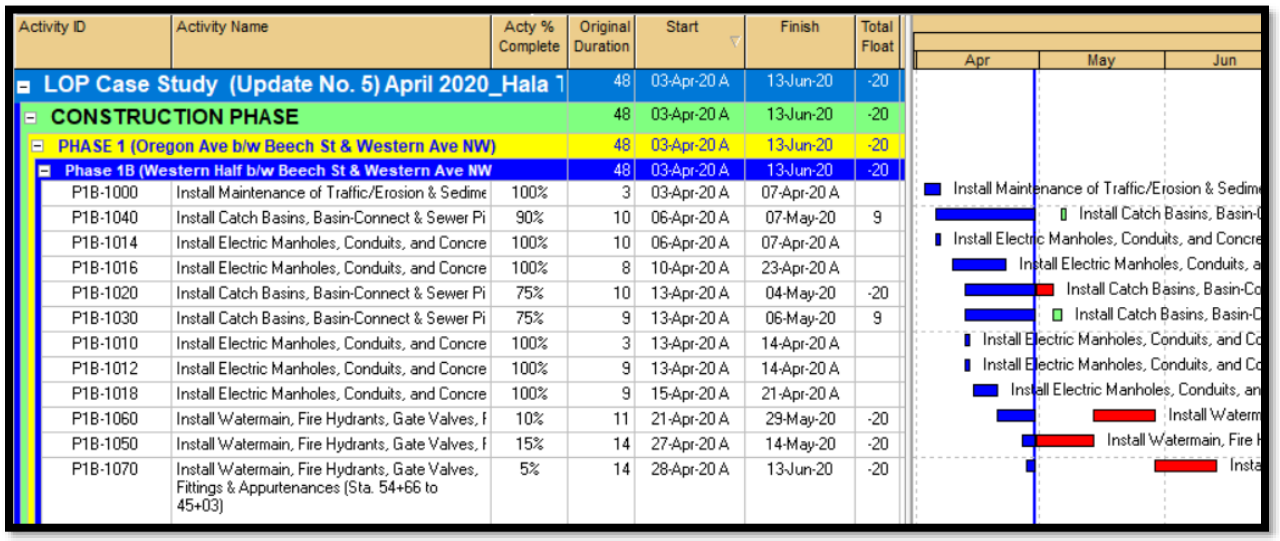
Figure 26: Summary of costs and labor hours for construction phase

As per *Update No. 5*, April 2020

Update Month	Budgeted Total Cost	Cum Budgeted Total Cost	Actual Total Cost	Cum Actual Total Cost	Budgeted Labor Units	Actual Labor Units
1-Mar-20	$1,007,100	$2,446,181	$1,064,575	$2,168,140	832	1337
1-Apr-20	$1,318,229	$3,764,410	$855,360	$3,023,500	952	547

The actual total cost for April 2020 was less than the budgeted cost, meaning that less work was done than originally planned in the March schedule. Moreover, almost half of the planned labor hours were stated, with a difference of 405 labor units. The actual labor hours were 43% of the planned labor. This substantiates project management's claim that almost 50% of the field crews and heaving machinery operators did not attend work throughout April. The schedule update for April 2020 substantiates this point, outlining the actual progress as follows:

Figure 27: Actual construction progress during April 2020 as per Update No. 05



Activity ID	Activity Name	Acty % Complete	Original Duration	Start	Finish	Total Float
LOP Case Study (Update No. 5) April 2020_Hala T			48	03-Apr-20 A	13-Jun-20	-20
CONSTRUCTION PHASE			48	03-Apr-20 A	13-Jun-20	-20
PHASE 1 (Oregon Ave b/w Beech St & Western Ave NW)			48	03-Apr-20 A	13-Jun-20	-20
Phase 1B (Western Half b/w Beech St & Western Ave NW			48	03-Apr-20 A	13-Jun-20	-20
P1B-1000	Install Maintenance of Traffic/Erosion & Sedime	100%	3	03-Apr-20 A	07-Apr-20 A	
P1B-1040	Install Catch Basins, Basin-Connect & Sewer Pi	90%	10	06-Apr-20 A	07-May-20	9
P1B-1014	Install Electric Manholes, Conduits, and Concre	100%	10	06-Apr-20 A	07-Apr-20 A	
P1B-1016	Install Electric Manholes, Conduits, and Concre	100%	8	10-Apr-20 A	23-Apr-20 A	
P1B-1020	Install Catch Basins, Basin-Connect & Sewer Pi	75%	10	13-Apr-20 A	04-May-20	-20
P1B-1030	Install Catch Basins, Basin-Connect & Sewer Pi	75%	9	13-Apr-20 A	06-May-20	9
P1B-1010	Install Electric Manholes, Conduits, and Concre	100%	3	13-Apr-20 A	14-Apr-20 A	
P1B-1012	Install Electric Manholes, Conduits, and Concre	100%	9	13-Apr-20 A	14-Apr-20 A	
P1B-1018	Install Electric Manholes, Conduits, and Concre	100%	9	15-Apr-20 A	21-Apr-20 A	
P1B-1060	Install Watermain, Fire Hydrants, Gate Valves, F	10%	11	21-Apr-20 A	29-May-20	-20
P1B-1050	Install Watermain, Fire Hydrants, Gate Valves, F	15%	14	27-Apr-20 A	14-May-20	-20
P1B-1070	Install Watermain, Fire Hydrants, Gate Valves, Fittings & Appurtenances (Sta. 54+66 to 45+03)	5%	14	28-Apr-20 A	13-Jun-20	-20

The actual progress on activities during the month of April does not match the progress on activities projected by *Update No. 04* (March update), as illustrated by **Figure 24**.

Earned Value Analysis

The earned value analysis will be performed using the following metrics:[61]

PV = Planned Value = baseline estimated earnings

EV = Earned Value = pay estimate approved earnings

SV = Schedule Variance = EV-PV

SPI = Schedule Performance Index = EV/PV

These metrics are useful for analyzing the schedule's performance in relation to the costs: a negative SV and an SPI<0 indicate that the project is behind schedule; an SV equal to zero (0) and an SPI equal to 1 mean that it is on schedule; and a positive SV and an SPI>0 mean that it is ahead of schedule.

Firstly, the earned value metrics will be analyzed for *Update No. 04* (March 2020 update) to determine the schedule's pre-impact status and condition. The purpose of studying the pre-impact status is to accurately determine which disruptions were the responsibility of the impact and which were not. The same analysis will then be conducted on the impacted period represented by *Update No. 05* (April 2020 update).

Update No. 04 (March 2020)

Monthly planned earnings:	$1,007,100
Monthly actual earnings:	$1,064,575
To Date planned earnings (PV):	$2,446,181
To Date actual earnings (EV):	$2,168,140
Schedule Variance (SV):	-$278,041

Schedule Performance Index (SPI): 0.89

Monthly production: Daily planned production: $32,487/CD

Daily earned production: $34,341/CD

The actual monthly earnings for March were higher than the planned earnings, resulting in a higher daily production rate. However, the project was still behind schedule in terms of cumulative earnings (by $278,041) with an SPI of 0.89. Recall that the project was experiencing delays due to the issue specific to the relocation of poles.

Next, the impacted month of April 2020 will be analyzed.

Update No. 05 (April 2020)

Monthly planned earnings: $1,318,229

Monthly actual earnings: $855,360

To Date planned earnings (PV): $3,764,410

To Date actual earnings (EV): $3,023,500

Schedule Variance (SV): -$740,910

Schedule Performance Index (SPI): 0.8

Monthly production: Daily planned production: $43,941/CD

Daily earned production: $28,512/CD

April's actual earnings were behind the planned earnings by almost 35%. The project fell further behind schedule as the SV decreased to -$740,910 and the SPI decreased from 0.89 to 0.8.

Moreover, the final completion date was pushed further during *Update No. 05* and was scheduled for December 20, 2021.

During April 2020, the schedule variance decreased by -$462,869. In attributing this to the loss of productivity as claimed by the contractor, the project is approximately 16 days behind schedule due to decreased earnings during April. The number by which the project is behind schedule due to earnings and loss of productivity was calculated by dividing the difference between SV in April and March by the earned daily production in April.

Moreover, COVID-19 caused a reduction in the daily productivity by $15,429 in the month of April 2020. This number was calculated by dividing the schedule variance difference (-$462,869) by 30 days in the month of April.

The pandemic has thus caused productivity loss during April 2020, as proven by the decrease in budgeted vs. actual labor hours and earnings. Moreover, as shown in the daily production rate during April, COVID-19 alone has delayed the schedule by 16 days in terms of earnings.

Discussion of Research Results

The results prove that civil construction was impacted by COVID-19 despite most states, including the DMV area, deeming it essential. As of the date of this report, the DMV-based projects did not face closure at any point during the time of the impact, and were permitted to normally resume work while other industries in the area experienced total shutdown. The results of this research are surprising not due to the mere existence of the impact, but rather its magnitude. For instance, the time impact analysis determined that the final completion date of the Bus Route project in Maryland was delayed by 26 calendar days due to the shutdowns mandated to reduce COVID-19 exposure. The delay in this case was attributed to the shutdown of the supplier's facilities. The shutdown lasted an average of 36-40 calendar days and consequently subjected the project to a 26-day delay. Moreover, the pandemic has created loss of productivity in the roadway reconstruction project throughout April 2020, as proven by the decrease in "budgeted vs. actual" labor hours and earnings. Moreover, April's daily production rate demonstrates a 16-day delay to the schedule in terms of earnings, which can be solely attributed to COVID-19. This should be of primary concern to all owners, developers, contractors, subcontractors, suppliers, and vendors working on projects that remained active during the impact of COVID-19.

The way in which these results emphasize the necessity for an action plan, to control the projects during the impact and ultimately recover losses, demonstrates their significance. They reveal the anticipated consequences of another wave of COVID-19, or another pandemic, for the construction industry. This research must therefore serve as a lesson for stakeholders in the

construction industry, to help them to prepare for similar situations when planning future projects. Based on the results, stakeholders with projects that are currently active may benefit from the following recommendations.

Firstly, the contract specifications must include a provision on pandemics. For instance, the specifications for the Bus Route project include an item on the claims and time extension requests, but do not specify pandemics. Although a time extension request (due to the pandemic) could be sought through the specification on claims, a comprehensive section on pandemics would reduce misunderstandings and disagreements, thereby facilitating claim resolution.

Secondly, the owner should require the bidders to allocate money in their bids toward costs of PPE; inefficiencies that may result from future pandemics; and sanitization- and hygiene-related efforts. Had this been the procedure before COVID-19, the roadway reconstruction project's contractor would have recovered some or all costs upfront. This recommendation is already being followed by the owner of the tunneling project in Virginia, who required the bidders to include a bid item for COVID-19.

Thirdly, documentation of labor productivity must be maintained throughout the project's entire lifetime. In the roadway reconstruction project, failure to achieve this before and during the impact limited the viable methods for quantifying the subsequent loss of productivity.

Fourthly, contractors and owners' project management should always contain reserve preparations for completing the schedule on time in the event of another force majeure event like the pandemic. This may include listing substitute suppliers in other states that produce

materials of a similar quality and can be contacted if the contracted supplier cannot meet the schedule for any reason. Moreover, a plan to re-sequence work and use different means and methods (such as advanced robotics that could eliminate the close contact between workers) should also be prepared, to attenuate the extent to which the original plan and progress are disrupted by an event.

Finally, use of virtual communication must be encouraged as a substitute to face-to-face interaction, especially in the time of pandemics. When COVID-19 first entered the region and many were unfamiliar with Zoom, construction companies began providing training sessions regarding the use of video conferencing software.

Conclusion

The results of this research reveal that civil construction in the DMV area was impacted by COVID-19 despite having been deemed essential. Quantifying the impact determined the necessity for modifications to the projects' contract time and/or costs, thereby emphasizing the impact's magnitude. COVID-19 impacted active projects in one or both of two ways: delays in supply chain and labor disruptions in the field.

Regarding the Bus Route project in Maryland, quantification revealed that the slippage of the final completion date due to procurement delays was in the amount of 26 calendar days. Although the extent of the delay is unique to the project under discussion, the results imply that civil construction in the US and other countries worldwide will have experienced delays if material was not on site at the time of the impact. The impact reaches beyond a request for a time extension. The contractors and owners of any project affected by the pandemic will be forced to accommodate for subsequent additional costs, including overhead costs for the project's extended timeline; liquidated damages; and acceleration or mitigation costs.

Meanwhile, active projects also experienced loss of productivity due to the impact of COVID-19 on field labor. The loss of productivity stems from the absenteeism of sick or cautious workers and/or social-distancing restrictions prohibiting gatherings or collective work in a confined area. This research quantified loss of productivity on a roadway reconstruction project in Washington DC and determined a reduction of $15,428 in daily production earnings; 53% reduction in labor hours; and a slippage of 16 days of progress in terms of earnings and productivity. Again, these numbers are specific to this project. In other words, other projects will not necessarily be

impacted in the same way. However, the results prove that even when performed in the open air and deemed essential, civil construction work was still impacted by COVID-19. The significance of the impact is even greater on a global scale. For instance, migrant workers working in construction sites in the Gulf Countries of the United Arab Emirates and Saudi Arabia, as well as in Singapore, have been severely impacted by COVID-19, resulting in significant loss of productivity at active construction sites (Kiley, 2020) (Tan, 2020).[62] [63] The impact also revealed inequalities in care and exposure prevention. In these countries, construction labor is mostly undertaken by migrant workers from South Asian countries such as India and Bangladesh. The accommodation provided by their sponsor or company typically consists of buildings containing rooms that fit up to 12 bunk beds in each. These confined living conditions, in which the workers share bedrooms, restrooms, and kitchens, create an extremely high risk of infection. Consequently, in March and April 2020, these countries experienced a marked increase in the number of COVID-19 cases, most notably among the migrant labor category. This not only impacted the lives of these workers but also the progress of the projects they were working on. Indeed, the case study used in this research to examine labor productivity loss in the US is a smaller scale impact of COVID-19 when compared to construction sites worldwide, whose labor is performed primarily by migrant workers living in confined housing.

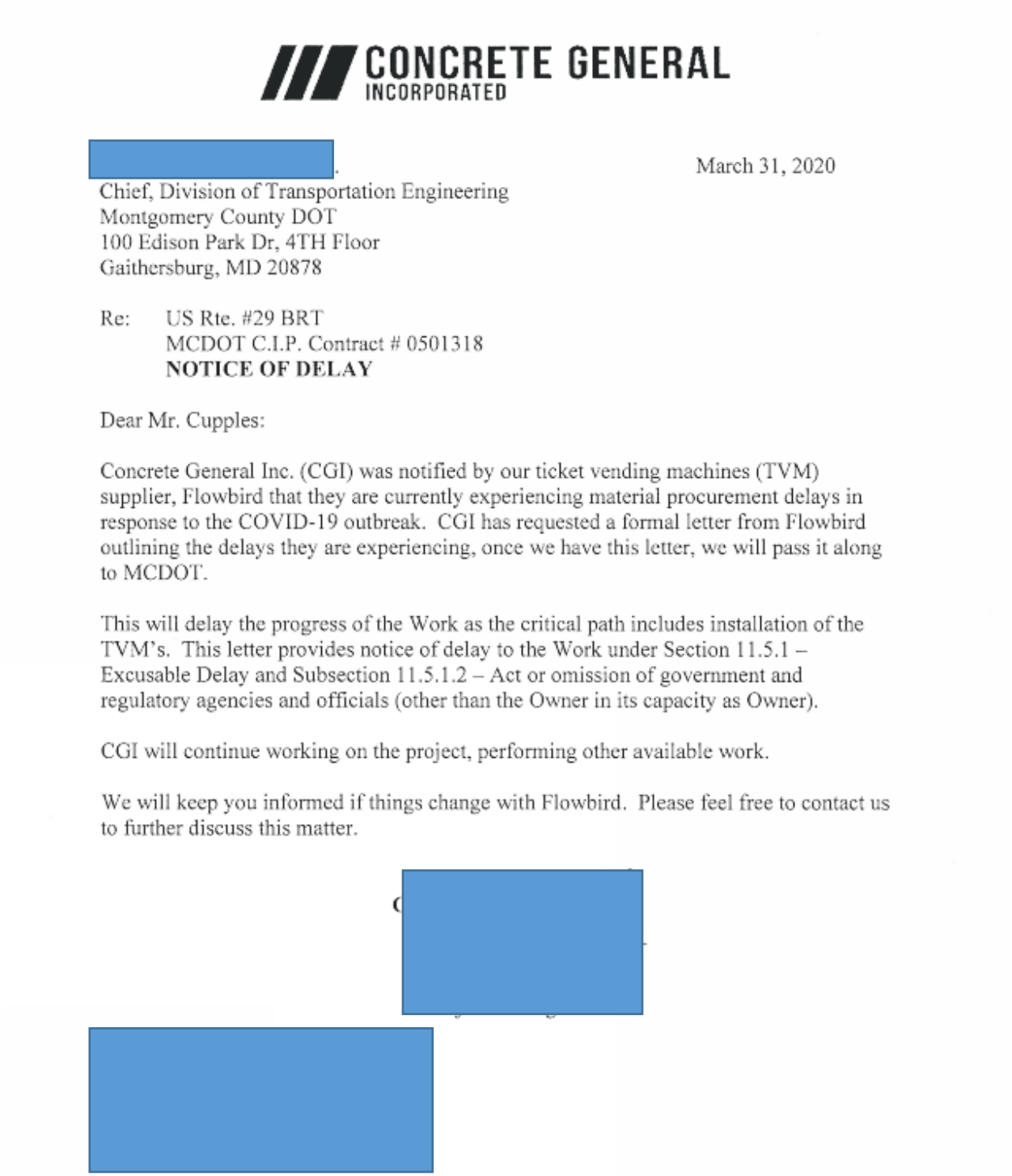
The limitations of this research include the demographic restrictions and lack of data on global projects, drawing specific conclusions on construction projects undertaken exclusively in the US. Future researchers can investigate the impact of COVID-19 on construction in countries such as the UAE, whose labor and culture are structured differently. Such research would

benefit stakeholders in the UAE's construction industry by encouraging them to make changes that would reduce migrant workers' risk of exposure. Meanwhile, in the context of the roadway reconstruction project, this research encountered other limitations, including the lack of data and insufficient documentation provided by the contractor regarding labor productivity. As documentation on daily productivity rates can assist in conducting the measured mile study, this was particularly challenging. Future generations of researchers can investigate labor productivity loss through different methods, including the measured mile study.

Additionally, future generations of researchers worldwide can investigate the inclusion of bid items and contract provisions to recover losses caused by pandemics. Moreover, future research can investigate ways in which projects can plan alternative suppliers and procure critical materials, to attenuate the impact of any delays on the project's completion date; for instance, a contractor may plan and contact different suppliers of steel to circumvent the impact of the contracted supplier hypothetically becoming incapable of delivering material by the agreed-upon date.

Appendix A-Notices of Delay on Different Projects in the DMV Area

Figure 28: First Notice of Delay Resulting from COVID-19- Bus Route Project in MD



CONCRETE GENERAL
INCORPORATED

[redacted]

March 31, 2020

Chief, Division of Transportation Engineering
Montgomery County DOT
100 Edison Park Dr, 4TH Floor
Gaithersburg, MD 20878

Re: US Rte. #29 BRT
MCDOT C.I.P. Contract # 0501318
NOTICE OF DELAY

Dear Mr. Cupples:

Concrete General Inc. (CGI) was notified by our ticket vending machines (TVM) supplier, Flowbird that they are currently experiencing material procurement delays in response to the COVID-19 outbreak. CGI has requested a formal letter from Flowbird outlining the delays they are experiencing, once we have this letter, we will pass it along to MCDOT.

This will delay the progress of the Work as the critical path includes installation of the TVM's. This letter provides notice of delay to the Work under Section 11.5.1 – Excusable Delay and Subsection 11.5.1.2 – Act or omission of government and regulatory agencies and officials (other than the Owner in its capacity as Owner).

CGI will continue working on the project, performing other available work.

We will keep you informed if things change with Flowbird. Please feel free to contact us to further discuss this matter.

[redacted]

[redacted]

Figure 29: Second Notice of Delay Resulting from COVID-19- Bus Route Project in MD

CONCRETE GENERAL
"Building Bridges"

April 3, 2020

[redacted]
Division of Transportation Engineering
Montgomery County DOT
100 Edison Park Dr, 4TH Floor
Gaithersburg, MD 20878

Re: US 29 BRT Improvement
C.I.P. Contract # 0501318
Notice of Delay from COVID-19 Epidemic/Quarantine/Restrictions

Dear Sir:

This letter serves as notice of delay to the completion of the work arising from unforeseeable causes and without the fault or negligence of the Contractor. This delay arises from the state of emergency and catastrophic health emergency to control and prevent the spread of COVID-19 epidemic. The Governor's recent order, number 20-03-30-01 dated March 30rd, 2020 amended and restated previous orders and addressed the state of emergency and catastrophic health emergency and implemented quarantines and restrictions for the entire State of Maryland.

State, local and federal guidelines have currently deemed transportation as an essential and critical function, so construction activities have not stopped at the project. We are mitigating impacts to the project to the best of our ability and have yet to fully identify the total impacts from unforeseeable causes of the COVID-19 epidemic.

The following is additional information as required by article 11.6 of our contract.

11.6.1.1 – A detailed Statement of the reasons and causes for the delay

- This delay arises from the state of emergency and catastrophic health emergency to control and prevent the spread of COVID-19 epidemic. The Governor's recent order, number 20-03-30-01 dated March 30rd, 2020 amended and restated previous orders and addressed the state of emergency and catastrophic health emergency and implemented quarantines and restrictions for the entire State of Maryland.

11.6.1.2 – Inclusive dates of the delay (start date only if end date is not known)

- Start date of March 30, 2020 and end date is unknown

11.6.1.3 – Specific portions of the work affected by the actual or prospective delay; provide specific activity names and Numbers from the most recent CPM schedule of record.

- Unknown currently

11.6.1.4 – Status of work (affected activities) affected before commencement of the delay.

- State, local and federal guidelines have currently deemed transportation as an essential and critical function, so construction activities have not stopped at the project. We are mitigating impacts to the project to the best of our ability and have yet to fully identify the total impacts from unforeseeable causes of the COVID-19 epidemic.
- CGI letter dated March 25, 2020 notification of LFI shutdown.

11.6.1.5 – Effect of the delay on available "float" for referenced activities.

- Currently there is no float in the project schedule.

11.6.1.6 – Specific action (if any) required by the A/E and/or the owner to remedy or mitigate the delay.

- Other than continuing to deem transportation as an essential and critical function, so construction activities can continue. No other actions are needed.

This notice letter is to preserve our right to seek relief for both extended time and additional costs resulting from the COVID-19 epidemic and its associated impacts. We will continue to monitor the situation and inform you as things unfold and change.

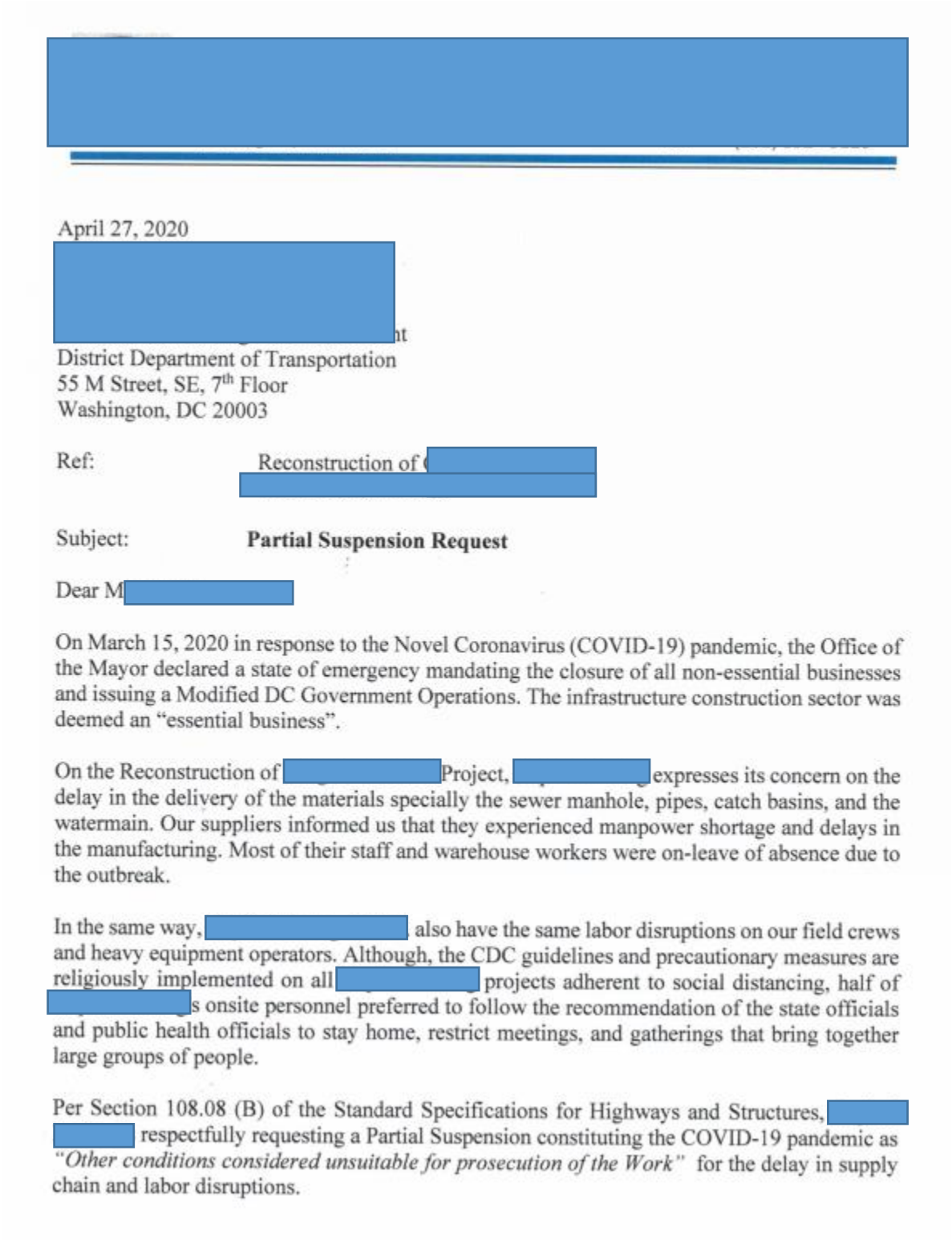
I trust this letter is sufficient to preserve our rights under the Supplemental General Conditions of Construction Contract Article 11.6 Time and Related Cost Adjustments.

Please feel free to contact me or Mike Higgins, General Manager, should you have any questions regarding this issue.

Sincerely,
Concrete General, Inc.

cc: 

Figure 30: Partial Suspension Request- Roadway Reconstruction Project in DC



April 27, 2020

[redacted]

District Department of Transportation
55 M Street, SE, 7th Floor
Washington, DC 20003

Ref: Reconstruction of [redacted]

Subject: **Partial Suspension Request**

Dear M[redacted]

On March 15, 2020 in response to the Novel Coronavirus (COVID-19) pandemic, the Office of the Mayor declared a state of emergency mandating the closure of all non-essential businesses and issuing a Modified DC Government Operations. The infrastructure construction sector was deemed an "essential business".

On the Reconstruction of [redacted] Project, [redacted] expresses its concern on the delay in the delivery of the materials specially the sewer manhole, pipes, catch basins, and the watermain. Our suppliers informed us that they experienced manpower shortage and delays in the manufacturing. Most of their staff and warehouse workers were on-leave of absence due to the outbreak.

In the same way, [redacted] also have the same labor disruptions on our field crews and heavy equipment operators. Although, the CDC guidelines and precautionary measures are religiously implemented on all [redacted] projects adherent to social distancing, half of [redacted] onsite personnel preferred to follow the recommendation of the state officials and public health officials to stay home, restrict meetings, and gatherings that bring together large groups of people.

Per Section 108.08 (B) of the Standard Specifications for Highways and Structures, [redacted] respectfully requesting a Partial Suspension constituting the COVID-19 pandemic as *"Other conditions considered unsuitable for prosecution of the Work"* for the delay in supply chain and labor disruptions.

Thank you for your consideration. As much as we would like to accelerate the completion of this project, the safety of everyone is of utmost importance while we move through these uncertain times.

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