Exhibit 19

UK construction counts the productivity cost of COVID-19

23 June 2020

The impact of COVID-19 is causing productivity losses of around 35 percent on the UK's construction sites, triggering extensive programme delays and spiralling costs that exacerbate the sector's underlying performance problems.

Our new productivity research finds that the uncertainty of whether labour will arrive on site, social distancing measures and material delays are compounding the productivity gap.

Using data from 70 medium-sized UK construction projects, our Suiko consultancy business has modelled that a £20m commercial real estate project with an 81-week programme before the pandemic would typically suffer productivity losses of 20 percent.

Now, a project of this scale is seeing this rise to 35 percent productivity losses with project completion delays of up 32 weeks late and increases of around £600,000 in preliminary costs alone.

Analysis of 45 projects delivered during the pandemic reveals that labour shortages together with the impact of social distancing is accounting for around seven percent of productivity losses. A further one percent is being lost through the poor transfer of design information while remote working. In addition, late material deliveries or unavailability is leading to another seven percent loss.

The construction sector's reliance on the flow of global material supply chains continues to cause disruption and although some shortages have been addressed, pinch points in the domestic supply chain are also continuing to impact productivity with delays being reported in the arrival of plasterboard and aggregates.

Stephen Gallagher, Principal Consultant said that poor planning and inefficiency was a major contributor to the problem: "UK construction has systemic productivity challenges. In particular, the final phases of a project are typically the most inefficient as contractors are often behind schedule and must throw extra labour at sites to try and get buildings finished on time. This usual fix will not be possible with social distancing and reduced labour.

In the age of COVID-19 the internal fit-out phase is the most challenging because numerous trades are working on site (often out of sequence), and there is a high volume and variety of materials arriving to site."

Against this backdrop there are wider economic risks of a faltering construction sector which remains one of the primary engines of UK growth. To mitigate the impact of COVID-19 and boost performance, the construction industry should embrace digital platforms, offsite construction methods and adopt the 'lean' approaches used by the manufacturing sector.

Boosting construction's productivity is key to supporting the UK's wider economic recovery. With low productivity and low margins, the construction sector has poor resilience to weather the immediate and long-term consequences of COVID-19 on the economy.

"Short-term, the sector needs to look at whether it can recover lost productivity on-site through smarter working practices. Lean can help increase productivity whilst dealing with lower resource levels, by removing large amounts of process "waste". Planned versus actual progress can be demonstrated in three dimensions using photo-realistic representations of activity on site and validated using the contractors' 4D schedule in order to increase efficiency. By embracing modern methods of construction, the COVID-19 impact on resource levels can be mitigated by taking processes off site.

These solutions have been present for some time, but their adoption is now urgent. We need to see a complete mindset shift to close the productivity gap."

Further resources

Please visit our **COVID-19 response page** for all of our resources relating to the impact of COVID-19 on the construction sector.

About Turner & Townsend Suiko

Turner & Townsend Suiko are a team of lean specialists who work across the construction, infrastructure and manufacturing sectors. We apply our award-winning five-step process improvement approach to improve productivity and grow profit for our clients across the world.

For further information contact:

Ben Steele
Senior Communications Manager

t: +44 (0)20 7544 4553
e: **ben.steele@turntown.co.uk**

Exhibit 20

COMPASS INTERNATIONAL INC.

COVID-19 CONSTRUCTION PRODUCTIVITY CHANGES:

We have been talking with a number of Construction Managers, Site Superintendents, and Estimators in the last couple of months regarding the loss of productivity on specific trades due to COVID-19 on Industrial Construction projects currently being constructed in the USA and Canada.

This is the feedback we are getting:

The majority of Refinery, Power, Manufacturing, Pharmaceutical, Food Production, and Owner companies are including clauses / contractual language in their construction contracts / Requests for Proposal (RFP's) to minimize the spread of COVID-19 within their production sites. Most of these contractual requirements will impact construction productivity, which include:

- Utilizing social distancing 2 meter / 6 foot rules on construction site.
- Construction staff and workers are required to wear masks, in some cases gloves and goggles.
- Extensive cleaning measures / protocols required by Owners. Some Owners are calling for dedicated COVID cleaning crews.
- Additional hiring of COVID mitigation/ testing site staff, requested by Owner.
- Increased field in-directs (site offices / lunch – change areas and additional support labor).
- Smaller, spread-out work crews, dictated by Owner.
- Required cool-down breaks in morning and afternoon due to the permanent wearing of masks, gloves, and safety glasses in high temperature locations.
- Provision of hand sanitizers and refills on a daily basis.
- The possible need for 10 or 14 day quarantine periods for certain construction workers.
- Additional site buses / drivers, needed for social distancing in transporting construction workers to work areas.
- COVID-19 temperature testing each day at the site entrance and providing new masks.

The following table indicates the productivity changes that have taken place since the onset of COVID-19 and the results of the feedback and our research.

#	TRADE/SKILL/WORK DESCRIPTION	PRE - COVID PRODUCTIVITY (a task that would take 100 hours to perform)	POST - COVID PRODUCTIVITY (impacted by COVID-19)
1	Site Clearance / Earthworks'/ Roads / Incoming Utilities	100 hours	105 to 110 hours
2	Concrete Work (Rebar, Formwork, and Concrete Installation)	100 hours	110 to 125 hours
3	Major Equipment (Towers, Compressors, Heat Exchanges, Pumps), Setting, and Alignment	100 hours	110 to 125 hours
4	Masonry / Brickwork / Wall Systems / Siding / External Envelope	100 hours	110 to 120 hours
5	Structural Steel / Platforms / Ladders / Railings	100 hours	110 to 120 hours
6	Architectural Finishes (Walls, Ceilings, Flooring, Painting)	100 hours	110 to 130 hours
7	Field Fabricated and Erected Piping (Utility and Process)	100 hours	115 to 135 hours
8	Offsite Fab Shop Piping (Utility and Process)	100 hours	105 to 110 hours
9	Electrical and Instrumentation / Building Automation	100 hours	115 to 130 hours
10	HVAC / Ductwork and Balancing	100 hours	110 to 125 hours
11	Roofing / Insulation and Waterproofing	100 hours	105 to 115 hours
12	Site In-Directs - Material Distribution, Site Clean-Up, Site Support, Scaffolding, Worker Temperature Checks, Dispensing Masks, Water, Additional Bus/ Transportation Drivers, Office/Lunch Area Cleaning and Warehousing	100 hours	115 to 125 hours

For additional benchmarks and similar types of construction costs, check out our 2021 Yearbooks.

If you have any questions or comments on this report, please contact:

John G. McConville, CCP
Operations Director – Compass International
(609) 577-4505
sales@compassinternational.net
compassinternational.net

View our annual cost estimating yearbooks at www.compassinternational.net

COMPASS INTERNATIONAL
(215) 504-9777
compassinternational.net
sales@compassinternational.net

Exhibit 21

AUGUST | 2020

PANDEMICS AND CONSTRUCTION PRODUCTIVITY: QUANTIFYING THE IMPACT

Commissioned by ELECTRI International. Conducted by Maxim Consulting Group and Marquette University.
Researchers: Michael McLin, Managing Director, Dan Doyon, Director, Brian Lightner, Associate Director, Maxim Consulting Group; Mark Federle, Associate Dean for Academic Affairs, Marquette University.

ELECTRI INTERNATIONAL
Research and Education for the Electrical Construction Industry

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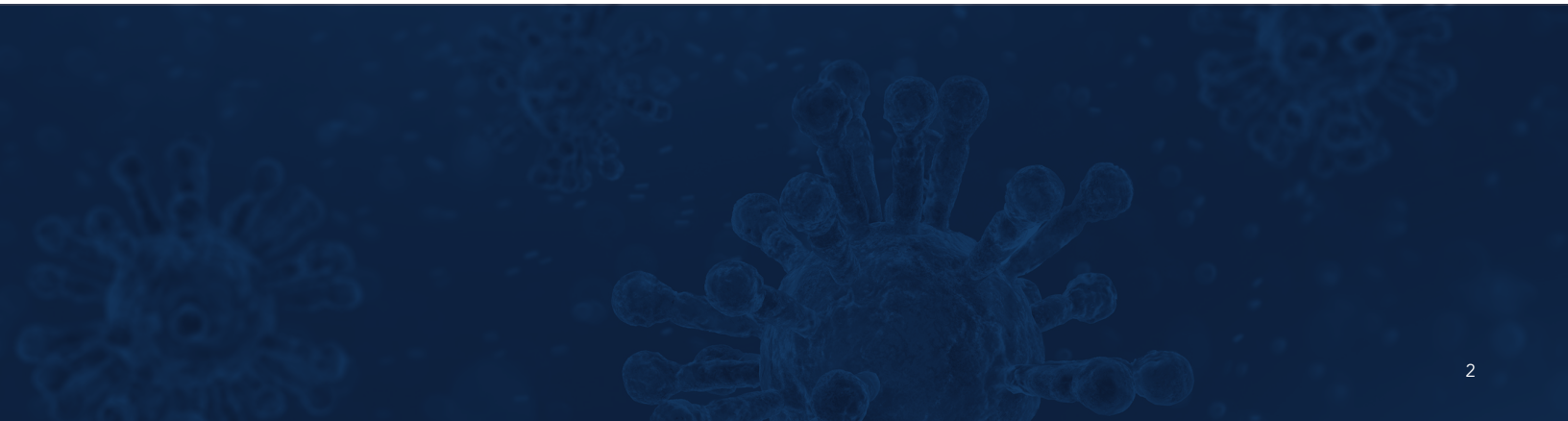

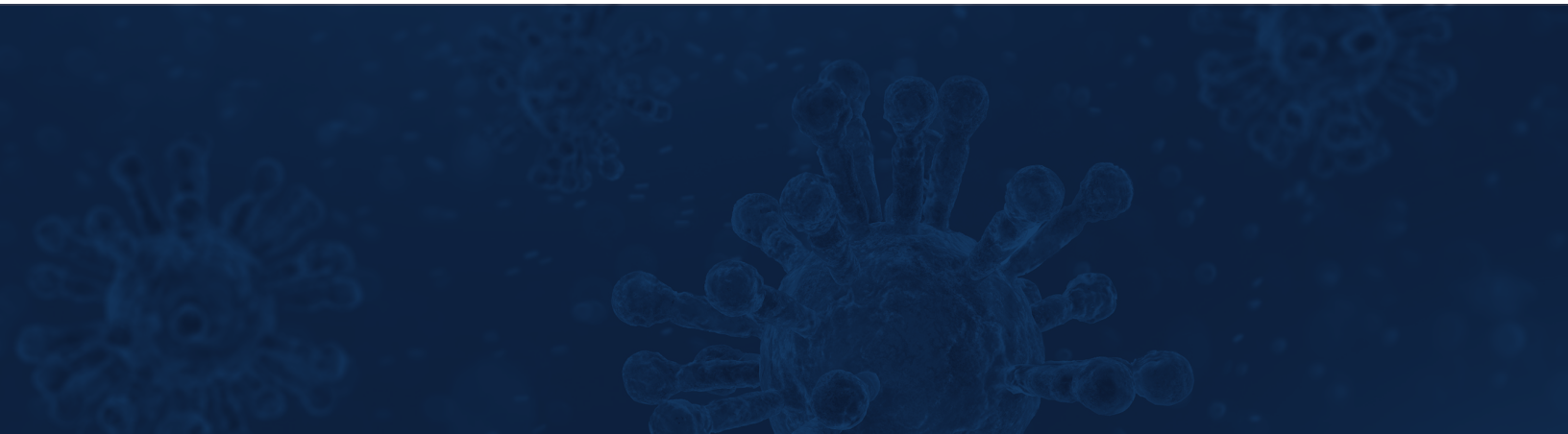

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* denotes founding member of ELECTRI'21 COUNCIL (1989-1990)
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Center for RESEARCH

Executive Summary

Overview

A pandemic can have far reaching impacts on the U.S. economy. Companies in once successful industries across the United States have felt the immediate impact of the current pandemic in the most devastating ways. Since March 2020, many companies have come to a complete and total shutdown, displacing more than 25 million Americans from their jobs. Other industries, such as the healthcare and medical research fields, have seen excessive stress placed on them not only in terms of resources and equipment, but also on the personal lives of the professionals administering these services. These are truly unprecedented times that were unforeseen just six months ago.

The federal government has tried to do its part to care for the unemployed, the small businesses, and even some large industries that have been most noticeably impacted by the government-directed shutdowns and forced isolations of our population. The CARES Act has gone a long way to help start bridging the gap from today toward recovery. Yet, it is not enough and cannot be the end of the support provided to corporations across this country.

The essential operations that have been asked to remain working during this pandemic are caught in the middle ground and left out of these often-discussed areas of our society and business. These industries are traditionally known to provide food, basic human necessities or some service that our government has deemed critical to the well-being of our citizens. These are the operations that keep our economy moving in some way to help prevent a total collapse of our infrastructure.

The construction industry is one of those essential industries that has continued to deliver its services to both private owners and government agencies alike. It has done so while adapting to and adhering to a continuously-updated and changing set of recommendations from our health, state, and federal government officials. During this time of essential operation, our construction workers continue to receive their paychecks; contributions to union pension and health funds continue without drawdowns; and our building owners receive their buildings per the completion schedules for which they have asked. While these are all positives for the economy, the unintended consequence of being deemed essential and working under these new mandates has fallen directly at the feet of the corporations that employ this workforce.

Most of these construction companies work on fixed price contracts with limited (if any) financial relief per the terms of their owner agreements. So, the added costs and inefficiencies of being an essential business are directly taken from the corporate profits. Without financial aid from our government, this industry will also suffer from the impact of this pandemic, but it will look different from the early impact on the people and industries our legislative branch has tried to save thus far during the pandemic.

It could be months or, in some cases, a few years from the start of this pandemic until we see construction companies fail. It will happen because they have no clear channel for equitable adjustment and have been contractually mandated to continue operations. The new normal being created from pandemic-driven health and social modifications is being seen early in the construction industry. Congress should take note as to what the potential financial or profitability ripple looks like as we start to reopen America.

Construction sites are usually vibrant micro-communities that thrive on fast-paced teamwork and require the precision of large numbers of men and women working together in tight spaces. They all play their parts, working together to erect massive buildings. Nearly every activity on a job site takes more than one person to complete, so the rule of social distancing creates a nearly impossible challenge. Hundreds of men and women line up daily to have

their temperatures scanned prior to beginning work. To move to and from their work areas, they ride in elevators in one-third the capacity that they once did in order to create sufficient space from each other.

This requirement takes up hours that used to be spent productively installing construction materials. Instead, these hours are now spent simply getting to the work area. Every activity is spaced at six-foot distances. Safety toolbox talks, stretch and flex programs, and daily meetings are all impacted as communication and coordination of activities has diminished at job sites. Each site has created its own version of shelter-in-place habits that have slowed down the industry to reduce the potential spread of this virus while continuing to work.

The findings of this study are based upon data collected from NECA members who represent some of the largest and most sophisticated contractors in the United States. The analysis and conclusions derived from the data set are intended to serve as a representation of the average impact on electrical contractors across the country. It should be noted that the research consultants performed a similar study for the sheet metal, HVAC and mechanical trades. The outcome of that study produced comparable results, as would be expected since the nature of the work impacts are very similar. Contractors may find variability in their own companies and find utility in conducting their own impact study. However, it would be difficult to recreate the same conditions that occurred globally and within the United States over the timeline of this study.

The construction industry thrives on challenge and innovation and will continually improve to deliver products safely to owners. In time, firms will adjust to this new normal and price the contracted work appropriately. However, in the near term, the industry's financial burden from the social restrictions placed on it may be so great that many companies will not survive to compete in the future.

Findings

Measurements of the impact of this pandemic suggest that construction productivity has been impacted by nearly 20%. **A rule of thumb for self-performing contractors is that a 10% impact on productivity results in a 100% impact on profitability.** Accordingly, contractors need to consider seriously the impact of this study on their profitability and seek equitable adjustments that adequately compensate them for the impact.

This study is divided into three distinct sections:

- Part I - Pandemic Mitigation Tracking specifically quantifies hours associated with preventative measures such as training, health screenings, cleaning and disinfecting, job site access, and administration - all instituted to minimize exposure.
- Part II - Productivity Benchmarking specifically quantifies the reduction in direct work productivity related to social distancing rules, staggered shifts, reduced crew sizes, increased personal protective equipment requirements, and related job site regulations.
- Part III - Business and Project Impacts specifically quantifies ancillary impacts experienced by most contractors who participated in this study.

The following section provides a description of each of the three distinct parts.

Part I - Pandemic Mitigation Tracking

Based on a random sampling of more than 92,000 labor hours, data collected to date suggest that **8.9% of labor hours is lost due to pandemic mitigation activities.** It is reasonable to expect that, if crews were not spending 8.9% of their available productive time working on pandemic mitigation, they would be putting work in place.

Contractors should prepare and submit change order requests to seek compensation for the impact of pandemic mitigation and prevention efforts instituted on their projects. Pandemic mitigation was never contemplated at the time of pricing a project and represents an unforeseen cost. Contained within this study is a change order calculator for contractors.

Part II - Productivity Benchmarking

The data indicate a 12.9% overall average productivity impact on Vertical Construction productivity as a result of the pandemic. It is important to note that this impact is additive to the 8.9% loss experienced as a result of mitigation tracking. Based on the current data, there are 62 minutes of lost productivity per day per employee's 8-hour work period.

While the study shows that the overall average impact on work productivity is 12.9%, Figure 8: Vertical Construction Productivity by Task Type Against Period, illustrates that certain task types clearly take a more significant impact to productivity. **The tasks that showed the greatest impact to work productivity, primarily due to close proximity of workers** were:

- **Overhead Rough In**
- **In Wall Rough In**
- **Trim**

The study clearly illustrates the need to file change orders to recover losses on out-of-scope work and losses in productivity. The current pandemic also demonstrates the necessity of implementing proper productivity controls. Contractors who are using accurate labor and productivity tracking systems are far better positioned to manage the crisis than those who are not. As a follow up to this study, the National Electrical Contractors Association (NECA) will conduct an outreach program to help educate contractors on "the how and why" of effective job cost-control systems.

Companies that have trended lower in productivity losses have established, organized, and trained their teams with new pandemic mitigation processes and procedures. Additionally, they have monitored and shifted work activities to accommodate required distance spacing between team members.

The average baseline productivity impact of:

12.9% (Productivity) + 8.9% (Mitigation) = 21.8% (Total Productivity Impact)

is substantial. Contractors should utilize this information to price an equitable adjustment properly employing both the Pandemic Change Order Calculator provided with this study and the study itself as backup verification for the impact.

Part III – Business and Project Impacts

To mitigate the impact of a pandemic on their field and project management staff, companies should focus on three specific areas:

1. Jobsite Impacts
   - Additional cleaning and the greater number of safety (PPE) requirements.
   - Distracted workers discussing the news.
   - Access issues (limited workers, temperature testing, single access).
2. Project Management Impacts
   - Less project review (fewer PM visits/ less rigorous monthly review meetings).
   - Additional time to track cost impacts (documenting pre-pandemic impacts on a project that would be a potential change order from post-pandemic impacts).
   - Time spent in project re-start planning.
3. Business Impacts
   - Project cancellations or projects delays.
   - Additional meetings: internally, with clients, with vendors, contingency planning, job re-start procedures.
   - Understanding rules and regulations issued by various governmental agencies.

Productivity Change Order Calculator and supplemental educational videos: https://electri.org/product/pandemics-and-construction-productivity-quantifying-the-impact/

Part I
Pandemic Mitigation Tracking

Objective

The objective of Pandemic Mitigation Tracking is to quantify lost productivity directly associated with jobsite pandemic mitigation requirements such as training, health screenings, cleaning and disinfecting, job site access and administration—all instituted to minimize exposure.

Data Collection and Methodology

To collect project hours on a daily basis, the consultants provided participants with an application for iOS and Android smartphones and tablets. A Microsoft Excel-based worksheet for participants with bulk daily time data offered an additional data collection option. Data collection began on April 15, 2020 and ended July 3, 2020.

A single data point for this research represents time reported to five standardized time codes, per project, per day. Standard definitions for each time code normalize the data across the range of participants in the sample. The time codes are:

- 100 - Total Hours Worked
- 200 - Hours lost to COVID Safety and Training
- 201 - Hours lost to COVID Distancing and Jobsite Access
- 202 - Hours lost to COVID Cleaning and Disinfecting
- 203 - Hours lost to COVID Administration.

Detailed definition of the types of activities per time code are included in Appendix A.

Definitions of activities for each time code category were drawn from:

- Local, state, and federal government guidelines for social distancing
- OSHA's *'Guidance on Preparing Workplaces for COVID-19'*
- OSHA's '*Interim Enforcement Response Plan for Coronavirus Disease 2019'*
- First-hand accounts provided by contractors.

Participants received instruction for using the data collection tools via a combination of methods:

- Webinar (live and recorded)
- PDF Instruction Manual
- Instructions and FAQ embedded in both data collection tools
- Direct access to the research project's consultants via phone, text or email for technical support and answers to their specific questions.

Each day, the research team reviewed sample size and geographic coverage using a heat map linked to the sample data set.

The analysis of the collected data centers around a single question: *Is it reasonable to expect that, on average, the percent of labor hours a contractor loses on jobsite pandemic mitigation requirements are hours not available to produce work at estimated rates of production and/or rates of production as defined in resources such as NECA's Manual of Labor Units 2019-2020?*

Sample Set

As shown in **Figure 1**, the sample data collected were geographically distributed across the United States and Ontario, Canada, and contained many major markets.

Figure 2 shows the "heat map" distribution and relative number of samples from each geographic location.

Figure 3 provides a table depicting the breakdown of hours collected and tasks coded to mitigation- related activities.

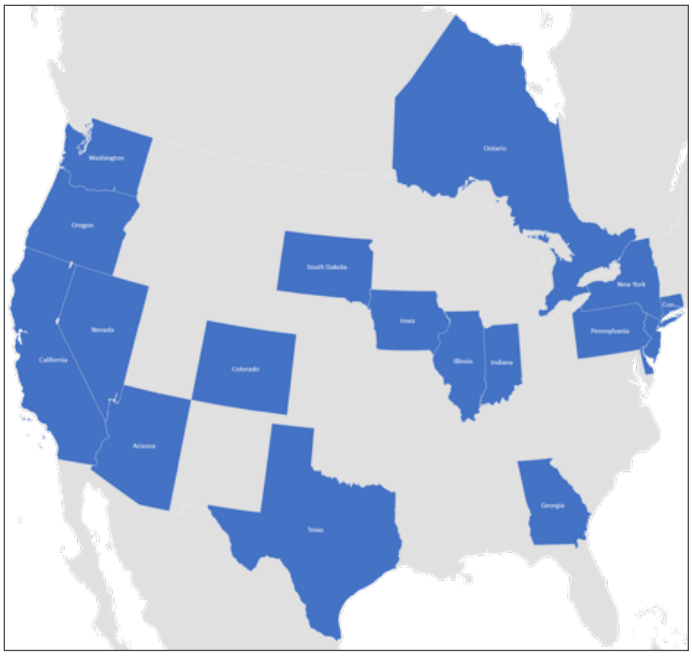


Figure 1 – State distribution of mitigation data

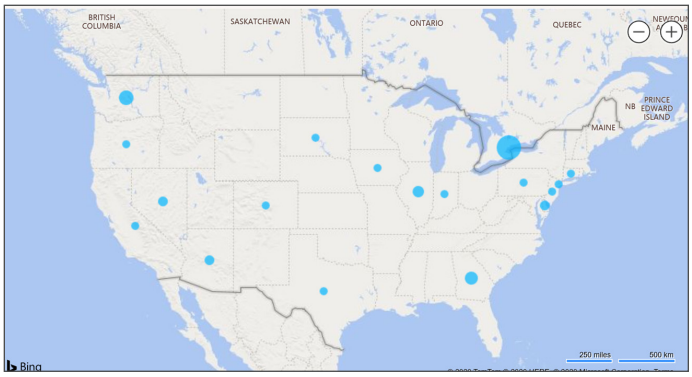


Figure 2 – Concentration heatmap of sample set data areas

	Total Hours	% of Total Hours	% of Mitigation Hours
Total Hours Available	92,390		
Mitigation Safety & Training	1.759	1.9%	21.2%
Mitigation Distancing & Access Rules	3,642	3,9%	43.9%
Mitigation Cleaning & Disinfecting	2,259	2.4%	27.2%
Mitigation Administration	642	0.7%	7.7%
Total Mitigation Hours	**8.302**	**8.9%**	**100.0%**

Figure 3 – Hours by task code for mitigation activities

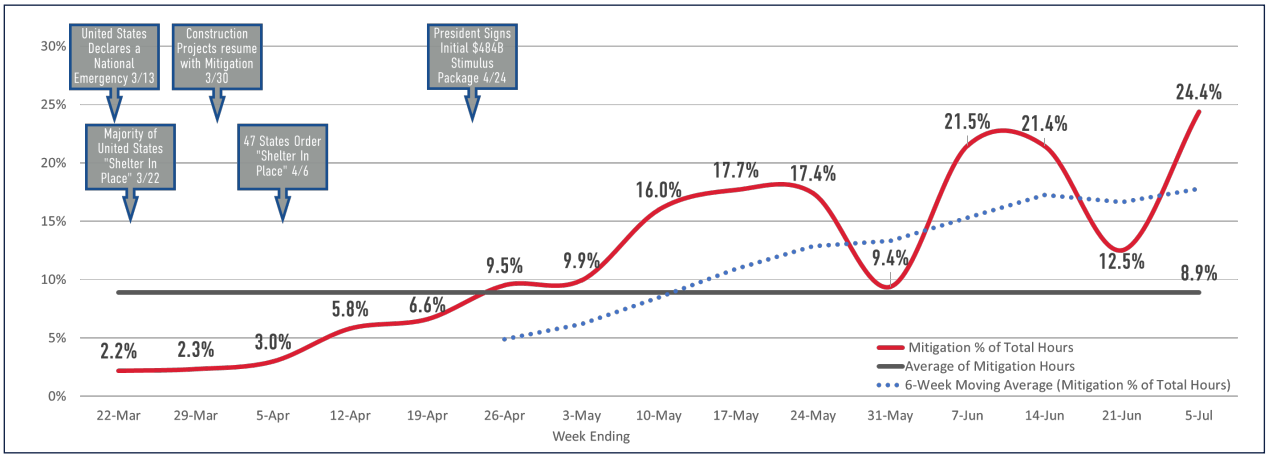


Figure 4 *– Mitigation hours as a percent of total hours by week*

Figure 4 provides a chart showing mitigation hours as a percentage of the total hours worked during each weekly period.

Summary Findings

On average, electrical contractors experience a daily 8.9% loss of production due to pandemic mitigation activities. Over 71% of the loss is due to the combined effects of distancing, access, cleaning and disinfecting activities. During an active pandemic, these are activities that crews manage throughout each day.

The next 21% of the loss is due to pandemic-specific safety and training meetings, toolbox talks, orientations, medical screenings, personal protective equipment fitting and training, etc. that occur on a more periodic basis.

The final 8% of lost time occurs due to pandemic-related administration such as additional paperwork, managing suspected cases and additional work coordination due to increased complexity in managing workflow. These activities are typically managed via onsite supervision.

In general, contractors should not be required to itemize the overall 8.9% mitigation loss into sub-categories since all categories require management on active projects during a pandemic. Federal distancing guidelines, OSHA requirements, and the resulting general contractor and subcontractor safety plans apply to most projects, regardless of region or type. For example, the following existing standards are referenced by OSHA as applicable in times of pandemic and apply to all projects across the country:

- 29 CFR § 1904, Recording and Reporting Occupational Injuries and Illness
- 29 CFR § 1910.132, General Requirements - Personal Protective Equipment
- 29 CFR § 1910.133, Eye and Face Protection
- 29 CFR § 1910.134, Respiratory Protection
- 29 CFR § 1910.141, Sanitation
- 29 CFR § 1910.145, Specification for Accident Prevention Signs and Tags
- 29 CFR § 1910.1020, Access to Employee Exposure and Medical Records
- Section 5(a)(1), General Duty Clause of the OSH Act

It is possible that local, state, owner-driven, or contractor-specific mitigation requirements could affect the degree and complexity required to comply with mitigation requirements. In such cases, contractors should use the 8.9% loss as a baseline from which modifications specific to their situation are made. Factors to consider are provided in the "Roadmap" section that follows.

Is the situation improving with time? It is too early to tell. It is reasonable to expect that the early uncertainty surrounding the necessity and degree of mitigation requirements will ease as the specific disease is better understood and enforcement agencies more clearly define requirements. It is also reasonable to expect that contractors will improve their ability to cope with mitigation requirements as time goes on, provided they know what to expect. Until then, to assess the degree of impact they will experience, contractors should consider several factors that will modify the current average including:

- GC/CM/Owner Site-Specific Safety Plans
- GC/CM Site Logistics Plans
- Quality of Work Coordination
- Local, state, or other modifiers to Federal Guidelines

With the number of hours and projects sampled, 8.9% is a solid calculation of the current average loss experienced daily by contractors across the country with a margin of error of ±3%.

Roadmap

Contractors should utilize the average loss in productivity in the following scenarios:

- Use the average provided (and the calculator provided as backup) to prepare change orders requesting relief for the time lost due to managing pandemic mitigation requirements.
- Use the average provided as a multiplier on an active project to forecast financial projections, schedule impact, and resource availability.
- Use the average provided as a multiplier both for estimating projects that will require pandemic mitigation factors as projects re-open and for future projects, assuming prolonged mitigation requirements.

Factors that should be considered as modifications to the baseline average include but are not limited to:

- Detailed knowledge of federal, OSHA, and CDC applicable guidelines and directives.
- Local and state modifiers or additions to federal, OSHA, and CDC guidelines and directives.
- Availability and clarity of owner, GC/CM project-specific safety plans.
- Project-specific characteristics that influence social distancing and logistics.
- Relationships with the GC/CM.

It should be noted that some traditional methods of schedule acceleration, such as additional manpower or overtime, are either not possible due to the nature of pandemic mitigation guidelines and directives or will compound the effects of activities such as waiting for access to work areas or gaining access to trailers for medical screenings, to name a few.

Contractors should look to their local NECA Chapters for news and information regarding additional training and education as well as updates to the data provided.

Productivity Change Order Calculator and supplemental educational videos:
https://electri.org/product/pandemics-and-construction-productivity-quantifying-the-impact/

Part II
Productivity Benchmarking

Objective

The aim of the Productivity Benchmarking had three elements:

1. Measure electrical contractor companies' pre- and post-pandemic direct work productivity
2. Measure the impacted tasks by market segment, project/job type and geographic area
3. Provide analysis, summary findings, and a roadmap to operationalize the results

To achieve this objective, the research consultants established a model to normalize data and provide a consistent and structured manner in which to collect and analyze the productivity data. More specifically, the consultant team:

- Documented specific tasks designed by an ELECTRI-designated Task Force. This enabled collection of percent completed and hours for common tasks across companies by market segment
- Constructed a formalized data gathering process from multiple electrical contracting companies across the US
- Defined specific critical dates that impacted contractor productivity (i.e. – Shelter-in-place orders)
- Measured, tracked, mapped and analyzed the data provided by contractors
- Built analytics models to generate insights into data and then summarized the results
- Utilized a double-blind methodology to ensure confidentiality with only the project leader (Maxim Consulting) knowing which contractor's data are aggregated in the results
- Provided contractors who participated in the study an individualized profile of their results versus the national numbers to assist them further with their quantification

Data Collection and Methodology

The Collection Process

The data collection process involved the generation of large amounts of data from contractors who provided the information using a formalized template.

For each data point, the project consultants collected the following information from contractors:

- Market Segment
- Project ID
- Project/Job Name
- Project/Job Type
- Location City
- Location State
- Contact Person
- Contact Person Phone
- Week Start Date
- Week Date
- Task Code
- Percent Complete
- Hours
- Week of Data Collection

Contractors received a specific selection of options for the Project/Job Type based on the federal government's establishment of essential projects:

- Chemical
- Commercial Facilities
- Communications
- Critical Manufacturing
- Dams

- Defense Industrial Base
- Emergency Services
- Energy
- Financial Services
- Food and Agriculture
- Government Facilities
- Healthcare and Public Health
- Information Technology
- Nuclear Reactors, Materials, and Waste
- Transportation Systems
- Water and Wastewater Systems
- Other (in any instance in which a specific state had a departure from the federal list)

Contractors received specific selection options for the Market Segment:

- Vertical Construction (high rise, mid-rise, commercial, healthcare, etc.)
- Horizontal Construction (traffic signalization, streets and bridges, agriculture, etc.)
- Line Construction (power transmission and distribution, substations, etc.)
- Systems only Construction (i.e. – fire alarm, low voltage, etc.)
- Maintenance (facility maintenance, etc.)

Data were normalized by providing contractors with the specific definition for the Task Codes associated with each Market Segment:

Market Segment	Task Code	Definition
Vertical	Underground	Utility and Communication Conduits, Site Lighting, Pole Bases, Trenching, Utility Transformer Pad, Ductbank, Secondary Feeder Conduits to Service, Vaults.
Vertical	In Slab	Branch Distribution Raceways (power, lighting, equipment), BAS Raceways, Feeder/Power Distribution Raceways. Life Safety & Communication Raceways, if acceptable.
Vertical	Overhead Rough In	Power, Lighting, and Equipment Raceways, Life Safety Raceways, Communications Raceways, BAS Raceways, Feeder Raceways if Not in Slab, Branch Home Runs.
Vertical	In Wall Rough In	The "In The Wall" Portion of the Raceway That Needs to Be Concealed in a Wall for Switches, Receptacles, Communication, Life Safety, BAS Devices, any Miscellaneous Equipment That Needs a Wall Rough In.
Vertical	Wire Pulling	Wire & Cable Installations for all Systems Below Slab or Overhead. Feeder Wire, Branch Power, Branch Lighting and Equipment Wire, Life Safety, Communications, and BAS Cabling.
Vertical	Trim	Light Fixture Installation, Power and Lighting Device Installation, Life Safety, Communication, and BAS Device Installation.
Vertical	Electric & Equipment Rooms	Switchboards, Panelboards, Electrical Switching Devices, VFD's, Mechanical Equipment Connections (HVAC, Plumbing, Process, etc.)
Horizontal	Traffic Signals	Below Grade Work, Set Poles & Equipment, Wiring.
Horizontal	Street Lighting	Below Grade Work, Set Poles & Luminaires, Wiring.
Horizontal	Interconnect	Below Grade Work, Below Grade Wiring, Overhead Work (if applicable).
Line Construction	Mobilization/ Demobilization	Mobilization/Demobilization of equipment, tooling and manpower to project. Includes warehouse support, trucking, on-boarding and establishment of laydown/office areas.

Market Segment	Task Code	Definition
Line Construction	Drilling/Pole Setting	Drilling of pole holes including caisson foundations, setting of wood/steel poles, plump/backfill of pole, torqueing of bolts on steel monopoles.
Line Construction	Framing	All framing of the poles including cross arms, insulators, attachment plates, grounding, riser material, equipment (cutouts, reclosers, transformers, cap banks, switches, etc.).
Line Construction	Anchors/Guys	Installation of anchor types and associated guying between the pole and anchor.
Line Construction	Wire Stringing	All tasks involved with the installation of wire including pulling ropes, pulling wire, clipping in and dead ending wire, and splicing.
Line Construction	Transfers	Moving wire or equipment from old pole to new pole (typical for distribution work)
Line Construction	Removals	Removal of any poles, framing, anchors/guys, wire, etc.
Systems	General Pathways	When included in our SOW this details cable tray (outside of TR's), sleeves, cable supports, etc.
Systems	ER/TR Buildout	Telecommunication room buildout includes ladder tray, racks, cabinets, patch panels, fiber panels, UPS/PDU's, and grounding associated with ER/TR's.
Systems	Horizontal Cabling	Includes category cabling to work area outlets. Depending on scope this can also include other systems type cable. Depending on project size the technical systems (AV, sound masking, paging, fire alarm, nurse call, etc.) would constitute a separate cost code.
Systems	Backbone Cabling	Includes copper, fiber, and coax type backbone cable between main ER and all associated TR's.
Systems	Horizontal Cable Termination & Testing	Includes terminating and testing both headend and station end cabling. This also can be broken out by floor, area, etc. depending on project size with separate cost codes for each. Also includes face plates and labeling.
Systems	Backbone Cable Termination & Testing	Includes termination and testing of all backbone cabling. This also can be broken out by floor, area, etc. depending on project size. Also includes patch panel labeling.
Maintenance	UPS Maintenance	Mobilize/Demobilize, Facility Check-in Process, OEM Operational Testing, Battery Access/Inspections, Load Bank Testing, Test Reports Data Gathering, OEM Supply Chain Scheduling.
Maintenance	Batteries Maintenance	Mobilize/Demobilize, Facility Check-in Process, Valve Regulated Battery Testing, Flooded Cell Battery Testing, Torque and Tighten Connections, OEM Supply Chain Scheduling.
Maintenance	Generator Maintenance	Mobilize/Demobilize, Facility Check-in Process, OEM Operational Testing, Load Bank Testing, Fuel Polishing, OEM Supply Chain Scheduling.

Sample Set

The data collected for Vertical Construction were normalized into seven distinct task types:

- Underground
- In Slab
- Overhead Rough In
- In Wall Rough In
- Wire Pulling
- Trim
- Electric and Equipment Rooms

As shown in **Figure 5,** the sample data collected were geographically distributed across the country and contained many major markets.

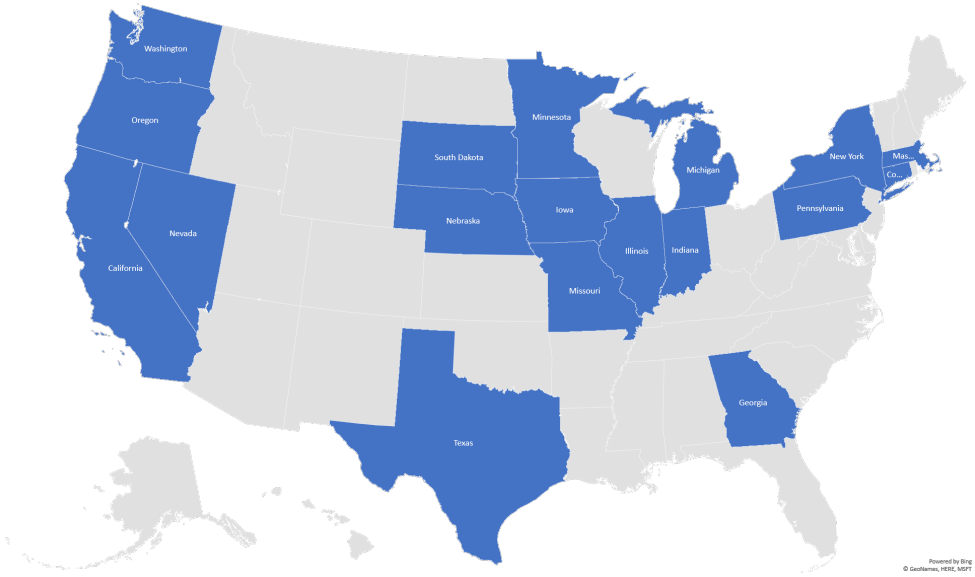


Figure 5 *– State distribution of productivity data*

Figure 6 shows the "heat map" distribution and relative number of samples from each geographic location. The largest data samples were collected from California, Illinois, Michigan, Nevada, Pennsylvania, and Washington.

Figure 7 shows productivity contrasted against external events. The researchers observed productivity reactions to specific external events and a general improvement trend with negative productivity impact from March 29th through May 3rd.

While the study shows that the overall average impact on work productivity is 12.9%, **Figure 8** illustrates that certain task types clearly take a more significant impact to productivity. **The tasks that showed the greatest impact to work productivity, primarily due to close proximity of workers** were:

- **Overhead Rough In**
- **In Wall Rough In**
- **Trim**

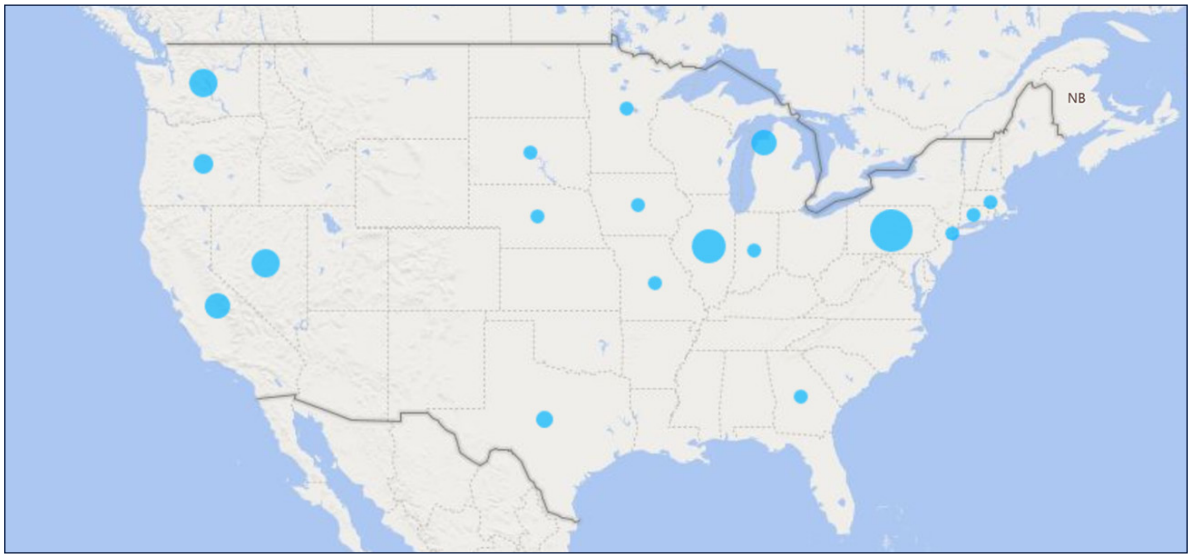


Figure 6 – *Concentration heatmap of sample set data areas of United States*

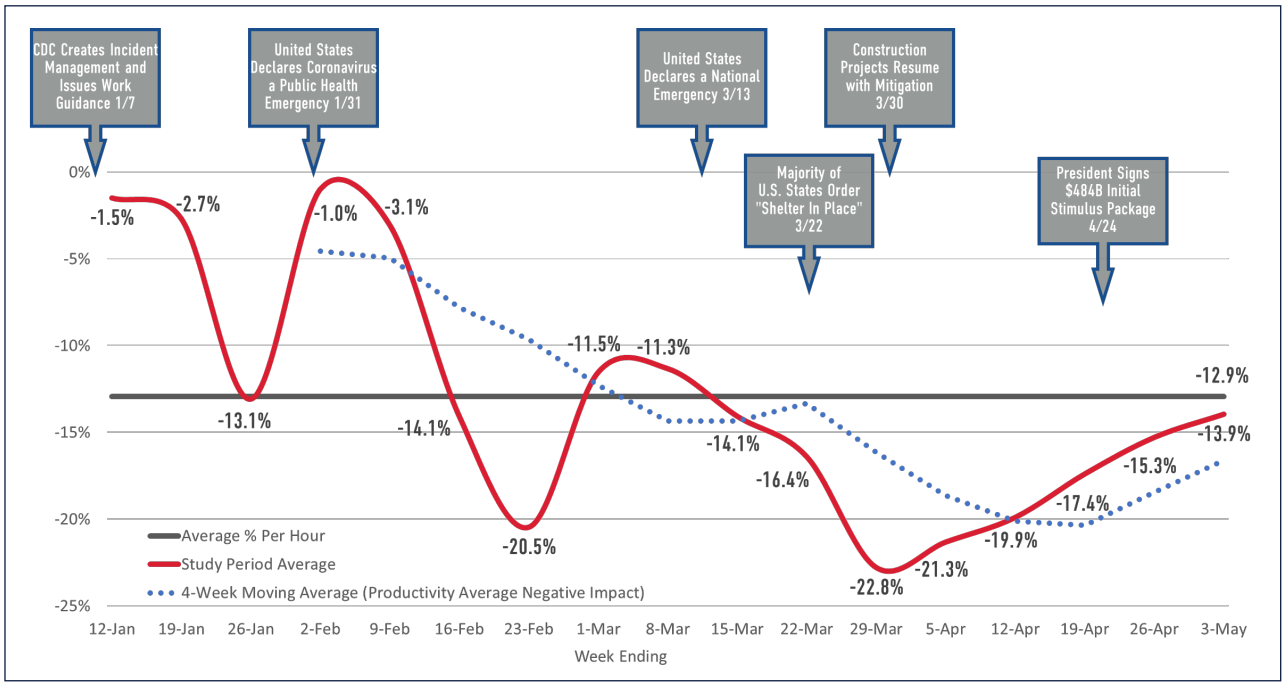


Figure 7 – *Vertical construction productivity against events*

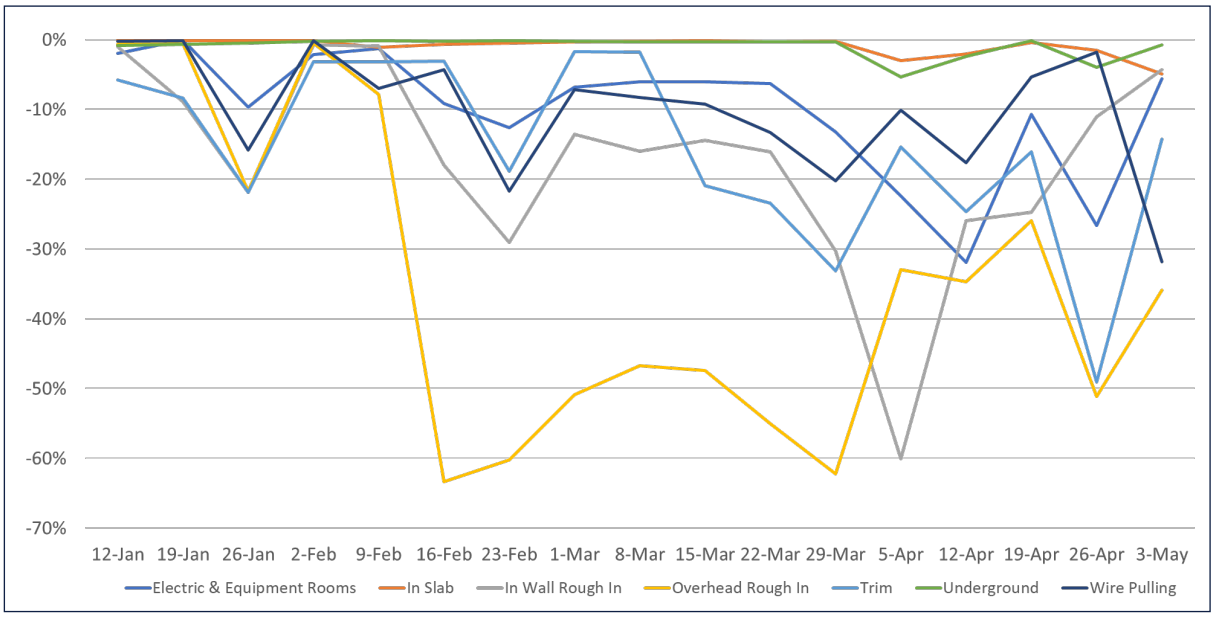


***Figure 8** – Vertical construction productivity by task type against period*

Summary Findings

This study indicates a 12.9% overall average pandemic impact on Vertical Construction productivity. Based on the current data, the result is 62 minutes of lost productivity per day per employee 8-hour work period. This is in addition to the daily 8.9% loss of production due to pandemic mitigation activities, creating a total productivity loss of 21.8%. This means, on average, there is a total productivity loss of 105 minutes per day per employee's 8-hour work period.

Roadmap

Companies that have trended lower in productivity losses have established, organized, and trained their teams with new pandemic mitigation processes and procedures. Additionally, they have monitored and shifted work activities to accommodate required distance spacing between team members.

The baseline productivity impact of 12.9% (Productivity) + 8.9% (Mitigation) = 21.8% is substantial. Contractors should utilize this information to price an equitable adjustment properly employing both the Pandemic Change Order Calculator provided with this study and the study itself as backup verification for the impact.

Productivity Change Order Calculator and supplemental educational videos:
https://electri.org/product/pandemics-and-construction-productivity-quantifying-the-impact/

Part III
Business Impact of a Pandemic

The current pandemic has had a dramatic impact on the productivity of field and office personnel in the electrical contracting industry. Over the past few months, this impact on project acquisition, pre-fabrication, the available pipeline of projects, project execution both for the field and project management, and the interactions and payment cycle of clients have created dramatic changes.

Objective

The research for this portion of the project called upon representatives from all segments of the EC industry, both line and commercial. Data collection relied on discussion groups, case studies, and an industry Flash Survey to untangle and characterize objectively the relationship between productivity and this pandemic. The objective was to develop of a set of best practices and identify necessary education and training that would enable electrical contractors to better manage their projects and businesses and mitigate the impact of a pandemic on their field and project management staff.

Data Collection and Methodology

Using discussion groups, case studies and an industry survey, as noted above, the researcher collected anecdotal data on the impacts the pandemic has had on electrical contractors beyond those impacts on their labor productivity. The four discussion groups and ten case studies focused on the ways electrical contractors were able to adapt their business practices working remotely, allow for social distancing in the workplace, and identify new ways of interacting with suppliers and clients working from home.

The survey focused on gathering data that pertain to impacts on the jobsite, project management, overall business operations, and other items identified by the participants themselves. Participants indicated the impacts in each of these four areas as High, Medium, Low or No impact. This format allowed the researcher to quantify the relative magnitude of the impact within each area.

As discovered in the discussion groups and case studies, impacts varied dramatically, based on the type of construction. Contractors mentioned that large HealthCare projects managed by National CM/GC firms seemed to be the most impacted. For some smaller work involving a crew of one, contractors actually reported improved productivity. In some instances, contractors used the absence of workers in client facilities to increase their sell-additional-work volume. This approach helped ECs take care of projects that, during normal times, clients might not have had the time or access to start.

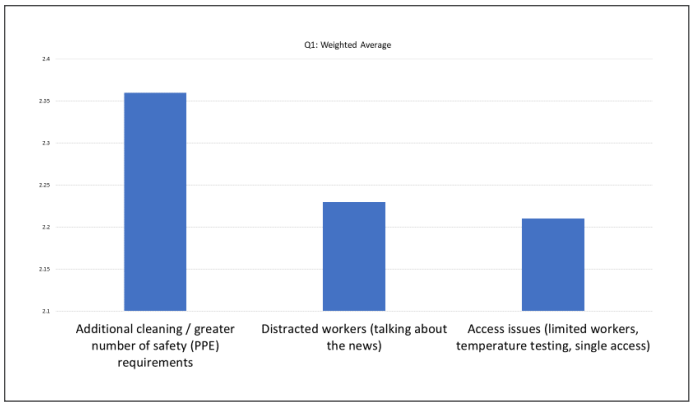
Contractors identified their top three impacts using this scale:

3 = High Impact
It has resulted in significant financial harm to your business
2 = Medium Impact
It has resulted in some financial loss to your business
1 = Low Impact
It has not impacted your financials in a meaningful way
0 = No Impact
Absolutely no impact on your financials.

Jobsite Impacts

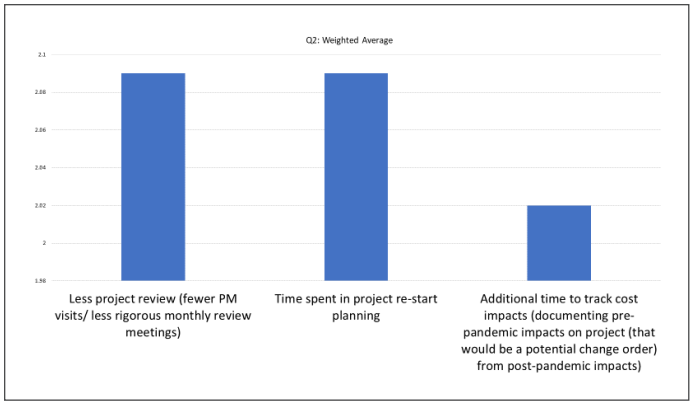
Contractors reported their three most significant jobsite impacts were **additional cleaning and the greater number of safety (PPE) requirements.** On this point, 89% of the participating contractors

indicated this had a High or Medium financial impact, with an average of 2.32. The second highest impact was from **distracted workers discussing the news** with 80% of the contractors stating this had a High or Medium financial impact, with an average of 2.26. Note: this topic had the highest number of contractors selecting this as High impact at 44%) The third highest impact area was **Access issues (limited workers, temperature testing, single access),** coming in at 83% of contractors indicating this had a High or Medium financial impact, with an average of 2.23.



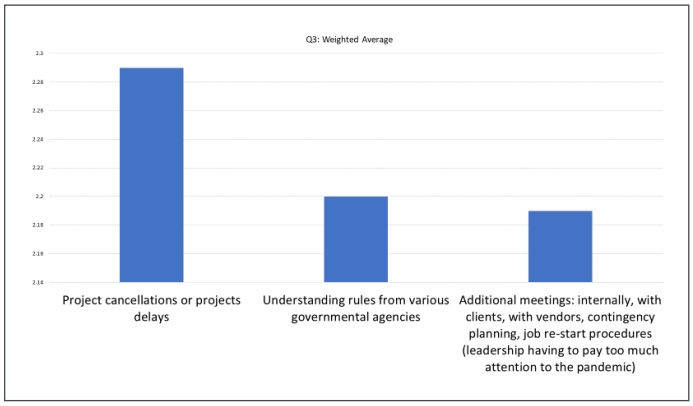
Project Management Impacts

Contractors reported their three most significant project management impacts were **less project review (fewer PM visits/less rigorous monthly review meetings).** For this factor, 73% of the contractors indicated a High or Medium financial impact, with an average of 2.15. The second highest impact was from **additional time to track cost impacts (documenting pre-pandemic impacts on a project (that would be a potential change order) from post-pandemic impacts).** Here, 75% of the contractors rated this as a High or Medium (selected by 2/3 of the contractors) financial impact, with an average of 2.04. The third highest impact area at 71% was **time spent in project re-start planning.** Contractors indicated this had a High or Medium financial impact, also with an average of 2.04.



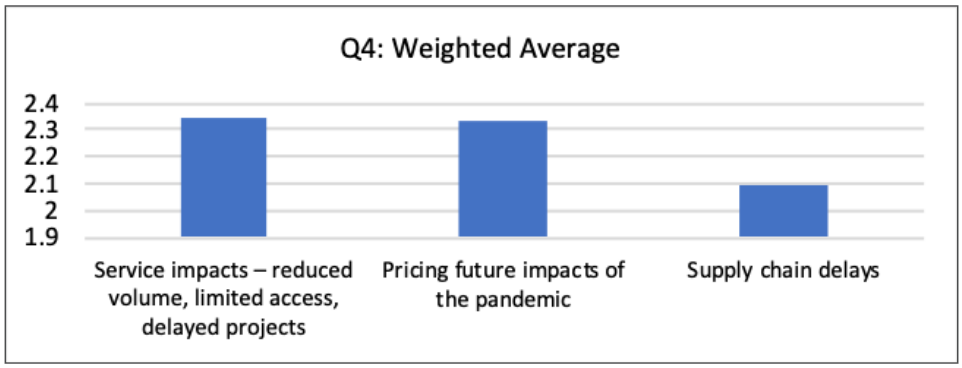
Business Impacts

Contractors noted their three most significant business impacts were **project cancellations or project delays.** For this topic, 86% of the contractors reported a High or Medium financial impact. This particular impact also had the highest overall average of any item in the survey at 2.34. The second highest impact concerned **additional meetings: internally, with clients, with vendors, contingency planning, job re-start procedures (leaders having to pay too much attention to the pandemic).** For this, 82% of the contractors indicated a High or Medium financial impact, with an average of 2.22. The third highest impact area was **understanding rules from various governmental agencies,** with 76% of contractors noting this had a High or Medium financial impact, also with an average of 2.18.



Other Impacts

Contractors reported their top two most significant other impacts were **pricing future impacts of the pandemic** with 84% of the contractors indicating these had a High or Medium financial impact and an overall average of 2.34. Following closely was **service impacts – reduced volume, limited access, delayed projects** with 83% of the contractors indicating these had a High or Medium financial impact and an overall average of 2.33. The third highest impact area was **supply chain delays**, with 78% of contractors noting this had a High or Medium financial impact and an average of 2.09.



Operationalizing the Findings with Best Practices

Following the analysis of the interviews and case studies, these best practices are offered to help electrical contractors better manage a future pandemic. The argument can also be made that these are best practices for the EC industry – with or without a pandemic environment.

1. Follow notice requirements detailed in your contract. Do not give away your rights by not following the contract.
2. Rely on NECA for current information. Identify and assign one person (or more) in your organization to keep up with changes that may be announced several times per day.
3. Include the cost of a pandemic in any quotation for future work. This would apply to both changes in field productivity and the cost of meeting pandemic requirements such as limited access, health documentation, temperature screening, etc.
4. Understand and ensure that fair Force Majeure and delay clauses are included in your contract. Some contractors reported contracts specifically identifying this pandemic as a known item, thereby excluding known items from any possible Force Majeure clauses
5. Track accounts receivable and follow-up quickly. Due to the nature and timing of this research initiative, many participating contractors had not yet experienced significant slowdowns in their accounts payable. They attributed that fact to the short horizon they are experiencing thus far during this pandemic. Most thought those financial impacts would be felt 60 to 90 days after a billing cycle had been completed.
6. Manage the firm's cash and learn whether there are governmental program changes that allow the company

to borrow or defer payments. To "hoard" or keep cash, contractors reported the need to understand what programs can help with cash flow and how to use the firm's bank to negotiate better line-of-credit terms.

7. Small contractors, especially, must make sure to find the time to work "on" the business rather than just "in" the business. Many small business owners indicated that, after working in the field all day, it was difficult to keep up with rapidly changing information.
8. Ensure the company's technology is sufficient to support remote work. Some contractors reported forced investment in technologies rather than planned investment. In those situations, they noted that cost inefficiencies occurred due to the need to purchase quickly, whether the item was communication technology/bandwidth or large numbers of laptops. For the longer term, some contractors are planning for a more robust system to manage payroll, purchasing, and job costs.
9. Encourage diversification within market segments. Contractors who seemed most impacted were those heavily reliant on a single market segment that itself was significantly impacted. For example, in this pandemic, the automotive, hospitality, and retail markets all experienced a much bigger negative impact than other market segments.
10. Keep an appropriate stock of PPE equipment. For some electrical contractors, the purchasing manager spent the entire day for multiple weeks trying to locate needed PPE. Anticipate future changes and requirements (face shields, cleaning solutions, etc.) with which companies may be forced to comply.

Appendix A

Pandemic Mitigation Tracking Data Collection Definitions & Tools

Figure 9 *– Pandemic mitigation app data collection tool*

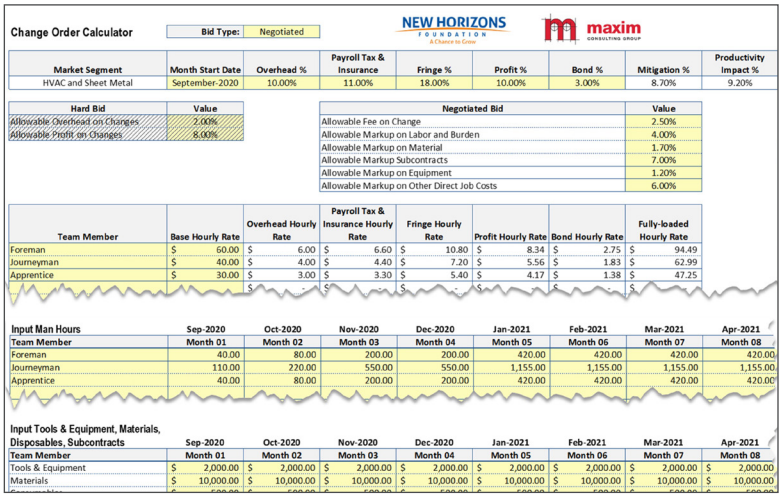
Cost Code Definitions		
Cost Code	**Cost Code Name**	**Example activities in Cost Code**
100	Total Crew Hours Worked	Sum of all labor hours worked on your project for the day.
200	COVID Safety & Training	Any/all forms of time lost due to COVID-specific safety huddles, orientations, respirator training & fitting, equipment handling, air flow equipment maintenance, sneeze shielding, etc.
201	COVID Distancing & Access Rules	Any/all forms of time lost due to site logistics, waiting to access work areas, waiting on medical screening, extra distance walking to lunch tents, additional coordination or reworking due to inaccessible work areas, etc.
202	COVID Cleaning & Disinfecting	Any/ all forms of time lost due to COVID-related cleaning, disinfecting, personal hygiene, filter management, disposal, etc.
203	COVID Administration	Any/ all forms of time lost due to COVID-related administration, paperwork, management of suspect or positive cases, additional work coordination meetings, etc.

Figure 10 *– Pandemic mitigation app activity definitions*

Appendix B

Productivity Change Order Calculator

Change Order Calculator Input



Change Order Calculator — Bid Type: Negotiated

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Market Segment	Month Start Date	Overhead %	Payroll Tax & Insurance	Fringe %	Profit %	Bond %	Mitigation %	Productivity Impact %
HVAC and Sheet Metal	September-2020	10.00%	11.00%	18.00%	10.00%	3.00%	8.70%	9.20%

Hard Bid	Value
Allowable Overhead on Changes	2.00%
Allowable Profit on Changes	8.00%

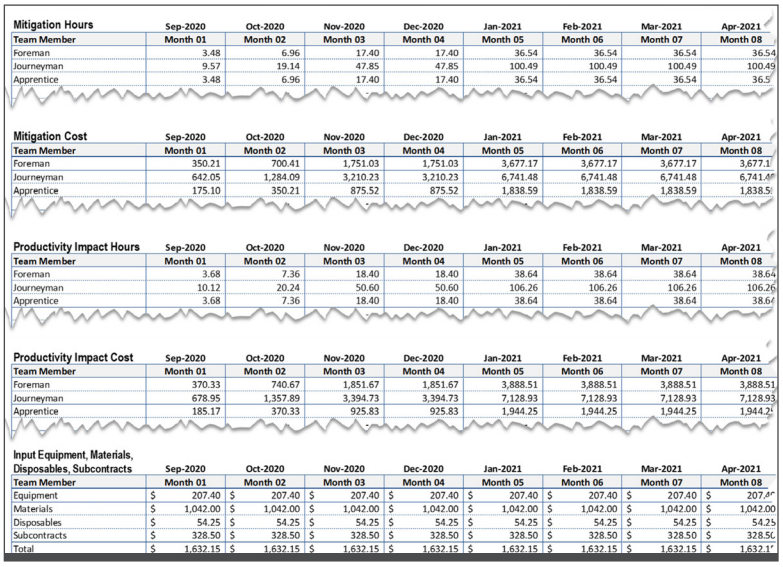
Negotiated Bid	Value
Allowable Fee on Change	2.50%
Allowable Markup on Labor and Burden	4.00%
Allowable Markup on Material	1.70%
Allowable Markup Subcontracts	7.00%
Allowable Markup on Equipment	1.20%
Allowable Markup on Other Direct Job Costs	6.00%

Team Member	Base Hourly Rate	Overhead Hourly Rate	Payroll Tax & Insurance Hourly Rate	Fringe Hourly Rate	Profit Hourly Rate	Bond Hourly Rate	Fully-loaded Hourly Rate
Foreman	$ 60.00	$ 6.00	$ 6.60	$ 10.80	$ 8.34	$ 2.75	$ 94.49
Journeyman	$ 40.00	$ 4.00	$ 4.40	$ 7.20	$ 5.56	$ 1.83	$ 62.99
Apprentice	$ 30.00	$ 3.00	$ 3.30	$ 5.40	$ 4.17	$ 1.38	$ 47.25
		$ -	$ -	$ -	$ -	$ -	$ -

Input Man Hours — Team Member	Sep-2020 Month 01	Oct-2020 Month 02	Nov-2020 Month 03	Dec-2020 Month 04	Jan-2021 Month 05	Feb-2021 Month 06	Mar-2021 Month 07	Apr-2021 Month 08
Foreman	40.00	80.00	200.00	200.00	420.00	420.00	420.00	420.00
Journeyman	110.00	220.00	550.00	550.00	1,155.00	1,155.00	1,155.00	1,155.00
Apprentice	40.00	80.00	200.00	200.00	420.00	420.00	420.00	420.00

Input Tools & Equipment, Materials, Disposables, Subcontracts — Team Member	Sep-2020 Month 01	Oct-2020 Month 02	Nov-2020 Month 03	Dec-2020 Month 04	Jan-2021 Month 05	Feb-2021 Month 06	Mar-2021 Month 07	Apr-2021 Month 08
Tools & Equipment	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00
Materials	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00

Change Order Calculator Detail



Mitigation Hours — Team Member	Sep-2020 Month 01	Oct-2020 Month 02	Nov-2020 Month 03	Dec-2020 Month 04	Jan-2021 Month 05	Feb-2021 Month 06	Mar-2021 Month 07	Apr-2021 Month 08
Foreman	3.48	6.96	17.40	17.40	36.54	36.54	36.54	36.54
Journeyman	9.57	19.14	47.85	47.85	100.49	100.49	100.49	100.49
Apprentice	3.48	6.96	17.40	17.40	36.54	36.54	36.54	36.5

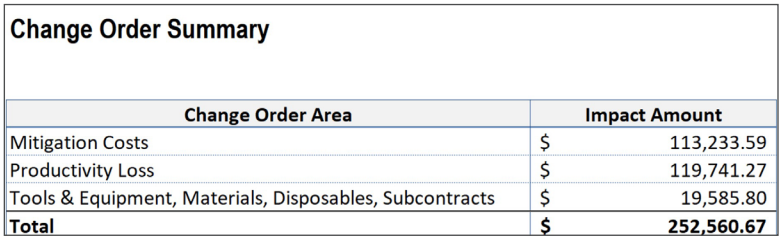
Mitigation Cost — Team Member	Sep-2020 Month 01	Oct-2020 Month 02	Nov-2020 Month 03	Dec-2020 Month 04	Jan-2021 Month 05	Feb-2021 Month 06	Mar-2021 Month 07	Apr-2021 Month 08
Foreman	350.21	700.41	1,751.03	1,751.03	3,677.17	3,677.17	3,677.17	3,677.1
Journeyman	642.05	1,284.09	3,210.23	3,210.23	6,741.48	6,741.48	6,741.48	6,741.4
Apprentice	175.10	350.21	875.52	875.52	1,838.59	1,838.59	1,838.59	1,838.5

Productivity Impact Hours — Team Member	Sep-2020 Month 01	Oct-2020 Month 02	Nov-2020 Month 03	Dec-2020 Month 04	Jan-2021 Month 05	Feb-2021 Month 06	Mar-2021 Month 07	Apr-2021 Month 08
Foreman	3.68	7.36	18.40	18.40	38.64	38.64	38.64	38.64
Journeyman	10.12	20.24	50.60	50.60	106.26	106.26	106.26	106.26
Apprentice	3.68	7.36	18.40	18.40	38.64	38.64	38.64	38.64

Productivity Impact Cost — Team Member	Sep-2020 Month 01	Oct-2020 Month 02	Nov-2020 Month 03	Dec-2020 Month 04	Jan-2021 Month 05	Feb-2021 Month 06	Mar-2021 Month 07	Apr-2021 Month 08
Foreman	370.33	740.67	1,851.67	1,851.67	3,888.51	3,888.51	3,888.51	3,888.51
Journeyman	678.95	1,357.89	3,394.73	3,394.73	7,128.93	7,128.93	7,128.93	7,128.93
Apprentice	185.17	370.33	925.83	925.83	1,944.25	1,944.25	1,944.25	1,944.2

Input Equipment, Materials, Disposables, Subcontracts — Team Member	Sep-2020 Month 01	Oct-2020 Month 02	Nov-2020 Month 03	Dec-2020 Month 04	Jan-2021 Month 05	Feb-2021 Month 06	Mar-2021 Month 07	Apr-2021 Month 08
Equipment	$ 207.40	$ 207.40	$ 207.40	$ 207.40	$ 207.40	$ 207.40	$ 207.40	$ 207.4
Materials	$ 1,042.00	$ 1,042.00	$ 1,042.00	$ 1,042.00	$ 1,042.00	$ 1,042.00	$ 1,042.00	$ 1,042.00
Disposables	$ 54.25	$ 54.25	$ 54.25	$ 54.25	$ 54.25	$ 54.25	$ 54.25	$ 54.25
Subcontracts	$ 328.50	$ 328.50	$ 328.50	$ 328.50	$ 328.50	$ 328.50	$ 328.50	$ 328.5
Total	$ 1,632.15	$ 1,632.15	$ 1,632.15	$ 1,632.15	$ 1,632.15	$ 1,632.15	$ 1,632.15	$ 1,632.1

Change Order Calculator Output



Change Order Summary

Change Order Area	Impact Amount
Mitigation Costs	$ 113,233.59
Productivity Loss	$ 119,741.27
Tools & Equipment, Materials, Disposables, Subcontracts	$ 19,585.80
Total	**$ 252,560.67**

Productivity Change Order Calculator and supplemental educational videos:
https://electri.org/product/pandemics-and-construction-productivity-quantifying-the-impact/

Appendix C

Double-Blind Productivity Benchmark Participant Survey

The research study utilized a double-blind methodology to observe pre- and post-pandemic construction productivity impacted by behavioral interventions. Blinding or masking refers to the withholding of information regarding treatment allocation from one or more research study participants. It is an essential methodological feature of studies that helps maximize the validity of the research results.

The Consulting Research Team

Michael McLin, Managing Director at Maxim Consulting Group, works with construction-related firms of all sizes to evaluate their business practices and assist with management challenges. His areas of specialization include organizational assessments, strategic planning, project execution, productivity improvement, prefabrication, peer groups, and training programs. McLin has consulted with some of the most sophisticated contractors in the U.S. and his industry experience includes some of the most complex construction projects undertaken across the country. He is adept at utilizing available tools and analysis to identify opportunities and challenges within an organization. In addition to his expertise in many facets of the construction world, McLin is a nationally-recognized public speaker and published author.

Dan Doyon, Director at Maxim Consulting, works with construction-related firms to solve complex business challenges that drive revenue and profitability. His broad experience in business process improvement across construction and related industries provides him with a unique perspective to identify and solve operational issues. His subject expertise includes organizational assessments, strategic business planning, financial planning and analysis, technology, organizational design and transition, productivity improvement, peer groups, and prefabrication system design. With his guidance and recommendations, companies have driven over $160 billion in top line sales growth and hundreds of millions in operational savings through improved processes.

Brian Lightner, Associate Director at Maxim Consulting, is responsible for client evaluation and implementation processes. His extensive work with construction firms, including the first ISO 9000 certified General Contractor in the U.S., has focused on process improvement initiatives. He is keenly aware of the challenges that contractors face, including in their field operations. Lightner's areas of expertise include project planning/scheduling/execution; field productivity assessments; project recovery; and process improvement/integration/standardization. His experience with both construction specialties and highly-successful general contractors allows him to execute many exemplary field operation and productivity studies.

Mark Federle, Associate Dean for Academic Affairs at Marquette University, is a licensed Professional Engineer and Certified Professional Constructor. Prior professional engagements include serving as Chief Information Officer for The Weitz Company (Des Moines) and as Professor-in-Charge of Iowa State University's Construction Engineering program. He was elected to the National Academy of Construction in 2018 and is a Fellow of ASCE. Since the mid-1990s, Federle has worked with ELECTRI International and NECA as a researcher and instructor and has published extensively on electrical contracting in ELECTRICAL CONTRACTOR magazine.

ELECTRI INTERNATIONAL
Research and Education for the Electrical Construction Industry

1201 Pennsylvania Ave. NW, Suite 1200 Washington, D.C. 20004
T: 202-991-6257 www.electri.org
Index Number # F3434

Exhibit 22

Providing Vision and Leadership for the Future of the HVAC and Sheet Metal Industry

PANDEMICS AND PRODUCTIVITY: QUANTIFYING THE IMPACT

MITIGATION AND PRODUCTIVITY IMPACTS FOR SHEET METAL, HVAC AND MECHANICAL CONTRACTORS

NEW HORIZONS
FOUNDATION
A Chance to Grow

NEW HORIZONS
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Providing Vision and Leadership for the Future of the HVAC and Sheet Metal Industry

PANDEMICS AND PRODUCTIVITY: QUANTIFYING THE IMPACT

MITIGATION AND PRODUCTIVITY IMPACTS FOR SHEET METAL, HVAC AND MECHANICAL CONTRACTORS

July 2020

Prepared By:

Michael McLin
Dan Doyon
Brian Lightner

Maxim Consulting Group

NEW HORIZONS FOUNDATION CONTRIBUTORS

SUMMIT COUNCIL MEMBERS

The Summit Council is comprised of the Premier, Champion, Summit Counselor, Industry Mentors and Summit Circle contributor categories. All members of the Summit Council receive national public acknowledgment at industry annual meetings and other special events and programs. In addition, they have the opportunity to participate in shaping the agenda for the New Horizons educational and research program.

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Keith Atteberry, California

NEW HORIZONS FOUNDATION CONTRIBUTORS, CONTINUED

SUMMIT COUNSELOR - $100,000 AND UP, CONTINUED

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Sheet Metal Connectors, Inc.
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Stromberg Metal Works, Inc.
William Gawne, Maryland

Walsh Mechanical Contractors
Paul M. Le Bel, Sr., Massachusetts

NEW HORIZONS FOUNDATION CONTRIBUTORS, CONTINUED

INDUSTRY MENTORS, CONTRACTORS LOOKING TO THE FUTURE - PERSONAL PLEDGES OF $50,000

Guy Gast
Des Moines, IA

Jack Knox
Smyrna, GA

Ron Rodgers
Peoria, AZ

Angie & Michael Simon
Menlo Park, CA

Mark Watson
Hiawatha, IA

Keith Wilson
Albuquerque, NM

OTHER CONTRIBUTORS

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Cox Engineering Company
Jon Desmond, Massachusetts

D.D.S. Industries, Inc.
Dwight D. Silvia, Massachusetts

Dee Cramer, Inc.
Matt Cramer, Michigan

J.C. Cannistraro, LLC
David Cannistraro, Massachusetts

Lyon Sheet Metal, Inc.
Michael C. Corrigan, Sr., Missouri

Matrix Group International, Inc.
Joanna Pineda, Virginia

Novak Heating & Air Conditioning, Inc.
Randy Novak, Iowa

Sheet Metal Contractors Association of Central Pennsylvania
Lori A. Eshenaur

SMACNA - Sacramento Valley Chapter
Cheryl Sprague

SMACNA Mid-Atlantic
Bernie Brill

SMACNA of Oklahoma, Inc.
Matt Wansley

Viewpoint Construction Software
Karl Rajotte, Pennsylvania

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David McKamish, Pennsylvania

SMACNA - Kansas City Chapter
Stacey Smyly

SMACNA of Long Island, Inc.
Melissa Barbour

U.S. Sheet Metal, Inc.
Bruce J. Stockwell, Michigan
John Unger, Michigan

NEW HORIZONS FOUNDATION CONTRIBUTORS, CONTINUED

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Mark Malencia, Pennsylvania

Enterprise Holdings Foundation
Missouri

Florida SMACNA, Inc.
Lisa Falk

Jack's Mechanical Solutions, Inc.
Gabe Martinez, New Mexico

Murphy Company
Mark Bengard, Missouri

Tri-Metal Fabricators
Joe Toso, British Columbia, Canada

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Edmund J. Bransfield, Pennsylvania

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Energy Labs, Inc.
Ray Irani, California

LADCO, Inc.
Doug Hamilton, Iowa

MCA-SMACNA of San Antonio, Inc.
Sandee Morgan

SMACNA Arizona
Carol Goguen

THE CONSULTING RESEARCH TEAM

Michael McLin, *Managing Director at Maxim Consulting Group*, works with construction-related firms of all sizes to evaluate their business practices and assist with management challenges. His areas of specialization include organizational assessments, strategic planning, project execution, productivity improvement, prefabrication, peer groups, and training programs. McLin has consulted with some of the most sophisticated contractors in the U.S. and his industry experience includes some of the most complex construction projects undertaken in the U.S. He is adept at utilizing available tools and analysis to identify opportunities and challenges within an organization. In addition to his expertise in many facets of the construction world, McLin is a nationally recognized public speaker and published author.

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NEW HORIZONS FOUNDATION COVID-19 PRODUCTIVITY TASK FORCE

Thomas Martin
Task Force Chair, T.H. Martin, Inc.

Angela Simon
Western Allied Mechanical

Jim Jeffrey
Western Allied Mechanical

Rick Hermanson
Hermanson Company, LLP

Guy Gast
The Waldinger Corporation

Henry Nutt
Southland Industries

Chip Worden
Streimer Sheet Metal Works, Inc.

Jack Knox
R.F. Knox Company

Jim Morgan
Worcester Air Conditioning, LLC

Joseph Lansdell
Poynter Sheet Metal, Inc.

Peter Fortin
ACCO Engineered Systems

Tom Zahner
A. Zahner Company

Thomas Soles
SMACNA/New Horizons Foundation

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Overview

Pandemics negatively impact construction productivity. To date, no resource existed to aid contractors in quantifying these impacts for the purpose of seeking equitable compensation for lost productivity, adequately pricing upcoming work that will take place under pandemic driven work rules and conditions, and properly formulating financial projections that take into account stress on cash flow due to both decreases in productivity and the associated increases in overhead costs.

In late April 2020, New Horizon's Foundation retained Maxim Consulting Group, LLC to quantify these impacts so that industry contractors have a practical resource useful for mitigating pandemic related productivity losses. The study builds on and correlates to similar work published in ELECTRI International's "Pandemics and Construction Productivity: Quantifying the Impact" study.

Two methods are used to quantify the magnitude of pandemic related productivity losses and are described in detail in Parts I and Part II of this paper.

Part I - Pandemic Mitigation Tracking

A random sample of over 20,000 labor hours collected from Sheet Metal, HVAC and Mechanical contractors to date **indicates 8.7% of hours available on projects to do productive work are lost due to mitigation requirements such as PPE management, cleaning & disinfection, access rules, and extra administration time. Identical sampling methods used in the ELECTRI study indicated similar results for electrical contractors on over 92,000 hours sampled. The combined average loss on mitigation for MEP contractors is 8.8% on over 113,000 hours. It is reasonable to expect that if these hours were available, crews would be putting work in place**.

The combined sample sets of the two studies provide a convincing quantification of losses on mitigation tasks – contractors should prepare change orders to seek direct financial compensation for these lost hours as well as use this data to adjust scope and pricing for future work under similar conditions.

Part II - Productivity Benchmarking

Our study indicates an overall 9.2% average productivity impact on Sheet Metal, HVAC and Mechanical contractor productivity as a result of the pandemic. These productivity losses are *additive* to the mitigation impact of 8.7%, to produce a total productivity impact of 17.9%. These may occur due to non-mitigation related impacts including, but not limited to: extra mobilizations/demobilizations, work fatigue from anxiety and excess absenteeism, social distancing effects, off-shift work, altered delivery & material receiving, inspection and cleaning requirements, etc. **Based on the current data, there are over 85 minutes of lost productivity per day per employee's 8-hour work period**.

Companies that have trended lower in productivity losses have established, organized, and trained their teams with new pandemic mitigation processes and procedures. Additionally, they have monitored and shifted work activities to accommodate required distance spacing between team members. Leaving pandemic-related productivity losses of this magnitude unaddressed is a significant problem for contractors. For specialty contractors a loss of *10% labor productivity* often results in a *100% loss in project profitability*. **This means that on average in the study results, contractors are losing over 7% on projects**. The magnitude of this issue represents a very real threat to a contractor's ability to remain in business if left unmitigated. Worse, the nature of productivity losses is a lag effect that often goes unnoticed by conventional projection and reporting systems until it is too late. The true financial impact of productivity losses can take as long as 3-6 months to fully play out in a company's finances. Cash flow projections based on assumptions that do not include excess production costs and associated overhead costs can easily foster a false sense of security. This ripple effect is broadened as company resources (labor, equipment and management) assumed to be available to execute

new billable work are delayed as a result of slower productivity on existing work. It is only a matter of time before these impacts catch up to a company's cash flow cycles.

Contractors that adopt this information and put plans in place earlier are better equipped to weather the negative impact of pandemic driven productivity losses.

The average baseline productivity impact of:

8.7% (Mitigation) + 9.2% (Productivity) = 17.9% (Total Productivity Impact)

is substantial. Contractors should utilize this information to price an equitable adjustment properly employing both the Pandemic Change Order Calculator provided with this study and the study itself as backup verification for the impact.

PART I - PANDEMIC MITIGATION TRACKING

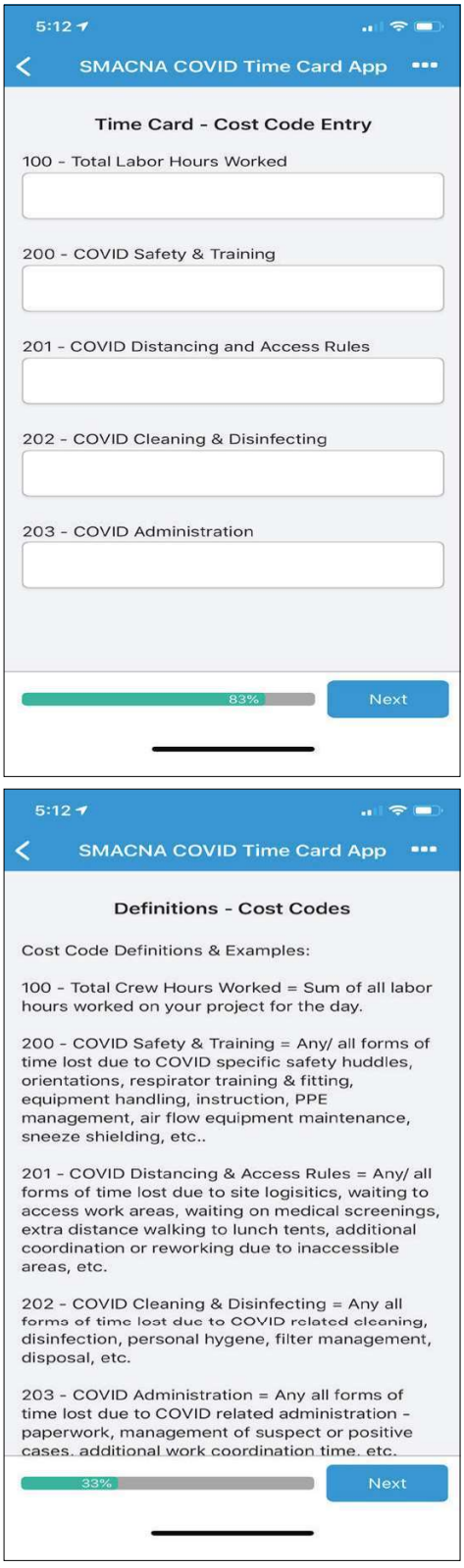
Objective

The objective of Pandemic Mitigation Tracking is to quantify lost productivity directly associated with jobsite pandemic mitigation requirements such as PPE management and training, health screenings, cleaning and disinfecting, job site access and administration, all instituted to minimize exposure.

Data Collection and Methodology

Labor hours on impacted projects were collected from field supervisors on a daily basis via an application developed by the consultants for iOS and Android smartphones and tablets. Data collection began on April 30th, 2020 and concluded on July 3, 2020. *Figure 1* shows the interface used by field supervision to enter time as well as the definitions provided to participants for normalizing data:

Figure 1: Application interface for entering daily time and included definitions for participants.



A single data point for this research represents time reported to five standardized time codes, per project, per day. Standard definitions for each time code normalize the data across the range of participants in the sample and were provided to participants in both a PDF instruction manual as well as embedded in the application itself. The time codes and definitions are:

- 100 – Total Hours Worked = Sum of all labor hours worked on the project for the day.
- 200 – COVID Safety & Training = Any/all forms of time lost due to COVID specific safety huddles, orientations, respirator training & fitting, etc.
- 201 – COVID Distancing & Access Rules = Any/all forms of time lost due to site logistics, waiting to access work areas, waiting on medical screenings, extra distance to lunch & break areas, etc.
- 202 – COVID Cleaning & Disinfecting = Any/all forms of time lost due to COVID related cleaning and disinfection of tools, equipment, and personal effects (including handwashing.)
- 203 – COVID Administration = Any/all forms of time lost due to COVID related administration, paperwork, management of suspected cases, additional work coordination meetings, etc.

Participants also categorized the type of crew for which time is reported. Crew types included are:

- HVAC/Sheet Metal Crew
- Mechanical Crew
- Plumbing Crew
- Composite (Combined Trades) Crew

Taken in combination with the results published in the ELECTRI study, the quantification provides a thorough cross section of impact across all the MEP trades.

Definitions of activities for each time code category were determined from:

- Local, state and federal government guidelines for social distancing
- OSHA's 'Guidance on Preparing Workplaces for COVID-19'
- OSHA's 'Interim Enforcement Response Plan for Coronavirus Disease 2019'
- Firsthand accounts provided by contractors.

Participants received instruction for using the data collection tools via a combination of methods:

- Recorded Webinar
- PDF Instruction Manual
- Instructions and FAQ embedded in the application
- Direct access to the research project's consultants via phone, text or email for questions and technical support

Each day, the consulting team reviewed sample size and geographic coverage using a heat map linked to the sample data set.

The analysis of the data collected centers on a simple argument: **It is reasonable to expect that the percent of labor hours, on average, that a contractor loses on jobsite pandemic mitigation requirements are hours not available to produce work at estimated rates of production and/or rates of production as defined in resources such as recognized manuals of labor units published by trade associations**.

Sample Set

Figure 2 provides a table that depicts the breakdown of hours collected and tasks coded to mitigation related activities for New Horizons Foundation – Sheet Metal, HVAC and Mechanical contractors.

Figure 2: State Distribution of Mitigation Data (New Horizons Foundation + ELECTRI).

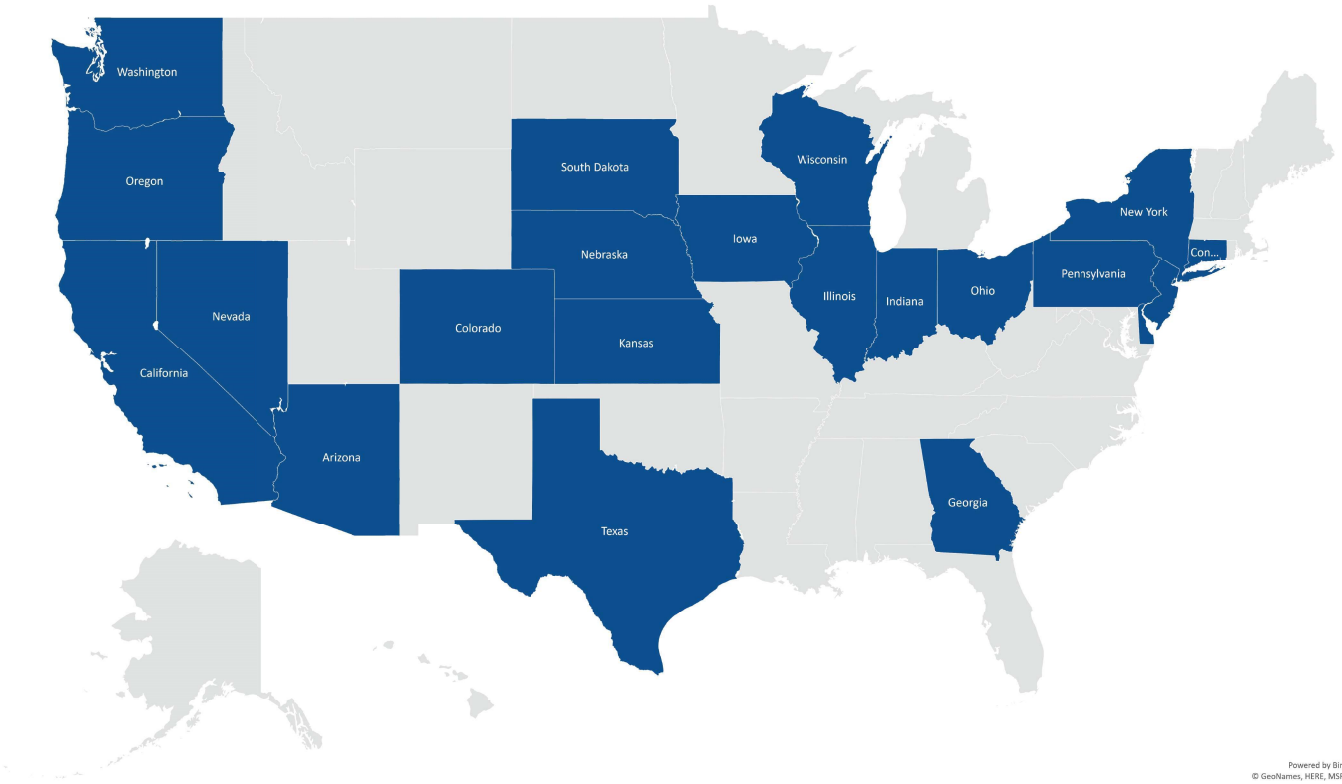


Figure 3 provides a table that depicts the breakdown of hours collected and tasks coded to mitigation related activities for the New Horizons Foundation study, covering all MEP trades.

Figure 3: Mitigation Hours by Task Code (New Horizons Foundation).

	Total Hours	% of Total Hours	% of Mitigation Hours
Total Hours Available	*20,893*		
Mitigation Hours: Safety & Training	470	2.2%	25.9%
Mitigation Hours: Distancing & Access Rules	439	2.1%	24.1%
Mitigation Hours: Cleaning & Disinfecting	580	2.8%	32.0%
Mitigation Hours: Administration	326	1.6%	18.0%
Total	**1,815**	**8.7%**	**100%**

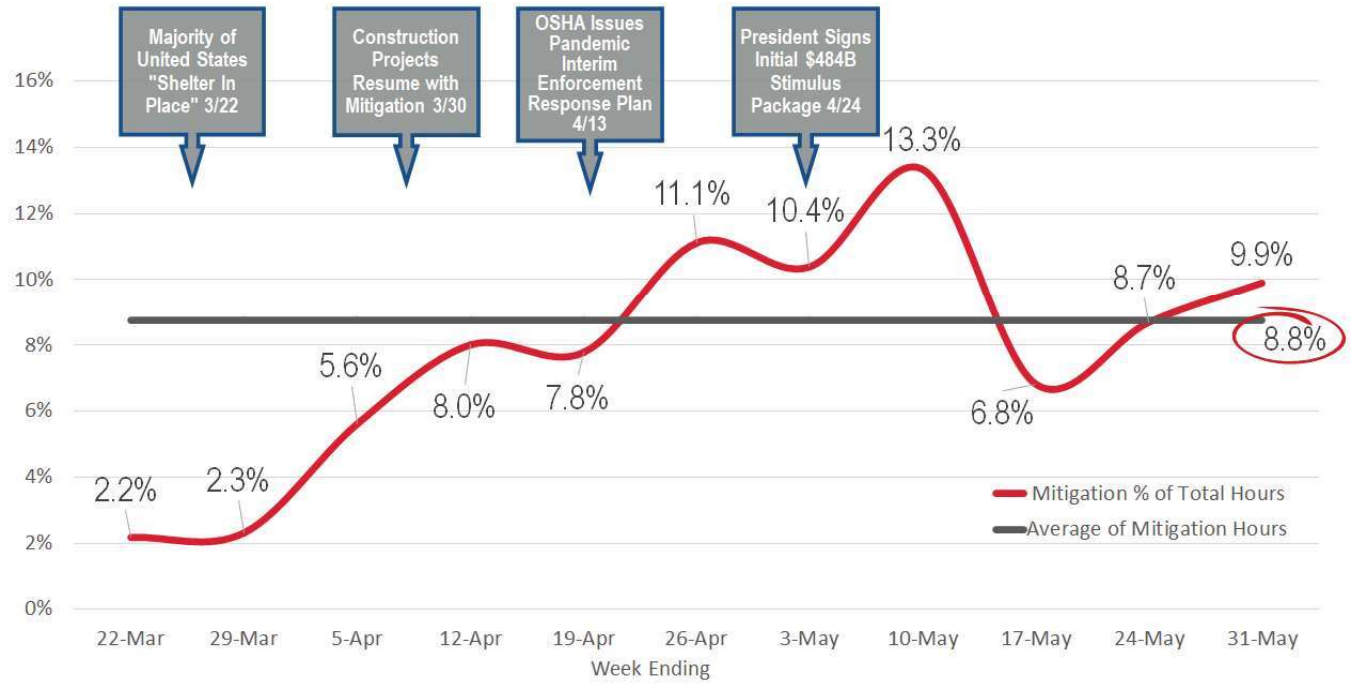
Figure 4 provides a table that depicts the breakdown of hours collected and tasks coded to mitigation related activities for combined New Horizons Foundation and ELECTRI studies, covering all MEP trades.

Figure 4: Mitigation Hours by Task Code (New Horizons Foundation + ELECTRI).

	Total Hours	% of Total Hours	% of Mitigation Hours
Total Hours Available	*113,213*		
Mitigation Hours: Safety & Training	2,229	1.94%	22.0%
Mitigation Hours: Distancing & Access Rules	4,081	3.6%	40.3%
Mitigation Hours: Cleaning & Disinfecting	2,839	2.5%	28.1%
Mitigation Hours: Administration	968	0.8%	9.6%
Total	**10,117**	**8.8%**	**100%**

Figure 5 provides a view of week over week mitigation percentage over the course of reporting in the combined studies.

Figure 5: Mitigation Hours as a Percent of Total Hours by Week (New Horizons Foundation + ELECTRI).



Summary Findings

On average, 8.8% of hours provided to impacted projects are lost by MEP trades as a result of mitigation tasks at the time of this publication.

Of the 8.8% loss, 22.0% of it is lost due to safety & training requirements, 40.3% is lost due to distancing and access requirements, 28.1% is lost due to cleaning & disinfecting, and 9.6% is lost due to administration.

These numbers can and should be used by contractors in the preparation of change orders, the pricing and adjusting of scope in upcoming work on impacted projects, and to 'stress' test financial projections.

In general, contractors should not be required to itemize the 8.8% loss into sub-categories since all categories require management on active projects during a pandemic. Federal distancing guidelines, OSHA requirements, and the resulting general contractor and subcontractor safety plans apply to most active projects, regardless of region or type. For example, the following existing standards are referenced by OSHA as applicable in times of pandemic and apply to all projects across the country:

- 29 CFR § 1904, Recording and Reporting Occupational Injuries and Illness.
- 29 CFR § 1910.132, General Requirements - Personal Protective Equipment.
- 29 CFR § 1910.133, Eye and Face protection.
- 29 CFR § 1910.134, Respiratory Protection.
- 29 CFR § 1910.141, Sanitation.
- 29 CFR § 1910.145, Specification for Accident Prevention Signs and Tags.
- 29 CFR § 1910.1020, Access to Employee Exposure and Medical Records.
- Section 5(a)(1), General Duty Clause of the OSH Act.

It is possible that local, state, owner driven, or contractor-specific mitigation requirements could affect the degree and complexity required to comply with mitigation requirements. **In such cases, contractors should use the 8.8% mitigation loss as a baseline from which modifications specific to their situation are made**. Factors to consider are provided in the section entitled "Roadmap" below.

Is the situation improving with time? It is too early to tell. It is reasonable to expect that early uncertainty surrounding the necessity and degree of mitigation requirements will ease as the specific disease is better understood and enforcement agencies more clearly define requirements. It is also reasonable to expect that contractors will improve their ability to cope with mitigation requirements as time goes on, provided they know what to expect. Until then, contractors should consider several factors to assess the degree of impact they will experience that will modify the current average including:

- GC/CM/Owner Site-Specific Safety Plans
- GC/CM Site Logistics Plans
- Quality of Work Coordination
- Local, state, or other modifiers to Federal Guidelines

With the number of hours and projects sampled, 8.8% is a solid calculation of the current average mitigation loss experienced daily by contractors across the country with a margin of error of ±1%.

Roadmap

Contractors should utilize the average loss in productivity in the following scenarios:

- Use the average provided as either direct calculation of loss in the preparation of change orders requesting relief for the time lost managing pandemic mitigation requirements or as backup to negotiations of change orders currently pending.
- Use the average provided as a multiplier on active projects to forecast financial projections, schedule impact, and resource availability.
- Use the average provided as a multiplier for estimating projects that will require pandemic

mitigation factors as projects re-open and for future projects, assuming prolonged mitigation requirements.

Factors that should be considered as modifications to the baseline average include but are not limited to:

- Detailed knowledge of federal, OSHA, and CDC applicable guidelines and directives.
- Local and state modifiers or additions to federal, OSHA, and CDC guidelines and directives.
- Availability and clarity of owner, GC/CM project specific safety plans.
- Project specific characteristics that influence social distancing and logistics.
- Relationship with the GC/CM.

Contractors should look to SMACNA for news and information regarding additional training and education as well as referrals for support and assistance in developing change order requests.

PART II – PRODUCTIVITY BENCHMARKING

Objective

The aim of the Productivity Benchmarking had three parts:

1. To measure sheet metal, mechanical and plumbing contractor companies' pre- and post-pandemic productivity;
2. To measure the impacted tasks by market segment, project/job type and geographic area;
3. Provide analysis, summary findings and a roadmap to operationalize the results.

In order to achieve the objective, the research consultants established a model to normalize data and provide a consistent and structured manner to collect and analyze the productivity data. More specifically, they:

- Documented specific tasks designed by a New Horizons Foundation-designated task force – this enabled us to collect percent completed and hours for common tasks across companies;
- Constructed a formalized data gathering process from multiple sheet metal, mechanical and plumbing contractors across the US;
- Defined specific critical dates that impacted contractor productivity (i.e. – Shelter in place orders);
- Measured, tracked, mapped and analyzed the data provided by contractors;
- Built analytics models to generate insights into data and summarized the results;
- Utilized a double-blind methodology with only the project leader (Maxim Consulting) knowing which contractor's data are aggregated in the results to ensure confidentiality;
- Provided contractors who participated in the study an individualized profile of their results versus the national numbers to further assist in quantification.

Data Collection and Methodology

The Collection Process

The data collection process involved the generation of large amounts of data from contractors providing the information in a formalized Microsoft Excel file template.

For each data point, we collected the following information from contractors:

- Market Segment
- Project ID
- Project/Job Name
- Project/Job Type
- Location City
- Location State
- Contact Person

- Contact Person Phone
- Week Start Date
- Week End Date
- Task Code
- % Complete
- Number of Hours

We provided the contractors with specific selection options for the Project/Job Type:

- Chemical
- Commercial Facilities
- Communications
- Critical Manufacturing
- Dams
- Defense Industrial Base
- Emergency Services
- Energy
- Financial Services
- Food and Agriculture
- Government Facilities
- Healthcare and Public Health
- Information Technology
- Nuclear Reactors, Materials, and Waste
- Transportation Systems
- Water and Wastewater Systems
- Other

We provided the contractors with specific selection options for the Market Segment:

- Shop - Sheet Metal
- Shop - Piping
- Shop - Plumbing
- Field - Sheet Metal
- Field - Piping
- Field - Plumbing
- Architectural Sheet Metal

We provided the contractors with specific selection options for the Task Code for each Market Segment:

Market Segment	**Task Code**	**Definition**
Shop - Sheet Metal	Duct (Pounds Per Hour)	Includes galvanized weight as you measure it, nominal, with or without waste, per your shop standards, including connectors, reinforcing.
Shop - Sheet Metal	Fittings	As above, if you segregate galvanized fitting weight/production. It can be included above with ductwork, in which case this cell will be empty.
Shop - Sheet Metal	Prefabrication/ Assemblies/ Modularization	Any work that is tracked in assembling finished joints of ductwork, fittings, and accessories or in line components, if you separate that in your shop.
Shop - Piping	Hangers and Supports	Generally all labor cutting, labeling, assembling clevis hangers, unistrut or racks.

Market Segment	Task Code	Definition
Shop - Piping	Weld Inches (Aggregate)	Includes cutting, handling, prep, tack and welding, loaded to the door.
Shop - Piping	Joint Inches (Aggregate)	Includes prefabrication of all other joint types, plastic, grooved joint, brazed or refrigeration.
Shop - Plumbing	Hangers and Supports	Generally all labor cutting, labeling, assembling clevis hangers, unistrut or racks.
Shop - Plumbing	Underground Sanitary Waste and Vent	Includes all cast or plastic cutting and assembly or kitting.
Shop - Plumbing	Above Ground Sanitary Waste and Vent	If you don't segregate this work, include it above. This would include fixture batteries and carriers.
Shop - Plumbing	Domestic Water	All work on copper, PEX, prefabrication and kitting.
Shop - Plumbing	Storm Drain	All work on cast or plastic systems, prefabrication and kitting.
Shop - Plumbing	Natural Gas	All cutting, prefabrication and kitting.
Shop - Plumbing	Specialty Systems	Headwall prefab, water treatment, skids or other assemblies not coded in Domestic systems above.
Shop - Plumbing	Fixtures and Trim	Prefabrication work assembling components and trim.
Shop - Architectural Sheet Metal	Single Ply Panel Systems	Single Ply Panel Systems.
Shop - Architectural Sheet Metal	Ornamental	Railings, Column Covers, specialty/custom architectural metal products fabrication.
Field - Sheet Metal	Hangers and Supports	All layout, inserts or anchors, and hangers, whether cable, rod or strap, trapeze and seismic, if any.
Field - Sheet Metal	Rough In - Risers	If risers are a segregated task from other LP and MP work.
Field - Sheet Metal	Rough In - Low Pressure	All labor downstream of terminal boxes, and all 2" or lower pressure class, whether it's supply, return or exhaust, and in line accessories, as well as hangers if you don't segregate hanger labor.
Field - Sheet Metal	Rough In - Medium Pressure	All supply air duct labor downstream of AHUs and upstream of terminal boxes, in line accessories, and hangers if you don't segregate hanger labor.
Field - Sheet Metal	Air Distribution and Trim	All grilles, registers and diffusers, terminal devices, louvers, flex and taps, if not installed in rough in.

Market Segment	Task Code	Definition
Field - Sheet Metal	Dry Side Equipment	Including AHU's, DOAS, VFR components, built up housings, fans, hoods, roof-mounted equipment, filters, and essentially all equipment not accounted for in the duct rough-in above (e.g. terminal devices if reported separately).
Field - Piping	Risers	All HVAC piping in risers, if tracked separately.
Field - Piping	Hangers and Supports	All layout, inserts or trapeze systems, seismic if reported separately from the rough in categories.
Field - Piping	Heating and Cooling Water	HVAC piping, whether welded or grooved, or small-bore copper, including work in Central Plants or equipment rooms, including condenser water.
Field - Piping	Condenser/Steam/ Refrigerant	Split system DX, or distribution piping for VRF systems.
Field - Piping	Wet Side Equipment	Towers, Chillers, Cooling Towers, Pumps, Heat Exchangers, DX Condensers, DOAS or VRF components.
Field - Plumbing	Hangers and Supports	Generally, all labor cutting, labeling, assembling clevis hangers, unistrut or racks.
Field - Plumbing	Underground Sanitary Waste and Vent	Includes all cast or plastic cutting and assembly or kitting.
Field - Plumbing	Above Ground Sanitary Waste and Vent	If you don't segregate this work, include it above. This would include fixture batteries and carriers.
Field - Plumbing	Domestic Water	All work on copper, PEX, prefabrication and kitting.
Field - Plumbing	Storm Drain	All work on cast or plastic systems, prefabrication and kitting.
Field - Plumbing	Natural Gas	All cutting, prefabrication and kitting.
Field - Plumbing	Medical Gas	Medical Gas.
Field - Plumbing	Specialty Systems	Headwall prefab, water treatment, skids or other assemblies not coded in Domestic systems above.
Field - Plumbing	Fixtures and Trim	Prefabrication work assembling components and trim.
Field - Architectural Sheet Metal	Building Enclosure Components	ACM composite panels, light gauge skin, metal panels (insulated and non-insulated).
Field - Architectural Sheet Metal	Metal Roofing	Zinc, Copper, Steel and other metal alloys constructed using standing seam, flat seam and other methods.

Market Segment	Task Code	Definition
Field - Architectural Sheet Metal	Flashing	Thin pieces of impervious material installed to prevent the passage of water into a structure from a joint or as part of a weather resistant barrier system.
Field - Architectural Sheet Metal	Ornamental	Railings, Column Covers, specialty/custom architectural metal products installation.

Data Set

Figure 6: State Distribution of Productivity Data.

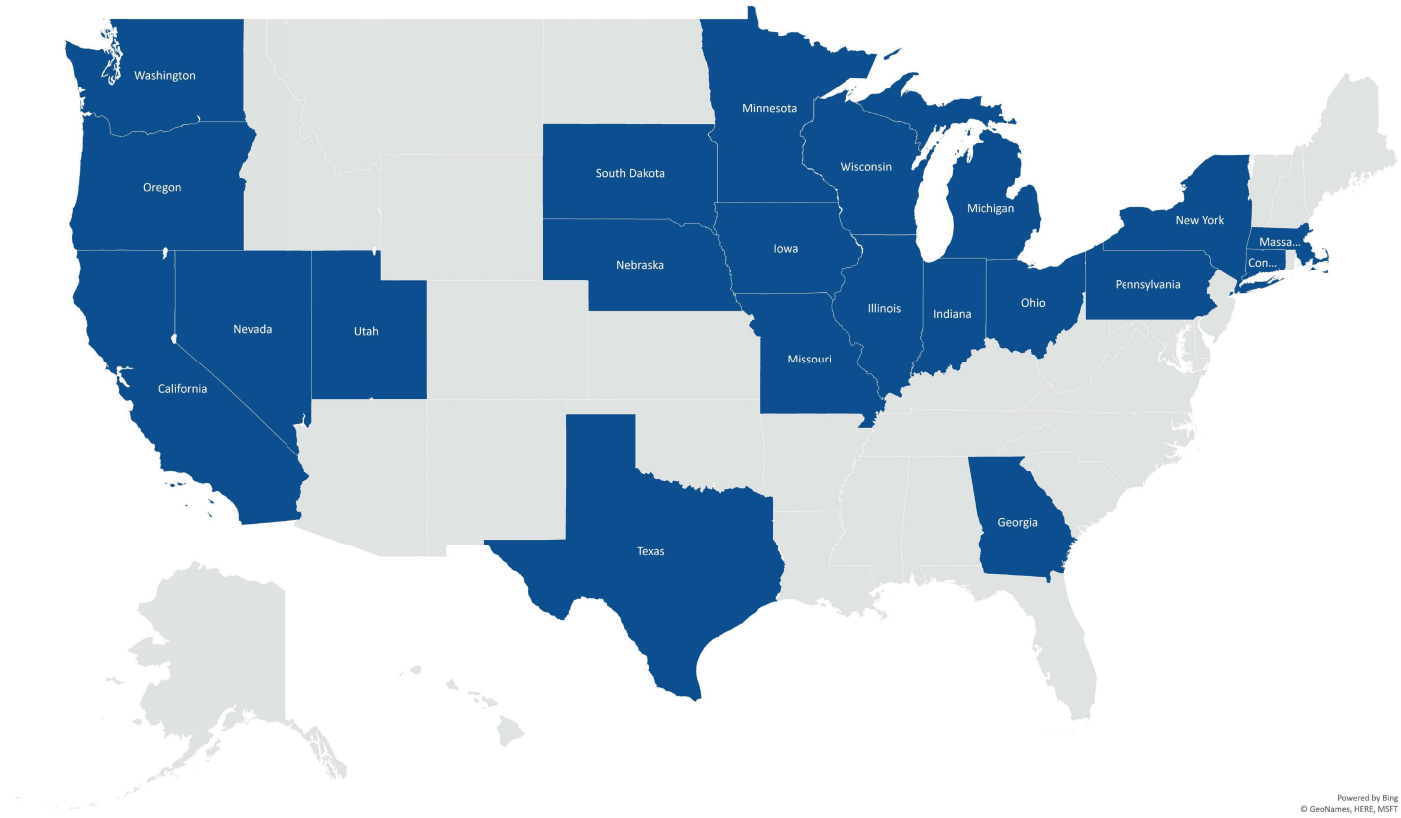


Figure 7: Concentration Heatmap of Sample Set Data Areas of United States.

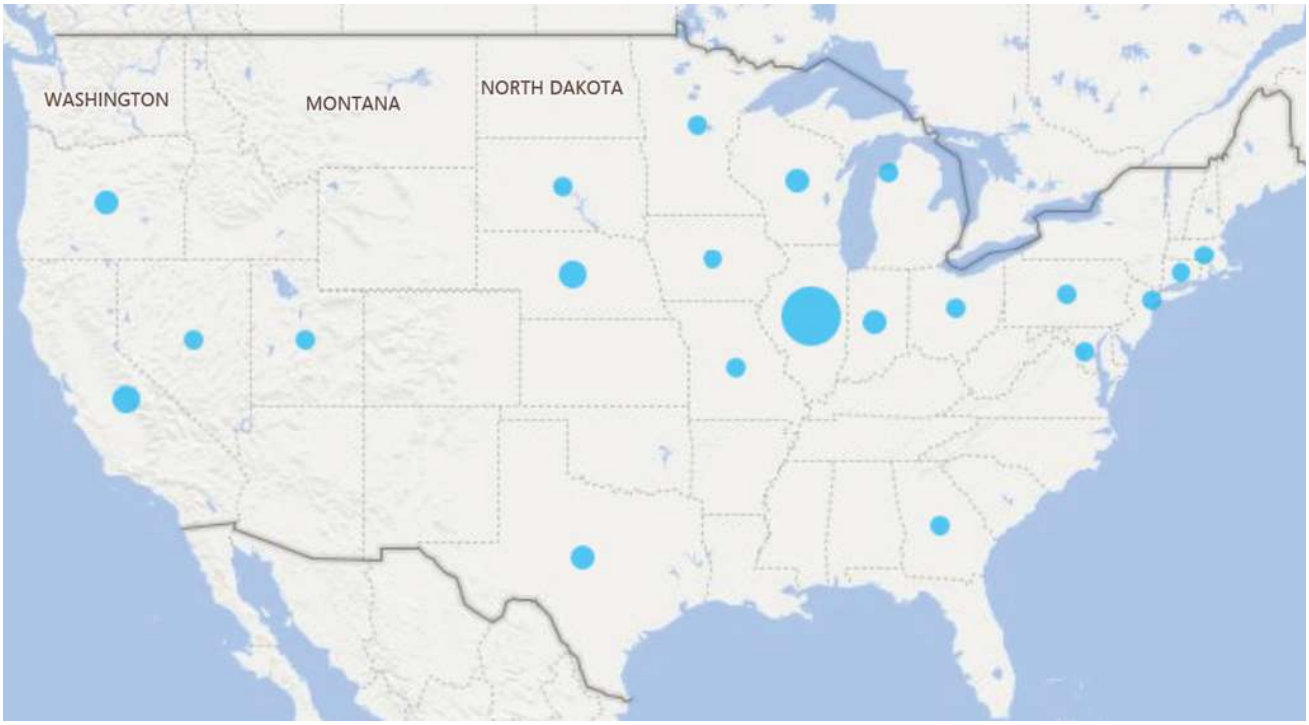
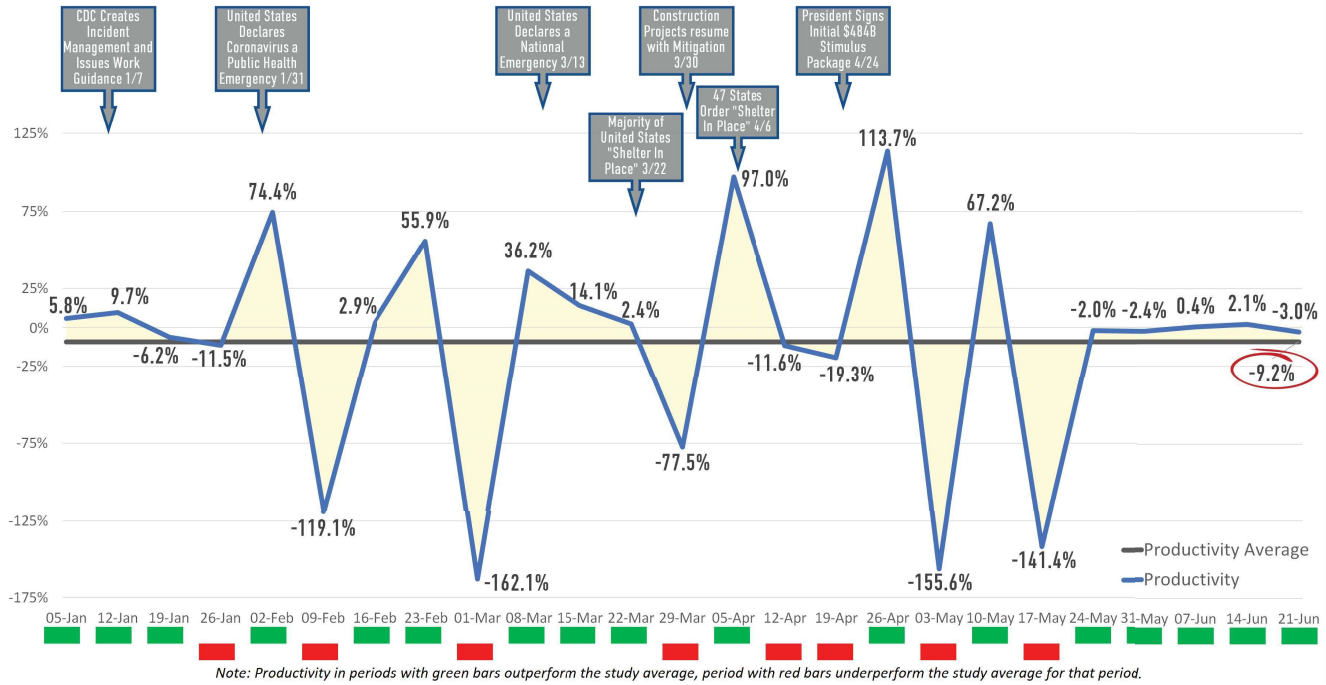


Figure 8: Sheet Metal, Mechanical and Plumbing Contractors Productivity Against Events.



Note: Productivity in periods with green bars outperform the study average, period with red bars underperform the study average for that period.

Summary Findings

Our study indicates an overall 9.2% average productivity impact on Sheet Metal, HVAC and Mechanical contractor productivity as a result of the pandemic. In the larger samples we received in the Midwest regional projects, **we are seeing the productivity loss approaching 11% on average. These productivity losses are *additive* to the mitigation impact of 8.7% (and confirmed by the New Horizons Foundation study data combined with ELECTRI at 8.8%), to produce a total productivity impact of 17.9%**. These may occur due to non-mitigation related impacts including, but not limited to: extra mobilizations/demobilizations, work fatigue from anxiety and excess absenteeism, social distancing effects, off-shift work, altered delivery & material receiving, inspection and cleaning requirements, etc. **Based on the current data, there are over 85 minutes of lost productivity per day per employee's 8-hour work period.**

Roadmap

Companies that have trended lower in productivity losses have established, organized and trained their teams with new pandemic mitigation processes and procedures. Additionally, they have monitored and shifted work activities to accommodate required distance working between team members. Contractors are using plotting pre-hangars (Trimble/HILTI) and the pre-fabrication dynamic to lessen the impact of these productivity tasks, Contractors taking advantage of and maximizing prefabrication disciplines to minimize field crews to increase efficiency.

The baseline impact of 9.2% is substantial. Contractors should utilize this information to price an equitable adjustment properly utilizing this study's associated Pandemic Change Order Calculator provided and this study as backup for the impact. Additionally, contractors should utilize this study as support documentation when requesting price adjustments.

The Pandemic Change Order Calculator can be found here:

www.newhorizonsfoundation.org/pandemiccocalculator/

APPENDICES

Appendix A: Pandemic Mitigation Tracking Data Collection Definitions & Tools

Figure 9: Pandemic Mitigation App Data Collection Tool.

Figure 10: Pandemic Mitigation App Activity Definitions.

Cost Code Definitions		
Cost Code	**Cost Code Name**	**Example activities in Cost Code**
100	Total Crew Hours Worked	Sum of all labor hours worked on your project for the day.
200	COVID Safety & Training	Any/all forms of time lost due to COVID specific safety huddles, orientations, respirator training & fitting, equipment handling, air flow equipment maintenance, sneeze shielding, etc.
201	COVID Distancing & Access Rules	Any/all forms of time lost due to site logistics, waiting to access work areas, waiting on medical screening, extra distance walking to lunch tents, additional coordination or reworking due to inaccessible work areas, etc.
202	COVID Cleaning & Disinfecting	Any/ all forms of time lost due to COVID related cleaning, disinfection, personal hygiene, filter management, disposal, etc.
203	COVID Administration	Any/ all forms of time lost due to COVID related administration, paperwork, management of suspect or positive cases, additional work coordination meetings, etc.

Appendix B: Double-Blind Productivity Benchmark Participant Survey

The research study utilized a double-blind methodology to observe pre- and post-pandemic construction productivity impacted by behavioral interventions. Blinding or masking refers to the withholding of information regarding treatment allocation from one or more research study participants. It is an essential methodological feature of studies that helps maximize the validity of the research results.

Exhibit 23

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Evaluation of measures to prevent the spread of COVID-19 on the construction sites

AbdulLateef Olanrewaju [a,*], AbdulRashid AbdulAziz [b], Christopher Nigel Preece [c], Kafayat Shobowale [d]

[a] Faculty of Engineering and Green Technology, Universiti Tunku Abdul Rahman, Jalan Universiti, Bandar Barat, 31900, Kampar, Perak, Malaysia
[b] Faculty of Built Environment, Universiti Malaysia Sarawak, 94300, Kota Samarahan, Sarawak, Malaysia
[c] College of Engineering, Abu Dhabi University, Abu Dhabi, PO BOX 5911, United Arab Emirates
[d] Air Force Institute of Technology, Nigeria, Kaduna, Nigeria

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ABSTRACT

COVID-19 is the most critical health and safety risk facing the global construction sector. The COVID-19 crisis leads to a reduction in site productivity, has increased compliance costs, delayed projects and increased construction workers' exposure to risk and infections. However, as countries begin to ease lockdowns and restrictions, there is a need to examine the measures that the construction companies can take to ensure workers are "Covid-safe". This research developed a questionnaire instrument that included 24 Covid-preventive measures on construction sites. Isolating sick workers, conducting daily checks for COVID-19 symptoms, preventing hugging/handshaking at the site, displaying health advisory posters and info-graphics, and providing face masks to workers are seen to be the main measures towards keeping sites "Covid-safe". The Principal Component Analysis structured the 24 measures into 4 components. The 4 components explained about 73% of the model, namely hygiene and control, equipment and monitoring, awareness, and incentives. The results found that compliance costs of health and safety regulations to prevent COVID-19 will increase project cost by more than 20%, site productivity will be reduced by up to 50%, and the pandemic will have caused a 40% increase in skill shortages. Cluster analysis was performed to cluster the sites in terms of their exposure to COVID-19 risk. In order to examine the practicability of the findings, the model was validated with 4 case studies. It is asserted that the research findings have the potential to keep sites "Covid-safe", which helps construction companies increase productivity, reduce project costs, reduce claims, and deliver projects on schedule. This research is the first to examine measures to prevent the spread of COVID-19 on construction sites, and the findings hold critical theoretical and practical implications for future research on health and safety management.

1. Introduction

The novel Coronavirus disease (COVID-19) is a contagious disease by a newly found coronavirus caused by the SARS-CoV-2 virus, which usually spreads when an infected person is in close contact with a vulnerable individual. In the long term, this pandemic is predicted to leave lasting scars on the global economy due to lower investments, an erosion of human capital, and fragmentation of global trade and supply linkages. It has been estimated that there will be a 5.2 per cent contraction in the global GDP in 2020. COVID-19 presents great challenges to public health. So far, the pandemic has affected 123, 902, 242 people with confirmed cases and has claimed more than 2, 727, 837 deaths (WHO, 2020a). The virus was initially thought to be "pneumonia of unknown origin" and was linked to a seafood market in Wuhan (Zhu et al., 2020). In fact, on January 2, 2020, WHO informed the Global Outbreak Alert and Response Network partners about the cluster of pneumonia cases in the People's Republic of China and on the 4 January WHO tweeted that there was a cluster of pneumonia cases but with no deaths (WHO, 2020b). Apart from China, the disease was first reported in Thailand based on the report by the Ministry of Public Health in Thailand on January 13, 2020 (WHO, 2020b). On January 14, 2020, in a press briefing, it stated that it is certainly possible that there is limited human-to-human transmission (WHO, 2020b). Moving forward, on

* Corresponding author.
E-mail addresses: olanrewaju@utar.edu.my (A. Olanrewaju), azarashid@unimas.my (A. AbdulAziz), christopher.preece@adu.ac.ae (C.N. Preece), k.shobowale@afit.edu.ng (K. Shobowale).

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nomenclature

A	Awareness
AGC	Associated General Contractors
ARI	Average Relative Index
CIDB	Construction Industry Development Board Malaysia
COVID-19	Coronavirus disease
EM	Equipment and Monitoring
HC	Hygienic and Control
I	Incentive
ILO	International Labour Organization
KMO	The Kaiser-Meyer-Olkin Measure of Sampling Adequacy
MCO	Movement Control Order
MCO	Movement Control Order
PCA	Principal Component Analysis
Q1	First quarter
Q2	Second quarter
Q3	Third quarter
Q4	Fourth quarter
SARS-CoV-2 virus	Severe acute respiratory syndrome coronavirus
SOP	Standard Operating Procedure
SD	Standard Deviation
UAE	United Arab Emirates
UK	The United Kingdom
USA	United States
WB	World Bank
WHO	The World Health Organization

January 16, 2020, the Japanese Ministry of Health, Labour and Welfare informed WHO of a confirmed case of a novel coronavirus in a person who travelled to Wuhan (WHO, 2020b). Underpinning the urgency of the infectious diseases, on February 4, 2020, The WHO asked the UN Secretary-General to activate the UN crisis management policy, which held its first meeting on 11 February. On March 7, 2020, to mark the number of confirmed COVID-19 cases surpassing 100, 000 globally, WHO issued a statement calling for action to stop, contain, control, delay and reduce the impact of the virus at every opportunity (WHO, 2020b). On the April 2, 2020, WHO reported evidence of transmission from symptomatic, pre-symptomatic and asymptomatic people infected with COVID-19, noting that transmission from a pre-symptomatic case can occur before symptom onset. WHO, 2020b). On January 30, 2020, four countries had evidence (8 cases) of human-to-human transmission outside China (e.g. Germany, Japan, the United States of America, and Viet Nam). WHO reported on 4 April that over 1 million cases of the virus have been confirmed (WHO, 2020b). Malaysia is placed at 82 with 74,295 cases and 384 death (Worldometers, 2020). Some 80% of the COVID-19 patients experience mild infection, while the infection is severe for the remaining 20% (WHO, 2019). It is a respiratory virus, and the main symptoms are dry cough, fever, and chills. In a relatively small number of cases it can lead to pneumonia and death. It is usually transmitted through droplets and fomites. Fomites are particles that remain on surfaces for a certain period (The World Bank, 2020). For example, if an infectious individual with COVID-19 coughed on their hands and then touched another surface, the particles would remain on the surface for some time. This means that cases of COVID-19 may be caused up to 72 h after that, depending on the nature of the particles. This may make its potential spread on construction sites very high because site operatives often have to work in groups and in enclosed spaces.

Like in other major economic sectors, the impact of COVID-19 on the construction sector is huge, complex, and sophisticated. More than 80% of the human resources in the construction sector that work on sites use dangerous materials and components, are exposed to harsh weather, work at heights, carry or convey heavy materials and components, work in unhygienic conditions, and have poor health and safety practices. Construction projects, except for those considered extremely necessary for national security reasons, were stopped, and construction site operatives were asked to stay at home to works on stage. The post-lockdown presents a great challenge to the global construction sector. The global construction sector will face many challenges such as insufficient site labour, closing of factories, low morale amongst the site operatives, low productivity, shortage of materials, failure to handover projects as stipulated, shortage of plants and materials, border closings, delays or inability to obtain required permits, and changes in the work culture on the sites. The virus has been spreading faster than the reasonable worst-case scenario of scientific estimates and projections (WHO 2020a). There are multiple dashboards and statistics about the spread and impact of COVID-19 on construction productivity across the world. Although there is no exact estimate on the impact of COVID-19 on construction projects, there is a series of pieces of evidence that it has a great impact on the construction industry in terms of delays, overruns, claims, and insurance. Similarly, report shows that construction sites are major spreaders of COVID-19 in many countries like Singapore, the UK, Qatar, India, the UAE, Malaysia, and the USA. Based on data from 70 medium-sized construction projects in the UK, it was found that COVID-19 will lead to project delays by 32 weeks, and an increase in preliminary costs by £600,000, and will lead to a productivity loss of 15% (Construction Manager, 2020a). Based on a survey conducted by the Associated General Contractors of America, 68% of the survey respondents opined that clients had asked them to halt or cancel projects (AGC, 2020). The AGC's (2020) research revealed that project delays due to COVID-19 are up to 23%. These delays in projects have been due to a shortage of personal protective equipment, materials, equipment, craft workers, and information (AGC, 2020). The Malaysian construction sector incurred a huge loss due to the pandemic (CIDB, 2020 and Department of Statistics, 2020a). The construction sector is one of the industries with little opportunity to work from home, and the sector remains largely labour intensive (Olanrewaju and Abdul-Aziz, 2015). As countries begin to ease the lockdown, this paper reports a study that investigated the measures that construction companies have used to reduce the spread of COVID-19 on sites during and after the lockdown. This is important because construction companies have to reopen and operate alongside a virus that has remained a great threat to the sector and the economies. To achieve this aim, this research identified, prioritized and categorized the COVID-19 preventive measures for construction sites. While prioritisation will help to examine the measures individually, categorizing the measures will help construction companies to streamline and enhance decision making to reduce the impact of the virus on the construction performance. Furhermore the Principal Component model was developed and validated with data from 4 construction sites. Although, there have been limited research on the impact of the COVID-19 crisis on a construction project, the studies are based on simulation (Araya, 2021a), literature (Pamidimukkala et al., 2021). As the impact of the pandemic on the global construction sectors is being examined (Pamidimukkala et al., 2021), there is no systemic and empirical evaluation measure to reduce it spread and impact on construction. Although, Araya (2021a) modelled the impact of the COVID-19 on project duration, they found that COVID-19 could extend project duration by between 30% and 90%. However, the estimation was based on simulation on one site only. Recognizing the inadequacy of the simulation results, in terms of oversimplification of real-life conditions, actual data from construction sites should be used rather than simulation (Araya, 2021a,b). The present research collected primary data through a survey questionnaire that was administered on

construction sites in Malaysia.

2. The construction sites as a main driver of COVID-19 transmission

COVID-19 presents severe health and safety challenge to the construction sector. The vulnerability of construction workers to illnesses, injuries, and deaths are high because site operatives work in unhygienic conditions, use sophisticated equipment, are exposed to harsh weather, use harmful materials, and carry heavy components and are exposed to infectious diseases. Zhou et al. (2015) reviewed safety management policies in the construction industry in 34 economies, from which it was concluded that despite the various measures taken to improve the safety records on sites, accidents and injuries continued to plague the construction industries. The COVID-19 pandemic required a new way of working through strengthened OSH measures, adaption of work arrangements, and management of stress and other psychosocial risks (ILO, 2020 and Occupational Safety and Health Administration, 2020). The main routes of infectious disease transmission on construction sites include contact, droplet, and airborne. Airborne means that the virus can be suspended in the air and linger in the air for a long time. Like most infectious diseases, the COVID-19 virus can be transmitted through direct and indirect contact. Direct contact is when the infectious agent is transferred to a vulnerable individual through physical contact with an infected individual. Indirect contact transmission occurs when a vulnerable individual comes into contact with contaminated items and surfaces such as construction materials, components, equipment, and food that have previously been touched by an infectious individual. COVID -19 can also be transmitted when an infected person coughs, sneezes, or talks and the droplets reach the mucosal surfaces of the eyes, nose, or mouth of a susceptible individual. However, because some of the droplets from COVID-19 are large and can survive for a long time in the air, it is also airborne. Hence, when the small suspended particles are inhaled by a vulnerable person, the droplets will enter the respiratory tract of the vulnerable person and lead to an infection.

COVID-19 affects people in different ways. The virus that causes COVID-19 is mainly transmitted through droplets generated when an infected person coughs, sneezes, or exhales. Most of these droplets are too heavy to hang in the air and quickly fall on the floor or surfaces. Individuals can be infected by breathing in the virus within close proximity with someone who has COVID-19, or by touching a contaminated surface, eyes, nose or mouth. According to the WHO, the spread of COVID-19 can be controlled by taking specific measures, including ensuring physical distancing, wearing a mask, keeping rooms well ventilated, avoiding crowds, cleaning hands, and coughing into a bent elbow or tissue. The symptoms of COVID-19 include dry cough, skin rash, tiredness, fatigue, runny nose, vomiting, aches and pains, sore throat, diarrhoea, conjunctivitis, headache, loss of taste, fever, irritation, or discolorations of fingers or toes. The pandemic has major repercussions on the health outcomes of other diseases as resources and medical staff are diverted to combat the COVID-19 scourge (Wilder--Smith et al., 2020 and Clemente-Suárez et al., 2021). As a result, those withother mental health disorders are not receiving enough attention. In Malaysia, many urology wards were converted to COVID-19 wards (Zhu et al., 2020 and Cleveland Clinic, 2020). In fact, many are scared or advised not to go to hospitals for their regular treatments for fear of contracting the virus. The lockdown and shortened hours of the hospital and health centres pose a great challenge to those with mental health problems.

The construction site is an epicentre of the spread of infectious diseases ((Liu et al., 2021; New Straits Times, 2020a, 2020b, 2020c, 2020d; Fadilllah, 2020c), with a very high spillover onto adjoining areas. Construction site operatives are occupationally exposed to a variety of infectious diseases on their sites. The delivery of construction projects involves a broad range of workers, including painters, electricians, scaffolders, plumbers, decorators, steel erectors and labourers, clerks of work, site engineers, site quantity surveyors, site supervisors, and construction managers. The variety of the workers allows occupational exposure to infectious diseases to become challenging, particularly with the limited space and poor hygiene at the sites. The impact of COVID-19 on the sites' activities is extremely high and complicated with severe problems, such as health and safety issues, delays, low profit margins, poor quality work, cost overruns, shortage of skilled workers and disputes. The construction sector is facing decisions about how to continue operation whilst keeping construction labour, especially the site operatives, safe and healthy from the scourge of the COVID-19 disease that is moving fast and is ill-understood. All construction projects, except for those considered extremely necessary for security reasons, have stopped operation and construction site operatives have been asked to stay at home. The Post-lockdown poses a great challenge to the global construction sector as it moves to recover from the effects of the COVID-19 pandemic. In the long term, the post-COVID-19 period will impact the construction industry greatly, the demand on the construction sector will be huge, especially as the government becomes eager to make investments in infrastructure and construction to revise the economy. This could be faced with a shortage of resources, however.

Whilst investments in public projects will increase, it may take some time for the private sector to improve significantly. Whilst the availability and affordability of the vaccine are ongoing, it is strategic to keep the virus under control. Although various vaccines may be available, it could be logistically complicated to administer. It may also take some time to research developing countries. Construction workers may also not be able to procure it. Keeping the virus under control on construction sites requires taking various measures to reduce the infection rate on the construction sites. The remainder of this paper is organized as follows. Section 3 discusses the impact of COVID-19 on costs and time for construction projects across the globe. Section 4 is devoted to the impact of the virus on the Malaysian construction sector. In section 5, the research design and data analytics for this research were explained. Section 6 contained descriptions of the results of the collected data set employed in this study. The discussions of the findings are presented in section 7. The general summaries of the findings are provided in section 8 as a conclusion and limitations.

3. Impact of COVID-19 on construction activities internationally

It has been estimated that there will be a 5.2 per cent contraction in the global GDP in 2020. This is the worst crisis since the greatest economic crisis since the depression 75 years ago, and this is the greatest health crisis since the flu pandemic 100 years ago. The virus has different impacts on the construction sector. For instance, whilst public construction is one of the sectors.allowed to operate during the lockdown, the activities in the private sector are still not in full or high operation. However, the operation of both the public and private sectors will be affected. As the supply chain has been disrupted by labour and materials shortages, the termination of contracts by the Government has begun. Many contractors have already been stressed, at least in the short run, and in an effort to minimise losses, many construction companies have already suspended or cancelled contracts and projects. Many construction companies operate with only a small capital base. Hence, the impact of COVID-19 could mean that most construction companies will have to seek alternate means of financing projects and claim management. In fact, according to PwC's survey on COVID-19, 81% of CFOs are considering cost reductions in response to the pandemic, and 60% of the construction companies plan to defer or cancel investments (PwC, 2020). In the long term, construction companies, the contractors, in particular, will be faced with low demand for both private and public projects, especially as the government's deficit and debt increase. Some construction companies may be able to sustain operations due to expertise and the backlog of projects before the COVID-19 crisis., In the longer term, construction companies will be affected by low demand and a shortage of resources. In general, construction companies with high

debt profiles may go bankrupt; subcontractors may stop operations due to a lack of financial support, and construction management practises (especially contract management, contract administration and procurement management, finance management, claim management, etc.) will assume prominent roles. Many of the current contract provisions will be revised to address COVID-19 related matters. Whilst many construction companies may prevent losses or litigation by relying on force majeure; it may not be a sufficient ground to stand on. Therefore, many renegotiations on the part of construction companies, clients, sponsors, legal advisers, and regulatory bodies are required. Furthermore, the pandemic will affect international projects and contracts as countries have enacted various acts and regulations to reduce the spread and impact of COVID-19 in the countries. Most countries have imposed entry restrictions on their citizens, and many embassies and consular offices have closed due to policy requirements. Many site workers have over stayed their visas without the opportunity to renew their visas or work permits. In countries like Singapore, Malaysia, Qatar, and the UEA, many foreign construction workers have been stranded at airports or quarantine centres for months. In fact, the situation has turned the labour camps for the construction workers on the Qatar 2022 World Cup into a "virtual prison", which has triggered serious health and safety concerns for the welfare of the workers (Business and Human Rights Resource Centre, 2020). Most of the provisions in the new acts and regulations are different from those that were in operations whilst the contracts were being signed. Even if the construction companies want to abide by them, it would not be immediate. Therefore, a key question is how contractors will ensure the health and safety of their operatives on the construction sites in order to reduce losses, project costs, and project duration, and increase productivity and maximise profits.

The pandemic is affecting the construction processes and phases, including the process of handover of completed and certified projects. For instance, some clients have been unable to take possession of their projects due to movement restrictions. PwC (2020) found that the financial stability, safety, and well-being of site operatives are the main challenges facing construction companies during the pandemic. Imported materials and components may arrive late or may never even arrive because many countries, such as China, the UK, and Italy, have slowed or shut down production of a wide range of key materials, such as steel and cement (EIC, 2020). Effectively, construction projects that depend on supplies from these countries may face supply chain disruptions. It has been estimated that the construction industries in the Middle East and North Africa (MENA) regions will see a −2.2% contraction in construction output in 2020 due to COVID-19 (International Construction, 2020). The French construction industry, despite being exempted from the nationwide lockdown, is expected to shrink by 9.4% in 2020 due to the pandemic (International Construction, 2020). US construction employment declined by 975,000 jobs in April 2020, according to the results of a survey conducted by the Associated General Contractors of America (AGA) and data from the construction technology firm Procore. COVID- 19 is also worsening the state of mental health pressure in the construction industry. It is a public health crisis. Construction workers are experiencing more vicarious trauma, depression, anxiety, exhaustion, and lack concentration. The impact of COVID-19 has made 65% of the Indian construction companies lose 40% of their profits (Global Construction Review, 2020). 14 workers at a 400ha at the LNG Canada Project Site overseen by American engineer Fluor and Japan's JGC tested positive for Covid-19 by Canada's Northern Health Authority (Northern Public Health Canada, 2020). New Zealand announced a stimulus package amounting to NZ$12 billion, which is part of the massive infrastructure package for the building and upgrading of roads, rail, schools, and hospitals across the country (Heights, 2020). The pandemic has reduced construction productivity by 70% even though there has been opening of the sites, and it has lowered the demand for construction around the world by a recorded margin.

Table 1
Value of construction work done, Q1 2010 - Q4 2020.

Quarter	Number of projects	Value of work done RM′000	Percentage change (%)	
			(QoQ)	(YoY)
Q4/2020	14,160	31,730,846	1.2	−14.2
Q3/2020	13,598	31,367,003	58.6	−13.1
Q2/2020	12,676	19,780,063	−43.6	−44.9
Q1/2020	11,857	35,040,152	−5.2	−6.3
Q4/2019	11,862	36,978,460	2.5	1.3
Q3/2019	11,018	36,076,604	0.4	−0.6
Q2/2019	10,579	35,919,139	−4	0.8
Q1/2019	9939	37,397,513	2.4	0.7
Q4/2018	9892	36,511,049	0.6	4.1
Q3/2018	9905	36,287,482	1.9	5.2
Q2/2018	9580	35,624,699	−4	5.3
Q1/2018	9259	37,123,931	5.8	5.9
Q4/2017	8747	35,077,956	1.7	7.7
Q3/2017	8844	34,495,002	2	8.1
Q2/2017	9405	33,825,084	−3.5	11.2
Q1/2017	9572	35,053,464	7.7	9.7
Q4/2016	9791	32,559,568	2	8.1
Q3/2016	9725	31,909,993	4.9	10.7
Q2/2016	9983	30,427,274	−4.7	11.7
Q1/2016	10,043	31,941,170	6	11.1

Department of Statistic Malaysia (2020c).

4. Impact of COVID-19 in the Malaysian construction sector

In Malaysia, the outbreak was linked to Chinese tourists that travelled from Singapore to Malaysia through Johor Baru on January 22, 2020. Eight suspected cases were directly linked to the first case (Abdullah, 2020). Twenty-two positive cases were reported during the first wave, and all were discharged after treatment (Khor et al., 2020). Various measures were implemented to curb the spread of the virus. Some of the measures include screening travellers at all entry points to Malaysia, increasing the number of hospitals to treat the infected victims, setting up provisional hospitals (Shah et al., 2020) and creating quarantine centres. By March 2020, five hundred and fifty-three cases were reported. In order to break the spread, the MCO (Movement Control Order) was implemented on March 18, 2020 across the whole county (Muhyiddin, 2020). The restriction was to last for two weeks, but because of the increase in the rate of infections globally and nationally, the restriction was extended. The Malaysian construction sector is one of the most severely affected sectors by the pandemic (Department of Statistics, 2020c). The construction sector incurred $6bilion in losses in the first three lockdown (Fadillah, 2020a). In the first and second phases of the lockdown between March 18 and April 14, RM11.6 billion were losses, and RM6.9 billion in losses were incurred between April 15 and April 28 in the third phase. Twenty-nine per cent of the losses was due to the unemployment of industry workers as construction projects had to be halted (Lee, 2020). The other losses were due to production and

shortage of materials and supply of machineries. The value of construction work done in the first quarter of 2020 contracted by 6.3 per cent (Q4 2019: 1.3%) year-on-year basis, amounting to RM35.0 billion (Q4 2019: RM37.0 billion) (Department of Statistics, 2020a). Furthermore, the value of construction work done in the second quarter of 2020 contracted by 44.9 per cent (Q1 2020: −6.3%) year-on-year basis, amounting to RM19.8 billion (Q1 2020: RM35.0 billion). (Department of Statistics, 2020b). However, the value of construction work done expanded by 58.6 per cent as compared to the second quarter of 2020, amounting to RM31.4 billion (Q2 2020: RM19.8 billion). However, on year-on-year comparison, the value of construction work done improved −13.1 per cent (Q2 2020: −44.9%) in the third quarter 2020. There is a significant decline based on the year-on year in the fourth quarter of 2020 compared to the fourth quarter in 2019. The quarterly and yearly performance of the Malaysian construction sector is contained in Table 1, from which a 5-year trend can be observed. Although some continuous recovery has been seen, especially on the quarterly basis, there is a decline, but it is high and will be high till the fourth quarter 2020 with the second wave of the crisis, which may extend to the fourth quarter of 2021.

While employment in other sectors improves, there is also a significant increase in the unemployment rate in the construction sector during the outbreak (Mahidin, 2020a). The decline in employment in the construction sector may reflect shortages of labour supply in both sectors (Mahidin, 2020a). Inspections conducted by the CIDB involving 3282 construction sites from April 20 to July 2, 2020 revealed that 84% complied with the COVID-19 SOP on construction sites (The Edge Market, 2020),15% were warned for violating the guidelines, while 1%, or 19 sites, were closed down. Furthermore, inspections involving 7699 construction sites nationwide from April 20 to June 14 (Fadillah, 2020b). 370 construction sites received a warning for not adhering to the COVID-19's SOP, while another 17 were ordered to close pending further instructions. Some of the offences include not conducting body temperature checks or providing hand sanitiser, not enforcing social distancing and failure to obtain approval to commence work (Fadillah, 2020b). However, legal issues relating to claims due to COVID-19, including extending the completion duration would be resolved via a COVID-19 (Temporary Measures) Bill (Fadillah, 2020b). Many experienced construction workers were laid off due to the pandemic (Rodzi, 2020). Many construction foreign workers have returned to their countries due to the lockdown and have not been able to return to Malaysia (Wahab, 2020) due to various movement restrictions and visa procedures. On April 27, 2020, the (CIDB) published the first guidance documents in relation to the execution of construction works during the lockdown. The SOP outlines measures the CIDB considers will reduce the impact of the MCO and the COVID-19 pandemic on the construction sector. With about 12 months of total and partial lockdown, several weeks or months of productivity have been lost. The implications of these statistics are that in order to clear the backlog of construction projects that were suspended, abandoned and delayed and to meet with new demand pose great challenge and risk to the construction industry. Thus, over the next 2–5 years, the industry will struggle to meet demand amidst a shortage of materials and labour.

Globally, although there is increasing attention to conduct research on the impact of the pandemic (Araya, 2021a), risk mitigation measures (Radulescu et al., 2020) and measures to reduce the impact of the pandemic, there is no empirical research that evaluate the impact of the pandemic on productivity on construction sites. There is no empirical research that evaluated the impact of the virus on the schedule and cost of construction projects and importantly, on the measures to reduce the spread of the pandemic on construction sites. This aims to lay the foundation for an improved understanding of the impact of COVID-19 on construction projects, and possible measures available to construction companies to reduce the spread of the virus on sites in an effort to increase productivity, and reduce loss and claims in Malaysia and globally.

5. Research design and data analytics

The research combined both exploratory and explanatory methods by asking both why and how questions. Although health and safety have received considerable attention in the construction management literature, the literature on the impact of COVID-19 on the construction sector is nascent globally. The constructs on the survey form were based on on-site observations, interviews with site operatives (i.e., project managers, construction, health and safety personnel), and the authors' experiences. The constructs were collated and pretested amongst seven different site operatives. The final survey form was designed based on the consideration of the input of the pretext results. Therefore, this research has not been directed by any sound theories in the literature, but rather, it has been formulated based on practices, experience, and the cross-examination of media reports. Specifically, the questions that this research has sought answers to are: 1) What are the impacts of COVID-19 on the project? 2). What are the measures to reduce the spread of COVID-19 on sites? 3), How can the "Covid-safe" measures be structured for decision making on construction sites? and 4) How can sites be classified in terms of the "Covid safe" measures? The primary data collected were based on snowball sampling. Snowball sampling is a non-probability sampling technique that is used if there is less information on the potential respondents. However, one of the limitations of this technique is that the number of respondents will not be known to the researcher. Also, its findings may not be generalisable; but with large respondents, the findings can be representative. Thus, its basic premise is that if sufficient data are collected and objectivity is maintained, the results will be indicative of the population (Olanrewaju and Idrus, 2020).

The questionnaires were administered to the respondents online. The survey was launched on 6/15/2020 and opened until October 27, 2020. The respondents were asked, based on evidence, to tick the degree to which they agreed with each of the constructs on the survey form. The measures to be Covid-safe on sites were measured on a 6-point continuum scale of 1–6, where 1 denoted not taken at all, 2 least taken, 3 less taken, 4 moderately taken, 5 denoted strongly taken, and 6 denoted extremely taken. The measures were positively worded. Higher scores indicated a higher taken measure. The considerations of the measures were determined by the average relative index (equation (1)) and the standard deviation.

$$ARI = \frac{\sum_{i=0}^{6} a_i x_i}{6\sum_{i=0}^{6} x_i} \times 100 \qquad \text{(Equation 1)}$$

Where $a_i$was the index of a group; constant, expressing the weight given to the group; xi was the frequency of the responses; i = 1, 2, 3, 4, 5, and 6, and was described as below: $x_1, x_2, x_3, x_4, x_5 x_6$ were the frequencies of the responses corresponding to $a_1 = 1, a_2 = 2, a_3 = 3, a_4 = 4,\ a_5 = 5,$ $a_6 = 6,$ respectively. For interpretation, an ARI score of 1.00–16.67 denoted not taken at all, 16.68–33.33 denoted least taken, 33.34–50.00 denoted less taken, 50.01–66.67 denoted moderately taken, 66.67–83.33 denoted strongly taken, and 83.34–100 denoted extremely taken. There was a pooled difference of 1.0% between each of the scales. The other statistical tests computed were the one-way test, Split-Half Coefficient reliability tests, convergent validity, and mode. The *t*-test was conducted to test the hypothesis of whether each of the measures could reduce the spread of COVID-19 or not on construction sites. The principal component analysis (PCA) was also conducted to cluster the measures taken to be Covid-safe for effective decision making. The PCA is a form of an unsupervised machine learning algorithm that is used in grouping constructs but without information loss. PCA is the popular form of factor analysis, and it is one of the decomposition libraries in data science. Unlike the factor analysis that aims to develop a measurement model for latent variables, it is a linear combination of related variables in the dataset. It is used to analyse interrelationships amongst a large number of variables in a dataset to cluster the variables into more

Table 2
Respondent's organization.

Organization	Frequency	Percentage	Cumulative Percentage
Main Contractors	75	63.6	63.6
Sub-contractors	24	20.3	83.9
Suppliers	5	4.2	88.1
Others	14	11.9	100.0

Table 3
How many percentage increases will compliance to health and safety regulation due to the COVID-19 have on your project cost?

Cost increase	Frequency	Percentage	Cumulative Percentage
Less than 10%	10	8.7	8.7
10–20%	21	18.3	27.0
20–30%	20	17.4	44.3
30–40%	16	13.9	58.3
40–50%	15	13.0	71.3
50–60%	16	13.9	85.2
60–70%	3	2.6	87.8
70–80%	4	3.5	91.3
80–90%	2	1.7	93.0
90–100%	8	7.0	100.0

meaningful components or factors. It creates new uncorrelated constructs that maximise variance by clustering variables in a large dataset. The clustering can be computed based on the correlation or covariance matrix amongst the variables (Pituch and Stevens, 2016). It is useful in the field of pattern recognition and signal processing and constitutes a fundamental aspect of multivariate data analysis (MVDA) because it is a method of reducing the dimensionality of a multivariate dataset. However, the main uses of the PCA are descriptive rather than inferential (Jolliffe and Cadima, 2016). In addition, cluster analysis using K-means has been performed. K-means is an interdependent technique that is very useful in segmentation. The K-means analysis aims to create groups or classify objects with many similarities within a group. Thus, within a cluster, there will be many homogeneities, but there will be heterogeneity or dissimilarity amongst the groups. Unlike the factor analysis, the similarities are determined by a distance, not correlation or covariance. All the data gathered adopted the IBM SPSS Statistics Data Editor 25 for the data analytics.

6. Analysing the results of the survey

The online survey form was sent to more than 400 respondents working on different construction sites. The respondents were asked to forward the form to their colleagues/friends working on different sites. However, by the cut-off date, only 120 completed forms were received after several reminders. Missing data could have been addressed by either replacing the missing data with the mode or mean of the construct. However, the missing data were not treated in this way so as not to influence the data.

6.1. Analysing the respondents' profiles

The results of the survey are contained in Tables 2 and 3 and Figs. 1–3. 64% of the responses were from the main contractor organisations, and most of those from "other" organisations were from developers and consultancy firms (Table 2). The data revealed that 68% of the respondents obtained Bachelor's degrees, and 13% had MSc degrees. 17% had diploma grades, whilst the remainder had other qualifications (i.e., certificates). The respondents had their degrees in construction management (45.6%), civil engineering (18.3%), quantity surveying (17.2%), mechanical engineering (4.2%), architecture (2.5%), and others. 40% of the sites were involved in residential construction, and 62% of the sites were involved in industrial, commercial, and infrastructure projects. About 80% of the construction companies were not in full operation during the pandemic (Fig. 1). In fact, for some 50% of the companies, only 20% of their sites were in operation.

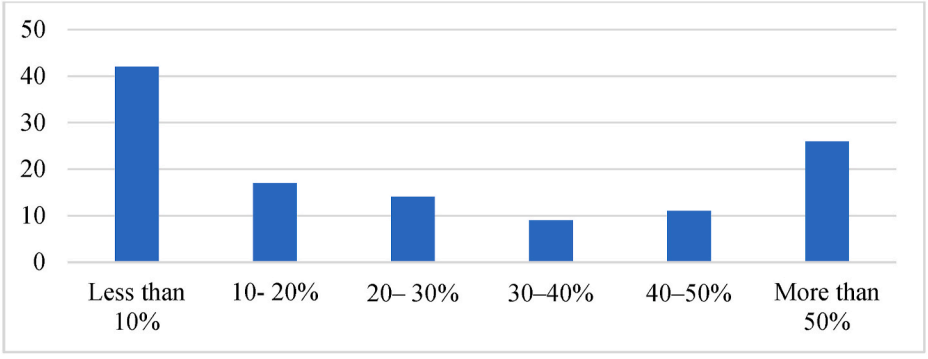

Fig. 1. How many percent of your sites were in operation during the lockdown?.

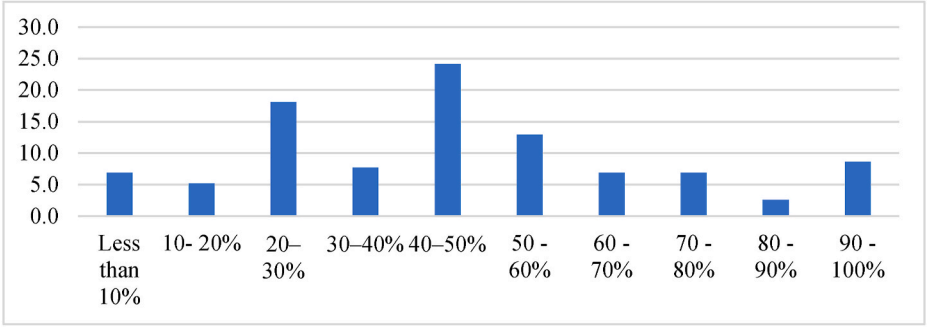

Fig. 2. To what extent will compliance to health and safety regulation due to the COVID-19 reduces the Progress/productivity project on sites?.

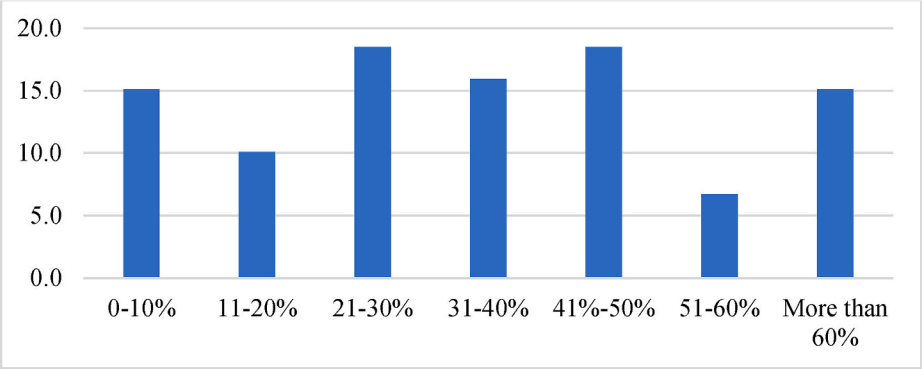

Fig. 3. To what extent has the COVID-19 creates skill shortage to your sites.

6.2. Impact of Covid-19 pandemic on construction projects

The first question that this research seeks answer to relates to the evaluations of the impact of COVID-19 on the project's time and cost. Previous studies (Araya 2021a) simulated that the project's duration can be extended by 30% and 90%. However, because it was based on a simulation of one project involving 100 workers, site data from multiple projects are required to validate the findings. Besides, the research does not include the impact of COVID on the cost of the projects. It is important to evaluate the impact of compliance due to the pandemic on project cost and time, to guide construction companies in claim management. While suspension or shutdown of a project could affect the project cost and schedule, it is the evaluation of the compliance cost that the contractors/subcontractor is most critical in claim management. In most countries, construction companies were allowed to operate but with strict adherence to the COVID-19's SOP. For instance, in some cases, only 50% of the workers are allowed access to enter the sites. Yet, the workers are required to wear a mask, use sanitisers, practise social distance, daily COVID test, site fumigation, among other measures (see the third research question). All these have a significant impact on-site productivity, profit margin, project's cost and duration. As Table 3 contained, the COVID-19′ compliance costs have a different impact on the project. The variability may be due to the project's size, location, and types of a project. It may also depend on the stage where projects stood at the time of the shutdown and if a project was suspended or not. However, in the estimation of 70% of the companies, compliance costs of the health and safety regulations for COVID-19 would increase the project costs by more than 20% (Table 3). The average percentage of the compliance cost is approximately 35% (30%–40%), and the standard deviation is 25%. In other words, complying with the new health and safety on construction sites due to the pandemic could increase the project's cost by10% to 60% in most of the projects or sites.

The major impact of the pandemic on the construction sector relates to the compliance with regulations. As a result, site productivity is highly affected. Therefore, it is not surprising that productivity is impacted. As Fig. 2 revealed, the impact varies, but in most cases, it is more than 10%. The data revealed that, on average, site productivity had been reduced by about 50%. With the mean score of 5.14 and a standard deviation of 2.445, it is obvious that adhering to the SOP of the pandemic on-site would reduce productivity by between 20% and 70% for most of the projects or sites. The findings are very exciting and have immense practical implications because, in many countries, only about 50% of the site operatives were allowed access to construction sites due to the pandemic. Thus, the findings seem to follow the reality in most countries.

Human capital in the construction sector has been severely impacted by the pandemic. Most of the construction site operatives were foreigners, and many foreign construction workers that returned to their countries could not return to Malaysia due to movement restrictions during the pandemic. Even the movement restrictions within the country restrict the movement of foreign workers from one state to another. Some also contracted the virus, which led to skill shortages.

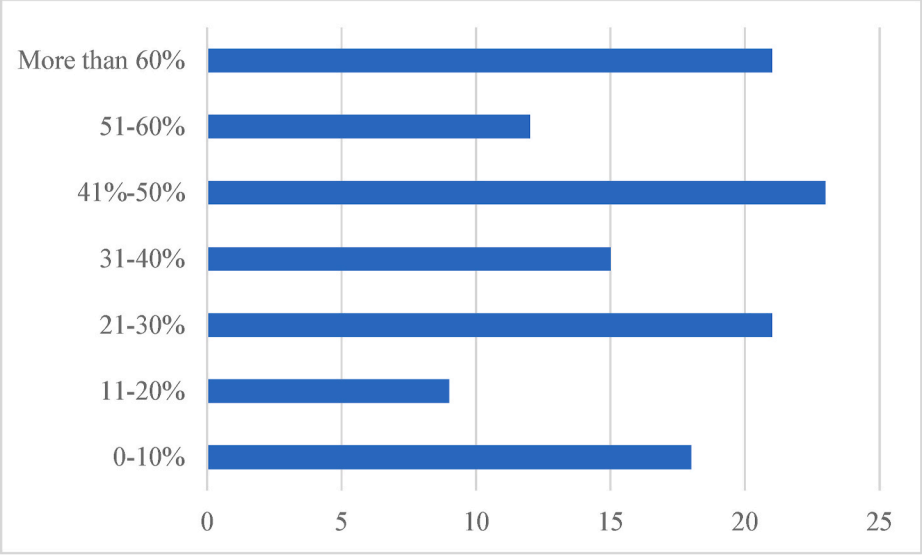

Fig. 4. What percentage of the coming year projects would be delayed/suspended/cancelled due to the COVID-19?.

Table 4
Reliability statistics.

Cronbach's Alpha	Part 1	Value	0.924
		N of Items	12
	Part 2	Value	0.932
		N of Items	12
	Total N of Items		24
Correlation Between Forms			0.893
Spearman-Brown Coefficient	Equal Length		0.944
	Unequal Length		0.944
Guttman Split-Half Coefficient			0.942

Therefore, it is not surprising that Fig. 3 revealed that COVID-19 has led to a skills shortage in most construction companies by up to 40%. Only about 50% of the companies have paid their staff fully during the pandemic. 30% advised their staff to take half payment, and the remainder were asked to take unpaid leave. However, foreign workers have only been paid when they work. Effectively, during the lockdown, foreigners have not been paid at all.

Although the condition is improving now, as compared to mid-2020, many projects are still shut down, delayed and many are still in the queue. Governments and public authorities will likely be aiming to advance spending on infrastructure projects as soon as possible. However, the pandemic has led to the delay and suspension of many projects due to shortage of skilled labour and materials, in addition to the movement and work restrictions. Even for the projects that continue during the pandemic, it is arguable the projects will be delayed. In fact, there are a significant numberof scheduled delays globally. Extant simulated data on a project shows that the pandemic can delay the project by up to 90%. However, Fig. 4 displays the extent to which the pandemic has or would delayed projects based on the data from the construction sites. Approximately 85% of the companies estimated that the pandemic will delay projects by upto 90% (Table 4). However, most of the site's projects would be delayed by about between 20% and 65%.

6.3. Results on the measures to minimise the spread of COVD on construction sites

The reliability test results indicated that the Guttman split-half Coefficient and correlation were very high (Table 4). Guttman tests the internal consistency reliability of the measures. In Guttman, it is assumed that the two halves of the test should produce similar accurate scores and error variance. Values of more than 0.60 for both the correlation and Guttman coefficient are recommended. The validity test was based on construct validity. Construct validity may be assessed through the discriminant and convergent validities. Most of the correlation results were more than 0.20 and less than 0.80. If the correlation is more than 0.80, it implies collinearity; if less than 0.2, it implies that the measures are not related (Olanrewaju et al., 2019). The results of the one-sample *t*-test confirmed the (Hr: U > U0) hypotheses that the measures can keep construction sites safe from COVID-19. However,

Table 5
Descriptive statistics of the measures to prevent COVID-19's spread.

Measure	Not taken at all	Least taken	Less taken	Moderately taken	Strongly taken	Extremely taken	ARI	SD	Lower	Upper	Std. Error Mean
Self-isolation for workers who fall ill/sick	1	2	2	21	29	64	87.40	16.92	84.33	90.50	1.43
All workers must be examined for likely COVID-19 symptoms daily	3	2	2	18	29	62	86.50	19.62	83.00	90.00	1.73
No hugging/hand shaking on the site	2	1	6	20	31	59	85.57	17.93	82.33	88.83	1.55
Display health advisory posters and info-graphics in a language understand by the workers	2	0	6	21	32	54	85.22	18.23	82.00	88.50	1.75
Provide face mask to workers	7	1	1	15	35	59	84.88	22.77	81.00	88.83	1.93
Provide health education to workers regular	0	2	4	22	48	43	84.32	15.90	81.50	87.00	1.50
Abide by government policy	1	1	6	20	47	44	84.03	14.95	81.00	87.00	1.55
Ensure regular supply of sanitiser	4	1	8	18	30	57	83.90	21.47	80.17	87.67	1.75
Keep social distancing	3	3	5	23	36	49	82.63	20.58	79.00	86.17	1.67
No gathering or crowding	6	1	4	20	39	49	82.50	21.03	78.67	86.33	1.82
Ensure regular supply of clean/fresh water	8	1	2	18	43	47	81.93	22.50	77.83	86.00	2.07
Wash hand frequently	6	3	10	18	31	50	80.37	23.12	76.17	84.67	2.05
Suspend non critical activities on sites until condition improve	5	2	8	25	42	37	79.13	20.83	75.33	82.83	1.90
Disinfect surfaces and objects used by others	5	2	10	28	32	42	78.85	22.48	75.00	82.83	1.88
Workers to cover their mouth and nose when they cough/sneeze	7	5	10	18	34	45	78.28	23.53	73.83	82.67	2.20
Company to provide separate accommodation for workers based on the projects works	6	2	10	29	30	42	78.15	23.53	74.00	82.17	1.97
Restrict/stagger access to site welfare facilities	7	2	5	27	43	34	78.10	22.65	74.17	82.00	1.83
Provide incentive to sick worker- with this they will report their medical status	7	5	5	25	39	37	77.55	24.10	73.33	81.83	2.27
Fumigate sites at least once daily – especially at close of day work	5	7	4	27	45	31	77.03	22.83	73.17	81.00	1.97
Wear special safety mask if working in less than 1m apart	7	6	12	24	32	36	75.07	24.00	70.67	79.50	2.23
Workers to work in teams but inter team's interaction is prohibited	9	5	9	27	45	24	73.25	23.85	69.00	77.50	2.05
Foods/drinks should be provided on sites-workers not allowed to eat outside during the working hours	13	5	11	30	35	25	70.17	26.25	65.50	74.83	2.38
Wear gloves	11	5	8	44	35	16	68.90	23.20	64.67	73.00	2.13
While using scaffold, restrict access to one person at a time	12	5	18	29	33	22	68.48	25.52	64.00	73.00	2.32

Table 6
KMO and Bartlett's test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.910
Bartlett's Test of Sphericity	Approx. Chi-Square	2723.309
	df	276
	Sig.	0.000

there were conflicts amongst the respondents with respect to 'foods/-drinks should be provided at sites as workers are not allowed to eat outside during the working hours; they must wear gloves; and while using a scaffold, access is allowed to one person at a time'. But, the null hypothesis (H0: U═U0) was accepted for the three measures of keeping sites Covid-safe. Furthermore, the results of the small standard errors were lower at an average of 2%. The practical implication of these results is that the measures can keep all construction sites safe. These results have been confirmed by the results of the confidence interval (at a 95% Confidence Interval). The results of the KMO (0.808) and Bartlett's test ($\chi 2\,(378) = 1567.206$, $p < 0.050$) implied that the respondents were drawn from the same population and that the measures taken together would help to keep sites Covid-safe.

Working on sites during the pandemic is expensive and risky to construction companies. Construction companies need to calculate their COVID risk on all projects. This will involve identifying works that could allow Covid transmission, evaluating the categories and the number of workers that may be at risk. This will also involve assessing the level of exposure of the workers to the virus. Then, finally and most importantly, there is a need to evaluate the measures of control that those construction companies can take to reduce the spread of the virus on the construction sites. Construction companies globally have taken multiple measures for the workers to be Covid-safe as they gradually return to sites fully to enable social distancing and comply with new government regulations on COVID-19. Most construction companies have been able to operate at full capacity for most of the Covid lockdown by taking into account some of these measures. The descriptive statistics on the measures are contained in Table 5. The survey found that 67% of the respondents estimated that all the measures were strongly taken and extremely taken. 20% of the respondents evaluated that the measures were moderately taken. Although 5% of the measures were not taken at all, 8% of the measures were less or least taken. The cumulative ARI score for all the measures was 83.14%, whilst the cumulative standard deviation (SD) was 22.73%. Eleven or 48% of the measures scored more than the average score. Taking into account the relationships amongst all the standard deviation values, the results of the ARI imply that nearly all the respondents estimated that the measures were necessary to prevent COVID-19 on sites. The ARI for all the measures was between 68.48% and 87.40%. Based on the index in the research design section, all the measures were grouped into 2 categories. In particular, eight of the measures were extremely taken. 16 of the measures were strongly taken.

6.4. Results of the PCA on the COVID-19 preventive measures

In this section, results on the answer to the third question, which is "how can the "Covid-safe" measures be structured for decision making on construction sites?" is discussed. For this purpose, the 24 measures were included in the PCA analysis. The eigenvalue technique was used to determine the number of factors to extract. In which case, only factors with eigenvalues of 1.0 or more were retained. Varimax was used for normalisation to reduce the complexity of the factors in order to maximise the variance in the model. KMO test and the Bartlett' Test of Sphericity were conducted to test the validity of the PCA. The analysis returned a Statistical Determinants of 1.838E-11. The commonalities for all the measures ranged from 0.541 to 0.888. The KMO was very high, and the Bartlett Test of Sphericity was significant (Table 6). The anti-image correlation matrix showed diagonal elements greater than 0.5 for most of the measures and all off-diagonal elements were close to 0. The results show that the commonalities for all the measures exceeded 0.54, indicating shared characteristics amongst the preventive measures. The rotations converged in 20 iterations. The results found that the measures to ensure "Covid safety" can be structured into 4 meaningful factors. This was also demonstrated in Fig. 5, as the function compressed out basically after the fourth component. The factors explained 73.01% of the total variance (Table 7). Table 8 contains the distribution of the measures to each of the components.

7. Discussion of the findings

The COVID-19 virus has affected various economic sectors globally. Its impact on the various aspects of the construction sector is huge. There is great urgency in the construction sector to provide information on the impact and measures to keep construction sites COVID-19 safe. In the following sections, the measures that have been taken to reduce its spread are presented. Based on the measures, a framework is also discussed along with the discussion on the validation of the model.

7.1. Discussion on the measures to reduce the spread of the Covid-19 on sites

This section discusses the answer to the second question, which is "what are the measures to reduce the spread of COVID-19 on sites?" Isolating sick workers is the main measure to keep sites "Covid-safe". This finding is stimulating because workers are required to take body temperatures. If the worker's temperature is higher than 37.5 °C, access

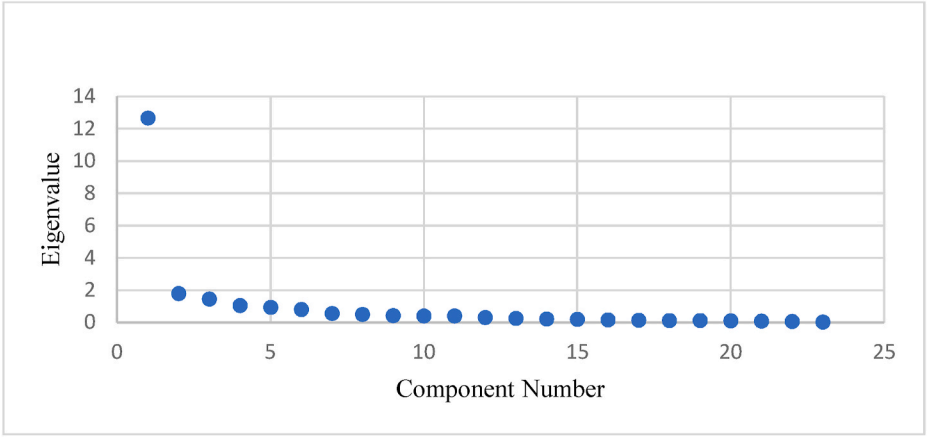

Fig. 5. Scree plot.

Table 7
Total variance explained.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	13.036	54.315	54.315	13.036	54.315	54.315	6.089	25.371	25.371
2	1.757	7.322	61.637	1.757	7.322	61.637	5.178	21.575	46.946
3	1.511	6.298	67.935	1.511	6.298	67.935	4.194	17.474	64.420
4	1.218	5.076	73.011	1.218	5.076	73.011	2.062	8.591	73.011
5	0.985	4.103	77.114						
6	0.818	3.407	80.521						
7	.615	2.562	83.083						
8	.533	2.219	85.302						
9	0.479	1.996	87.298						
10	0.430	1.792	89.090						
11	0.426	1.776	90.866						
12	0.350	1.459	92.325						
13	0.278	1.158	93.483						
14	0.253	1.054	94.537						
15	0.218	0.907	95.444						
16	0.186	0.774	96.219						
17	0.171	0.713	96.931						
18	0.157	0.655	97.586						
19	0.128	0.533	98.118						
20	0.114	0.476	98.594						
21	0.106	0.441	99.035						
22	0.084	0.350	99.385						
23	0.079	0.329	99.714						
24	0.069	0.286	100.000						

to the site would be denied. The workers will undergo a swap test and report to the nearest health centre for further observation. The Malaysian government has developed applications (i.e., MySejahtera) to monitor COVID-19 incidents. MySejahtera is an application developed by the Government of Malaysia to assist in managing the COVID-19 outbreaks in the country and has helped detect thousands of cases. Some construction companies have also developed their own computer application to trace the movement of workers on sites. Workers are required to scan QR codes when they enter any office. Therefore, it is not surprising that the next measure taken to prevent COVID-19 on the sites is to examine all workers for likely COVID-19 symptoms every day, especially before entering the sites. Apart from the usual temperature, many construction companies will also examine workers for other symptoms like dry cough, skin rash, tiredness, fatigue, runny nose, vomiting, aches and pains, sore throat, diarrhoea, headache, fever, irritation, or discolorations of fingers or toes. The extensive tests are normally conducted periodically by doctors that are engaged by the contractors. One of the main ways that COVID-19 can spread on sites is by direct physical contact. For instance, if an infectious individual touches an uninfected person. Hence, it is not surprising that handshaking or hugging amongst the site operatives is strictly discouraged on sites or even in the hostels. However, while hugging may not be prevalent, handshaking is a normal way of greeting amongst site operatives, especially among those from the same nationality/ethnic workers on sites or at the respective hostels provided by the contractors. Most of the site operatives in Malaysia are foreigners, and are generally from Pakistan, Bangladesh, Indonesia, Myanmar and Nepal. In order to keep everyone informed of the measures to reduce the COVID-19 infection, it is pertinent to display posters and info-graphics in a language understood by the workers. The posters will serve as a reminder to the workers and visitors of the possible Covid risks on site. The Covid posters will help create a high level of Covid consciousness on the sites. Effectively, they will prompt workers to use their personal safety equipment and to be conscious of their environment and co-workers.

The most common form of preventing the virus in most places on construction sites or outside of the workplace is using a face/nose mask. Wearing a mask is an effective measure to curtail the pandemic. In fact, many workplaces are placed under a 'mask mandate'. Contractors provide masks to their workers and the workers are being monitored to ensure their usage. Penalties are placed on workers who do not use the masks on the sites. Hence, it is expected that wearing masks will serve to prevent the spread of the virus on sites. Health education on construction sites is poorly conducted. In fact, many construction sites are unhygienic. It is making them major breeders of infectious diseases in places like Malaysia and Singapore. Dengue, malaria, and cholera are some examples of common diseases on construction sites. Some contractors provide health education to workers to create awareness amongst the workers on how to keep sites Covid-safe. The government has issued many new regulations to deal with Covid in workplaces. CIDB Malaysia has also embarked on inspections to ensure that workers adhere to the regulations on construction sites. However, only some 50% of Malaysians wear masks (Azlan et al., 2020). Many construction companies have been fined for violating the order. For example, all foreign construction operatives are required to perform a Covid -test before entering the sites and are required to wear a mask and do a daily temperature check.

The nature of construction activities entails carrying materials and components. However, one of the indirect ways that the Covid-19 virus is often spread is if vulnerable workers touch materials/components/items touched by an infected individual. Therefore, to prevent the spread, the use of hand sanitiser is imposed on all construction sites. Workers are required to use the sanitisers provided by the contractors on-site in the morning before their first task and regularly as they change activities or work. As such, it is expected to find that the contractors are required to ensure the availability and accessibility of the sanitisers to the workers on sites. Gathering or crowding, especially in a closed space, which is often the case on most building sites will trigger the rate of the infection directly or indirectly. Therefore, it is important that contractors enforce the no gathering approach as a means of preventing the spread of the virus on the construction sites.

Arguably most construction sites are unhygienic. According to the Business and Human Rights Resource Centre (2020), immigrant construction workers in Gulf countries are highly at Covid risk because the workers live in tightly cramped labour camps and often in unsanitary conditions, some without access to running water. Similarly, in fact, in the USA, many construction sites lacked clean or freshwater on sites during the COVID-19 pandemic. This research has found that ensuring the regular supply of clean/freshwater will go a long way towards

Table 8
Rotated component matrix.

Measure	Component			
	Hygienic and Control (HC)	Equipment and Monitoring (EM)	Awareness (A)	Incentive (I)
Workers to cover their mouth and nose when they cough/sneeze	0.768			
While using a scaffold, restrict access to one person at a time	0.760			
Workers to work in teams but inter team's interaction is prohibited	0.744			
Wear a special safety mask if working less than 1m apart	0.723			
Wash hand frequently	0.703			
No gathering or crowding	0.679			
Foods/drinks should be provided on sites- workers not allowed to eat outside during the working hours	0.630			
Wear gloves	0.602			
Keep social distancing	0.555			
Provide face masks to workers		0.822		
Ensure regular supply of sanitiser		0.757		
Disinfect surfaces and objects used by others		0.693		
Restrict/stagger access to site welfare facilities		0.680		
Fumigate sites at least once daily – especially at the close of day work		0.672		
All workers must be examined for likely COVID-19 symptoms daily		0.588		
No hugging/ handshaking on the site		0.574		
Company provides separate accommodation for workers based on the projects they are working on		0.472		
Display health advisory posters and info-graphics in a language understood by the workers			0.780	
Provide health education to workers regular			0.737	
Abide by government policy			0.632	
Suspend non- critical activities on sites until conditions improve			0.625	
Self-isolation for workers who fall ill/sick			0.605	
Provide incentive to a sick worker- with this, they will report their medical status				0.797
Ensure regular supply of clean/freshwater				0.533
Eigenvalue	13.036	1.757	1.511	1.218
Variance explained (%)	54.315	7.322	6.298	5.076
Internal consistency	0.685	0.657	0.676	0.665
Bartlett's Test of Sphericity	0.902 $\chi 2$ (36) = 909.458	0.887$\chi 2$ (28) = 743.530	0.8327$\chi 2$ (10) = 213.761	0.500$\chi 2$ (1) = 7.297
***p* for second order component analysis**	<0.001	<0.001	<0.001	<0.001
Variance explained for second order component analysis (%)	67.96	67.50	60.707	62.27
Cronbach's alpha for second order component analysis	0.939	0.930	0.832	0.679

reducing the spread of the virus, and it is remarkable that the next measure, supplying freshwater, is to ensure that workers wash their hands frequently. Hands should be washed with soap carefully, ensuring that all areas of the hands and forearms are well cleaned. To reduce congestion on the sites, many contractors have suspended none critical activities until the Covid curve has flattened to decrease the spread of the virus, especially due to physical contact. Therefore, it is interesting that this research found that the suspension of non-critical activities on sites is being implemented on construction sites. In Malaysa, during the first wave, construction companies were ordered to reduce site activities by up to 50% until the condition improved. Most construction companies have not returned to sites fully even after 6 months of the lockdown being suspended.

It was anticipated that disinfecting surfaces and objects used by others will greatly reduce the scourge of the virus. Therefore, if the particles fall on a surface or if an infectious individual touches a surface, the virus will be there for some time. Depending on temperature and humidity, the virus remains active for up to 72 h on surfaces and materials (Van Doremalen et al., 2020). The droplets could remain airborne for around 8–14 min in a confined space (Stadnytskyi et al., 2020). Therefore, apart from using hand sanitiser, it has been recommended that surfaces and objects that were previously used by others should be disinfected. However, because the virus is also airborne, the virus may be transported for some distance before it falls onto surfaces. Therefore, even if the materials or objects have not been used or touched by others, it is highly recommended that surfaces/materials/components should be disinfected if left for a long time as may be determined by the site safety manager or construction managers. Mouth and nose coverings were also found to be a practical measure to reduce the spread of the virus. This is very necessary, especially if the other workers are not using the mask during eating/drinking times or when alone. Workers may not use the masks when in isolation or far from other people. Wearing masks is not comfortable for most site operatives due to obstructions to breathing. Many of the workers carry heavy materials and components and need to move fast so that they can complete the assigned tasks. Most

Table 9
Additional measures listed by some of the respondents (Listed verbatism).

Strict control on health and safety	Strick compliance levels
Workers are restricted to visit other places (only to work site & quarters) unless necessary	Follow "SOP" which created and agreed by government in the future.
Scheduled working hours	Works in zoning.
Alternate working days for workers and staff to avoid too much of close contact. And some staff can work from home and only go to site for important issues.	Send safety or engineers go for safe distancing officer course and safe management officer course which relating to covid 19
Company should follow the government SOP all the time and educate all the staff and workers at site. No just talk on paper only.	Alternate working days for workers and staff to avoid too much of close contact. And some staff can work from home and only go to site for important issues.
Don't work	Reduce the number of workers working on site
No visitors allowed at site at all	Doing disinfection to the site 3 times a day
Separate the workers to different cluster according to their trade and position, to keep to workers in one group	Work from home unless necessary, smart use of technology, strictly follow SOP
Frequently give check up	Good staff & work rotation
Social distance and work from home	Force leave for everyone
Work from home unless necessary, smart use of technology, strictly follow SOP	Ensure the worker in fit condition for everyday and no symptom of covid-19
Close the site for a while to prevent Covid 19	Always stay hygiene.
Follow sop	Body temperature check and self-declaration
Worker work only 3 days per week	No visitors allowed at site at all
Make sure all the sop rules had been done	Stop works
Take shift to avoid overcrowded and always follow sop	Work under sop
Reduce the import of foreign labor at this period	Provide mask and safety distance
Adopt sop & new normal, monitor & proper practical enforcement at project site is the ultimate risk control. stay safe practice the new normal requirements set by MOH and the construction industry like MBAM & CIDB guidelines	Time slots for workers to minimise number of people on site at one time while working 24 h a day to compensate reduction of manpower.
Every worker should be provided with a basic set of tools needed for the tasks they are assigned to. Using of the same tool by multiple workers should be avoided. If tools are shared or stored for later use by another person, they need to be disinfected/cleaned	To continue on critical project with time frame for completion & delay other non-critical project kickstart. Manpower efficiency to increase with the limited resources available so that site would not be overcrowded.

SOP = standard operating procedures.

of the sites have workers working under the rain or sun with high humidity which is accompanied by a lot of sweat. Under such onerous conditions, wearing masks may not be easy for most of the construction site operatives. However, because the virus is airborne, it is important that they cover their noses and mouths to prevent the spread of the virus.

The contractors should provide separate accommodation for workers based on the projects they are working on to curtail the surge of the virus on sites. This would also minimise efforts on contact tracing in case a member of the gang/team is infected. Restricting or staggering access to site welfare facilities will reduce the workers' vulnerability to the virus because it will reduce overcrowding and congestion. The research further found that to reduce the spread of the virus, the contractors should provide incentives for sick workers. This is a strategic approach because it will prompt the workers to reveal their true medical status. The previous research found that construction workers engage in unhealthy behaviour to retain their jobs. They fear that if they reveal their medical status, they may be denied entry to the site if unwell. This is a very serious consideration for foreigners, as it may lead to their deportations. In fact, many patients in Malaysia lied about their COVID risks (Zhu et al., 2020) by not disclosing their movement and exposure to COVID-19. Hence, patients were requested to sign the "COVID-19 Risk Declaration Form" (Zhu et al., 2020). Whilst many contractors will disinfect surfaces and objects that have been touched by others, most of the contractors will fumigate the entire site at the end of the work day. With this, it is believed that the virus that fell on the surface or was suspended in the air will be destroyed before the start of work on the following day. The normal mask is required to be worn on. However, if the distance between the workers and other workers is less than 1 m, the contractors should provide a special safety mask for the workers to keep the virus under control. Working in teams but discouraging inter-team interaction will help to reduce the scourge of the virus, according to the surveyed construction companies. This is necessary in a case where someone in a team has contracted the virus. The rate of the spread will be confined to the team as workers in the other teams will not be infected with the COVID-19 virus as there is no interaction between teams. Rather than allowing workers to eat outside the sites, as is normally the case during the break period, contractors are now taking the initiative to either provide the food themselves to workers or engage the services of an external caterer. The contractors also provide workers with individually packed meals and utensils. This approach will ensure that the workers are not exposed to the public outside of the construction companies. Although the virus is transmitted by droplets, wearing hand gloves will help to reduce the spread of the virus in case the virus has fallen on the surface of the materials or the clothes of other workers. Using scaffolds during construction is prevalent on construction sites. The scaffolds are designed to maximise space but yet be able to provide the required access and support for the workers. Many operatives could be using the scaffold at the same time. However, to prevent contact whilst using the scaffold. It is required that contractors control access to the scaffold, even if the use of masks and gloves is strictly enforced.

Apart from the measures on the survey form, the respondents were asked to include other applicable measures they had taken or will take to break the chain of the transmission. Table 9 contained the list of qualitative data on other measures aside from those on the survey form. The measures are presented unedited.

Based on the qualitative data presented by some of the respondents in Table 6 above, many of the suggested measures revolve around those in the survey. Some of the respondents recommended that basic tools and masks should be provided. It is interesting to know that the respondents emphasised strict adherence to the SOPs (standard operating procedures) on Covid prevention. Many also suggested staggering work. For instance, some of the respondents opined that scheduling working hours and zoning of work will help in preventing the spread of the Covid virus. Some also said the movement to sites should be restricted. It is interesting to find that some suggested working from home. Where work to perform depends on many factors, including the nature and stage of the projects. It also depends on investment in technology. However, whilst this is commendable, most construction workers can not work from home. But, this does not imply that technology has no role to play in combating the spread of COVID-19 on sites. In fact, one of the respondents suggested that contractors should use innovative technology. In fact, Covid is a driver to change in the construction sector. Many contractors have moved to virtual ways of working. Drones and robotics can be used to perform some tasks. However, the major limitation of the adoption of technology is the cost implications. Investment in technology is very expensive, and many contractors may not be able to afford it considering the low-profit margin in the industry. Most of the contractors belong to the category of small and medium-sized enterprises with a low capital base and low-profit margin of less than 10%. It is exciting to note that many of the respondents stressed the need to enforce the implementation of the latest health and safety guidelines and SOPs on the measures to control the spread of the COVID virus. However, in support of this, one of the respondents wrote "Make sure they follow government rules to test for Covid-19 for every worker; not only foreign workers but local workers also". Another one wrote,"Ensure every person working at the site has to get a Covid-19 test". Many of the

respondents also suggested that the work duration be shortened. This is a good approach as this will also reduce congestion on the site. In many of the sites, workers are allowed access to sites in batches or teams. For instance, if the workers are divided into two teams, team A will allow access to the site on the alternative days (i.e. Monday, Wednesday, Friday and Sunday) while team B will take alternative turns. In fact, in an effort to reduce the spread of the virus, the Qatar government has restricted construction workers' hours to a maximum of 6 per day (Business and Human Rights Resource Centre, 2020). Respondents also suggest conducting disinfection periodically. This suggestion is in accordance with the government policy (Yaakob, 2020)

7.2. Discussion of the PCA framework

The discussion of the answer to the third question is presented in this section. Using the principal component analysis as a tool in preventing the spread of COVID-19 on construction sites will help to facilitate systemic decision making to interrupt the spread of COVID-19 on sites. This will inform policy, programmes, and interventions aimed at ensuring "Covid safety" and increasing productivity.

7.2.1. Component 1 – hygiene and control

There is a high positive correlation amongst the measures. More than 50% of the model was represented by this component. The component comprised nine measures to reduce the Covid scourge. The second-order analysis combined the nine measures into one component. Based on the WHO's guidelines, the COVID-19 virus can be contracted when it enters the mouth, nose, or eyes of a vulnerable person, which is more likely to happen when people are in direct or close contact (less than 1 m apart) with an infected person (WHO, 2020b). One of the primary means of interrupting the spread of the virus is through social distancing. Social distancing is keeping a distance of about a meter from the other workers. Many construction sites have been shut down because the workers cannot work "shoulders to shoulder" (Global Construction Review, 2020). However, the 1 m rule predates the COVID-19 but hinges on the principle that the droplet can be observed within I-metre. However, there are is still some significant chances that the virus can be transmitted within 1 meter. Hence, 2 m or more apart has been suggested. Furthermore, since the epidemic transmission of COVID-19 is driven by population densities (Rocklov and Sjodin, 2020), cramped accommodations and building sites mean social distancing is impossible for these workers. Research in the UAE also found that cramped accommodations and building sites mean social distancing may not be possible for construction workers (Business and Human Rights Resource Centre, 2020). It may not always be possible to keep a social distance of up to I meter on construction sites. If the workers require working at an interpersonal distance of less than 1 m and other organisational solutions are not possible, it is then necessary for all workers to use masks. These measures should be combined with wearing hand gloves and reducing overcrowding and congestion on the sites. Additionally, these measures are conducted along with making sure that workers wash their hands regularly with soap. For all these to be more effective, workers should be restricted from eating outside of the sites once they have entered the site in the morning. Food vendors may be contracted to supply foods and drinks to the site during the lunch period on-site rather than allowing the workers to eat outside, as they may expose the workers to the virus in the markets. Along the same path, workers should be informed or reminded to close their mouths and noses when they cough or sneeze. Equally, it is very important that these measures ensure that, where applicable, the use of the scaffold is closely controlled so that it will not be congested.

7.2.2. Component 2-protective equipment and monitoring [personal and companies]

This component has eight measures that were closely related and collectively contributed 7.32% of the model. Contractors are required to provide face masks to workers and ensure that sanitisers are regularly or always provided. These measures should be provided along with the disinfection of surfaces, tools, plants, and materials that have been used by others or left for a long time. Hand sanitiser and masks alone may not be enough to control the spread of the virus to vulnerable workers. Furthermore, to be more effective, regular fumigation of the sites should be conducted to ensure the whole site is not at Covid risk. Welfare facilities like toilets, bathrooms, and canteens on sites are normally few and small and are used by everyone regardless of the team/gang or location of the work. Visitors also use these facilities. Because of the wide and heavy usage, welfare facilities could be a secondary epicentre for the spread of the virus on a site. Additionally, a high level of restriction or monitoring is required with the use of the welfare facilities. Hand sanitiser should be provided at the entrance of the welfare facilities. Workers must use hand sanitisers before they enter and leave the facilities. Where possible, visitors should not be allowed to use the welfare facilities on the sites during the pandemic. The facilities should be regularly disinfected and fumigated. Depending on the size of the site and the number of workers, it could be disinfected and fumigated twice a day. Masks should be worn at all times, most especially when workers use the welfare facilities. Providing sanitiser and masks by the contractors will be more effective if their use are closely monitored. Notwithstanding, even if sites are fumigated, and masks and sanitiser are provided, daily examinations of the workers for possible COVID-19 is necessary. Whilst activities can be controlled on sites, to further break the chain of the transmission, contractors should provide separate accommodations for workers based on the projects they are working on. However, cramped accommodations in the UAE for construction workers and construction sites make it very impossible for workers to practice social distancing (Business and Human Rights Resource Centre (2020). Contractor should ensure that workers do not hug each other or shake hands whilst on the site. Universal personal protective measures need to be applied at all times to prevent unintentional COVID-19 transmission on the construction sites. Construction companies need to develop innovative and suitable personal protective equipment for their workers and ensure its implementation in the companies.

7.2.3. Component 3 – awareness

Keeping workers informed on the status of the Covid virus and on the government guidelines and regulations on ways to reduce the spread and impact of Covid on construction sites and the health of the workers themselves is important. Contractors should provide updated health information to workers regularly on Covid and display health advisory posters and info-graphics for the workers on the sites. To avoid being fined/penalised and to be Covid risk-free, contractors should ensure that all government guidelines and regulations on safety protocols for construction sites are strictly implemented. Providing information on the Covid-risk and abiding by government regulations should be combined with suspending noncritical work on sites. Effectively, the number of workers on sites will be reduced, which will ultimately reduce the rate of infections. This approach in tandem with government regulations to reduce the spread of various diseases by reducing the size of the workforce on sites and by reducing the number of days to work on sites in many countries. This is also in tandem with the government policy for isolating unwell workers pending a medical examination. Some measures taken by the government and the contractors were to postpone construction activities that are not critical because of the requirement of social distancing and providing Covid tests for workers. The contractors need to ensure that workers are examined every day, especially for temperature, cough, and sneezing, and workers that are sick should be kept under observation. Health education for workers and displaying infographic information on sites can break the transmission of Covid and should be combined with information on the government regulations and guidelines.

Table 10
ANOVA.

	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
Zscore: Provide an incentive to a sick worker- with this, they will report their medical status	6.124	3	.867	116	7.059	0.000
Zscore: Provide health education to workers regular	11.971	3	.716	116	16.714	0.000
Zscore: Provide face mask to workers	19.888	3	.512	116	38.882	0.000
Zscore: Keep social distancing	27.198	3	.322	116	84.347	0.000
Zscore: Suspend non -critical activities on sites until conditions improve	13.295	3	.682	116	19.494	0.000
Zscore: Ensure regular supply of clean/ freshwater	18.609	3	.545	116	34.169	0.000
Zscore: Ensure regular supply of sanitiser	26.186	3	.349	116	75.106	0.000
Zscore: All workers must be examined for likely COVID-19 symptoms daily	17.308	3	.578	116	29.933	0.000
Zscore: Fumigate sites at least once daily – especially at the close of day work	21.019	3	.482	116	43.585	0.000
Zscore: Foods/drinks should be provided sites- workers not allowed to eat outside during the working hours	19.097	3	.532	116	35.898	0.000
Zscore: Abide by government policy	21.895	3	.460	116	47.637	0.000
Zscore: Restricting or staggering access to site welfare facilities	27.623	3	.311	116	88.687	0.000
Zscore: Self-isolation for workers who fall ill/ sick	13.383	3	.680	116	19.687	0.000
Zscore: No gathering or crowding	25.366	3	.370	116	68.585	0.000
Zscore: Wear a special safety mask if your distance from other people is less than 1 m	20.583	3	.494	116	41.703	0.000
Zscore: Wear gloves	9.244	3	.787	116	11.750	0.000
Zscore: While using scaffold access allowed to one person at a time	18.678	3	.543	116	34.411	0.000
Zscore: Wash hand frequently	26.628	3	.337	116	78.966	0.000
Zscore: Workers to cover their mouth and nose with a tissue when they cough/sneeze	23.616	3	.415	116	56.892	0.000
Zscore: No hugging/ handshaking on the site	22.725	3	.438	116	51.866	0.000
Zscore: Disinfect surfaces and objects used by others	29.353	3	.267	116	110.053	0.000
Zscore: Company provides separate accommodation for workers based on the projects they are working on	18.909	3	.537	116	35.224	0.000
Zscore: Display health advisory posters and info-graphics in a language understood by the workers	16.091	3	.610	116	26.390	0.000
Zscore: Workers to work in teams but inter team's interaction is prohibited	19.725	3	.516	116	38.246	0.000

7.2.4. Component 4 – incentive

The framework shows that in order to accelerate breaking the chain of transmission of the virus, contractors need to encourage workers to make their medical status known. This is because workers, especially those who are not Malaysian, will be reluctant and scared to make their health status known. Infectious workers may be deported and required to pay for the cost of medical examinations, which is very high. The foreigners who constitute more than 80% of the site operatives are not entitled to health subsidies afforded to Malaysians and permanent residents. However, as the data revealed, this measure must be combined with the supply and availability of clean and fresh water that should be provided by the contractors on the sites. This is not peculiar. Immigrant workers working in the Qatar construction sector, especially those working on projects related to the Qatar 2022 World Cup, were found to be at high risk and particularly vulnerable to the virus (Business and Human Rights Resource Centre, 2020). Construction companies in many countries are now taking concerted steps to educate workers on the disease and carry out awareness-raising programmes, including those relating to hygiene.

Based on the data in Table 7, the efficacy of the measures to keep sites Covid-safe (CS)is:

$$CS = 54.315HC + 7.322\ EM + 6.298\ A + 5.076I\ . \quad (2)$$

The Covid risk of a site can be determined with this equation (equation (2)). By comparison, a site with a lower score will be considered high Covid risk, whilst a site with a higher score has a low Covid risk. In this context, a high Covid risk implies penalties for violating Covid policies, cost and time overruns due to low productivity and shortage of resources, and low-profit margins due to low productivity and shortage of resources, work suspension, and high medical costs.

7.3. Results and dicussion of the clustering

In this section, the results and discussion of question 4 are presented. Specifically, it provides the answer to "How can sites be classified in terms of the "Covid safe" measures?". To answer this question, first, a hierarchical cluster analysis was carried out to determine the number of the cluster-based Agglomeration schedule. The analysis observed 4 meaningfully differentiated cluster solutions. On that basis, the K-means cluster analysis was performed using 4 clusters. The K-Means algorithm grouped the 120 sites into Cluster 1, Cluster 2, Cluster 3, and Cluster 4 of sites 5, 33, 78, and 4, respectively. Based on the characteristics of the clusters, the clusters were named Lower-level intervention, High level intervention, Very-level intervention, and Medium level intervention. The data revealed that there were statistical differences amongst all the sites with respect to each of the measures to ensure "Covid safety" on the sites and that they are Covid risk-free. For this reason, the null hypothesis was that each measure did not have any significant effect on which group it would be classified in (H_0: U═U0), and the research hypothesis was that each of the measure had a significant effect on the class it would be grouped into (H_r: U ≥ U0). The ANOVA results imply that each of the measures had a significant impact on which group it

Table 11
Final cluster centres.

	Cluster			
	Lower-level intervention	High level intervention	Very high-level intervention	Medium level intervention
Zscore: Provide an incentive to a sick worker-with this, they will report their medical status	-.22394	-.52051	.31000	-.46604
Zscore: Provide health education to workers regular	−1.14714	-.51894	.40932	−2.23965
Zscore: Provide face mask to workers	−2.37001	-.50098	.45954	.71293
Zscore: Keep social distancing	−2.62541	-.54755	.54985	−2.48501
Zscore: Suspend non critical activities on sites until condition improve	−1.12954	-.51464	.41595	−3.00098
Zscore: Ensure regular supply of clean/fresh water	−1.31111	-.66496	.51243	−2.94214
Zscore: Ensure regular supply of sanitiser	−2.70908	-.57956	.52934	.79520
Zscore: All workers must be examined for likely COVID-19 symptoms daily	−2.31971	-.41580	.40830	.74406
Zscore: Fumigate sites at least once daily – especially atthe close of day work	−2.14499	-.62937	.51711	.29542
Zscore: Foods/ drinks should be provided sites-workers not allowed to eat outside during the working hours	−1.88171	-.57815	.50022	−2.09987
Zscore: Abide by government policy	−1.39713	-.64745	.52608	−4.12325
Zscore: Restricting or staggering access to site welfare facilities	−2.70400	-.50098	.53556	−2.83246
Zscore: Self-isolation for workers who fall ill/sick	−1.05578	-.67636	.44699	.75884
Zscore: No gathering or crowding	−2.45612	-.50703	.52236	−3.11459
Zscore: Wear a special safety mask if your distance from other people is less than 1 m	−1.96486	-.67234	.51553	1.04908
Zscore: Wear gloves	-.94781	-.53466	.35223	1.36096
Zscore: While using scaffold access allowed to one person at a time	−1.74594	-.60801	.50516	−2.08063
Zscore: Wash hand frequently	−2.02624	-.72752	.60282	−2.74776
Zscore: Workers to cover their mouth and nose with a tissue when they cough/sneeze	−1.85857	-.70200	.57234	−2.54907
Zscore: No hugging/hand shaking on the site	−2.08962	-.63828	.54804	−1.93765
Zscore: Disinfect surfaces and objects used by others	−2.61669	-.71364	.59263	.98367
Zscore: Company provides separate accommodation for workers based on the projects they are working on	−2.37401	-.30452	.39961	−2.74689
Zscore: Display health advisory posters and info-graphics in a language understood by the workers	-.37490	-.67170	.45108	−3.81150
Zscore: Workers to work in teams but inter team's interaction is prohibited	−2.06835	-.51262	.48412	−2.42599

should belong to (Table 10). The data revealed that disinfect surfaces and objects used by others, and workers must cover their mouths and noses when they cough/sneeze, wash hands frequently, no gathering or crowding on site, and keep social distancing contributed more to the cluster solution. However, wearing gloves, self-isolation for workers who fall ill/sick, provide an incentive for a sick worker, suspend non-critical activities on sites until the condition improves, and provide health education to workers regularly provided less impact on the separation in the cluster solution. However, all the measures were found to be important, with different impacts (Table 11). The sites in cluster 2 were similar to those in cluster 3 (Table 12). The sites in cluster 2 were also similar to the sites in cluster 4. The sites in cluster 1 were dissimilar to the sites in cluster 3.

Cluster 1 – Lower-level intervention. This segment consisted of 5 sites representing 4.17 per cent of the sample. The segment consisted of sites, that showed more commitment to creating awareness. However, they did not have high levels of commitment toward implementing and efforcing hygienic principles on sites. The welfare of the workers was not very important to the companies in this cluster. Cluster 2 – High-level intervention. About 28% of the surveyed site belonged to this cluster, and comprised 33 sites all together. The cluster was dominated by construction sites that were conscious of the Covid risk. They were

Table 12
Distances between final cluster centres.

Cluster	Lower-level intervention	High level intervention	Very high-level intervention	Medium level intervention
Lower-level intervention	1	7.020	11.849	9.817
High level intervention	7.020	1	5.271	9.624
Very high-level intervention	11.849	5.271	1	12.869
Medium level intervention	9.817	9.624	12.869	1

Table 13
Results of validation of the PCA framework.

		Site 1	Site 2	Site 3	Site 4
Respondent's Position		Project Manager	Quantity Surveyor	Health & Safety Officer	Site supervisor
Respondent's working experience		5–10years	5–10years	11–15 years	Below 3 years
Type of project		Residential building	Residential building	Residential building	Residential Building
The average number of workers in your site		400 to 600	Less 50	400 to 600	50–200
Class of company		G7/Developer	G7	G7	Developer
Location of project		Johor	Selangor	Penang	Perak
Measure:					
1	Our company takes extensive steps to prevent the spread of the virus with hygiene programmes and control (54.315HC)	5	4	5	4
2	Our company takes inclusive steps to prevent the spread of the virus by providing all equipment to workers and with effective monitoring in their implementations (7.322 EM)	5	3	5	5
3	Our company takes extensive steps to prevent the spread of the virus with awareness-raising and hygiene programmes (6.298A)	5	5	5	3
4	Our company takes extensive actions to prevent the spread of the virus by motivating and encouraging workers economically and socially (5.076I)	5	4	5	4
Overall measures		365.06	291.02	365.06	293.07
Ranking (1- most safe site)		1	3	1	2

concerned about educating and creating awareness of Covid among the workers. They have recognised the importance of hygiene in the workplace. Cluster 3 – Very high-level intervention. It is apparent that this cluster comprised 65% of the surveyed sites and fully aware of the impact of the Covid pandamic on the sites and took all measures to curtail its spread. They provided all the necessary equipment and support to the workers on the sites. The sites in this cluster also implemented and enforced all the safety measures to be "Covid safe". Cluster 4 – Medium level intervention. This cluster had only 4 sites, or 3.33% of the surveyed sites. Although, the companies paid less attention to the welfare of the workers. Moreover, implementing measures to reduce the spread of the virus on the sites was not organized.

7.4. Validation of the PCA proposed framework

There is no similar model for construction sites. The only existing models were based on the impact of the pandemic on project duration (Araya, 2021a) and were based on simulation only. To assess the efficacy of the developed model for preventing the spread of COVID-19 on sites was applied to 4 case studies to determine its practical application by building contractors. The cases involved were not involved in the development of the framework. The participants were selected based on their willingness to participate in the validation. The respondents were asked questions based on their experiences during the pandemic to evaluate the frequency at which they agreed with each of the following statements on a scale of 1–6 on their sites. Where 6 = Extremely frequent, 4 = Very frequent, 3 = Frequent, 2 = Less frequent, 1 = Least frequent, and 0 = Not applicable. The CS for the construction companies was computed as a product of the evaluated Likert scale point with the percentage of variance explained as shown in the equation (2). Subsequently, all the products were summed together for the sites. Finally, the sites were ranked in terms of the extent that they would be exposed to Covid risk or to be "Covid safe". A site with a high score on the Covid risk would be comparatively safer. Table 13 contains the summary of the case studies investigated. Sites 1 and 3 were the most "Covid-safe". The two sites applied the measures immensely on sites. However, despite taking the measures remarkably, the respondents still believe that the sites are not entirely "Covid-safe". For instance, the respondents were asked to indicate the extent to which the workers on their site were vulnerable to the virus. The respondent on-site 1 chose "Exposure to covid risk' and the respondent on-site 3 opinioned that the site is "Medium exposure risk". These evaluations could be accounted for by the 27% variance in the model.

8. Conclusion, implication and limitations of the study

This is the first comprehensive research that investigated the impact and validated measures to reduce the spread of COVID-19 on construction sites. This research has provided rich insight into simple and practical measures to reduce the rate of transmission of COVID-19 on sites. With respect to the first question, generally, the cost implications of Covid on the project are approximately 20%. However, this depends on the nature of the project. Big projects, projects that are at the critical phase and experiencing resource shortages, will experience up to 70% increased costs and could delay projects by up to 60%. With respect to the 2nd-second question, to combat the virus, both the contractors and the workers need to work together as the requirement to keeping the sites "Covid-safe" is multi-faceted. The contractors need to ensure that workers work in hygienic conditions and are provided with protective equipment to work safely. Workers also need to educate other workers on the Covid risk. Thirdly, for systemic decisions, the measures can be classified into 4 components including, clear control and monitoring techniques of the company and government policy should be enforced and implemented. Contractors also need to create awareness by providing the necessary information on government regulations and guidelines, and at the same time, incentivise the workers to comply with the company policy. Fourthly and finally, the extent to which the "Covid-19 safe" measures are taken on sites varies. A PCA model was developed and validated with raw data. The results show that the model is practical. Looking at the findings of this research from a practical point of view, the analyses and grouping of the preventive measures and sites have several implications. The first major practical contribution of

the present research is that it provides much needed empirical data on how contractors can keep sites "Covid-safe". The data shows that contractors should offer a duty of care technique to the frontline site workers. Such practical and straightforward techniques during the pandemic would include ensuring the availability and provision of clear water, and sanitary fittings, and appliances. The contractors should also provide hand gloves, masks, and medical facilities. This information is important given that there has been no comparative study as of yet. This will allow projects to be completed within budget and on time. A second important implication of this study derives from the findings on the uniqueness of the knowledge and information on keeping the sites clean and safe being posited within the data. Furthermore, whenever a new worker is engaged, or suppliers/visitors enter the site, precaution is required. Although the primary data for this research was collected in Malaysia, the findings have global implications. The measures that were explained are applicable on most construction sites outside of Malaysia. Similarly, the measures discussed have multiple implications for the control of many diseases because they can be used to reduce the spread of other types of infectious diseases like malaria, Ebola, and dengue on construction sites. However, whilst this research has provided insight into the approach to keeping sites Covid-safe, it has some limitations. In particular, though the respondents in this research provide a comparatively large sample, there is a need to increase the response rate. The number of measures may be increased in future research by looking at the qualitative data in Table 9. In addition, a similar survey may be administered outside of Malaysia, taking into account some possible country-specific conditions.

Conflict of interest

There is no any conflict of interest appertaining to the data in presented in this article and the authors have not received any financial support from companies, government or organization to conduct this study.

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Exhibit 24

Impact of COVID-19 Pandemic on Demand, Output, and Outcomes of Construction Projects in Singapore

Florence Y. Y. Ling[1]; Zhe Zhang[2]; and Aurelia Y. R. Yew[3]

Abstract: This study investigated the impact of COVID-19 pandemic on Singapore's construction industry in terms of construction demand, output, prices and project performance. A three-pronged research approach was adopted: a survey, analyzing published statistical data, and conducting in-depth interviews with subject matter experts. The survey revealed that projects suffered significant delays and cost overruns and lower quality. It was found that construction demand and output decreased by 27.9% and 28.6%, respectively. Some project owners postponed awarding contracts or calling tenders because prices exceeded their budgets. While waiting for bid prices to decrease, they re-evaluated the feasibility, scope, design, budget, and timeline of their projects. Contraction of construction output was found to be due to a severe shortage of labor and to lower productivity as a consequence of complying with many safe management measures. The results of autoregressive time-series modeling predicted that tender prices will continue to rise in the short term before decreasing after mid-2022. Although manual labor may be replaced by productive technologies if technology is cheaper than labor, this was not found to be the case. The originality of this research is that it empirically quantified project outcomes due to the pandemic and predicted tender price indexes for the next 5 years. These predicted indexes are useful for estimating the risk and markup to be added to the base construction cost. The value of this research is that it informs policy makers that regulations need to be enacted to compel the adoption of productive technologies to reduce reliance on labor. Otherwise, the worker shortage problems faced in this pandemic may continue to surface in future pandemics. The implication of adopting productive technologies is that project owners must increase the project budget because these technologies cost more than manual labor. However, the cost might be passed to end users, who will end up paying more. **DOI: 10.1061/(ASCE)ME.1943-5479.0001020.**

Introduction

The COVID-19 pandemic which started in 2020 has caused huge disruptions to human lives (Gautam and Hens 2020). In Singapore, the majority of construction laborers are migrant workers who stay in dormitories. Toward the end of 2020, the Ministry of Health (MOH) reported that 47% of the 323,000 migrant workers staying in dormitories had tested positive for COVID-19 (Yuen 2020). At the height of the COVID-19 pandemic in 2020, many migrant construction workers were hospitalized, quarantined, or isolated in their dormitories, and some chose to go back to their home countries.

It is not known the extent to which the pandemic impacted Singapore's construction demand, supply, and project outcomes (schedules, budgets, and quality performance), and how this will affect prices in the future. For contractors, knowing the impact of the COVID-19 pandemic and the root causes of poor project outcomes will help them seek solutions to problems they are facing, such as labor shortages, supply chain disruptions, project delays, and higher costs associated with project prolongation. For clients, developers, and end users, knowing the extent of project delays would enable them to make alternative arrangements if they cannot occupy their facilities in a timely manner. A delay in taking possession of a commercial facility could mean a delay in starting a new business venture (e.g., a hotel or factory), whereas a delay in the completion of a residential facility could mean postponement of home ownership or even of starting a family. Consultants would benefit from knowing the extent of project delays so that they can seek prolongation costs because they are retained in a project for a longer period and cannot be deployed to another project. It is important for all stakeholders to know the extent to which costs will increase so that more funds can be sought and paid out.

This study investigated the impact of the COVID-19 pandemic on the construction industry. The specific objectives were to (1) investigate how project outcomes were affected by the pandemic in terms of schedule, budget, and quality performance; (2) determine the extent to which construction demand and project opportunities decreased and how this affected project owners' short-term plans; (3) examine the extent to which construction output has decreased, the key reasons for this and whether the industry could rely less on labor; and (4) predict tender price indexes. The period of study for Objectives 1–3 was 2020. This period was chosen because data are available to investigate the state of the construction industry in the prepandemic stage [the first quarter (Q1)] and during the pandemic in the subsequent three quarters (Q2–Q4) of 2020.

[1]Professor, Dept. of the Built Environment, National Univ. of Singapore, 4 Architecture Dr., Singapore 117566 (corresponding author). ORCID: https://orcid.org/0000-0003-3451-4061. Email: bdglyy@nus.edu.sg

[2]Research Assistant, Dept. of the Built Environment, National Univ. of Singapore, 4 Architecture Dr., Singapore 117566. ORCID: https://orcid.org/0000-0002-9698-0626. Email: bdgzzhe@nus.edu.sg

[3]Research Assistant, Dept. of the Built Environment, National Univ. of Singapore, 4 Architecture Dr., Singapore 117566. ORCID: https://orcid.org/0000-0002-5608-7745. Email: aurelia.yew@u.nus.edu

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Literature Review

Supply, Demand, and Price

The law of demand states that at higher prices, buyers will demand less of an economic good, whereas the law of supply expresses that at higher prices, sellers will supply more of an economic good, and these two laws interact to determine the actual market prices and volume of goods that are traded on a market (Fernando 2020). In the construction industry, project owners are the buyers, contractors and consultants are the sellers, and the economic good is the construction product.

The demand for construction product is measured by the value of contracts awarded, whereas construction supply or construction output is measured by progress payments certified to contractors [BCA 2021b; COVID-19 (Temporary Measures) Act (COTMA) 2020 (No. 14 of 2020)]. Based on the progress payments certified, monthly payments are made to contractors for their work done in the previous month. The progress payment certified might not truly reflect construction output because on some projects, contractors are paid in advance to help them with their cash flow (BCA 2020a).

Several factors affect the demand for construction products. The higher the price of a construction product, the less people will demand that good, but, on the other hand, the higher the price, the higher is the quantity supplied by contractors (Fernando 2020). The general factors that affect the demand for construction products are in line with economic principles: consumer preference, changes in conditions that influence consumer preferences, and changes in income (Fernando 2020). Eichholtz and Lindenthal (2014) found that demand for housing increases with age and is determined by a household's human capital. The demand for commercial property is affected by the value of future rents, the business environment, economic confidence, gross domestic product (GDP), bank lending, credit, and interest rates (Davis and Zhu 2011). The key factors in the determination of commercial property prices are the discounted present value of future rents, and the real long-term interest rate augmented by the risk premium (Davis and Zhu 2011).

Factors that affect the supply of construction products include the availability of inputs or resources (e.g., labor and materials); the physical technology available to combine inputs; the number of contractors and sellers, and their total productive capacity over the given time frame; taxes; and regulations (Fernando 2020). Liu et al. (2016) discovered that the key factors for the successful supply of construction products are contractors' coordination and communications, contractors' experience with similar types of projects, contractors' ability in financial management, and contractors' design capability. Hosseini et al. (2018) found that there is a need to tackle corruption and consolidate responsible project management practices to ensure successful delivery of megaprojects. To supply construction services overseas, contractors need to have experienced key personnel, project management capabilities, specialist expertise, and financial resources (Gunhan and Arditi 2005).

The price of the construction product usually is determined by the cost of production plus a markup (Chao and Liaw 2019). With so much uncertainty in a pandemic, contractors might have difficulty submitting viable bids because they are not able to price the markup accurately. Overestimation can lead to bidding failure, whereas underestimation is the winner's curse because it can cause a financial loss to contractors (Choi et al. 2021). Owners also have difficulty ascertaining if the bid price obtained during a pandemic is reasonable. Therefore, the tender price index might be useful to both owners and contractors.

Modeling and forecasting construction costs using the tender price index helps to increase the accuracy of cost prediction. Tender price indexes can help both owners and contractors improve budgeting processes, prepare more-accurate cost estimates, and reduce the risk of price variations (Ilbeigi et al. 2017a). Tender price indexes are constructed based on how actual tender prices change from one period to another. Tender prices consider the price and availability of resources, governmental interventions, inflation, cash flow, and other macroeconomic factors (e.g., Choi et al. 2021; Xu and Moon 2013). Constructing indexes for construction projects is not easy due to uncertainties such as large short-term fluctuations and the failure of the index to capture all the factors influencing project costs (Choi et al. 2021). Time-series analysis has been used to measure, model, and forecast prices and trends such as asphalt-cement prices (Ilbeigi et al. 2017b), highway construction cost indexes (Shahandashti and Ashuri 2016), and construction cost indexes (Xu and Moon 2013; Choi et al. 2021).

COVID-19 Pandemic

The World Health Organization (WHO) declared the COVID-19 outbreak to be a pandemic in March 2020 (WHO 2020a, b). At the end of December 2020, there had been nearly 60,000 confirmed cases in Singapore (MOH 2021) out of a population of 5.7 million (Department of Statistics 2021). Among the positive COVID-19 cases, the vast majority (93.6%) were overseas migrant workers living in dormitories (MOH 2020a), and they were predominantly construction workers (Zhuo 2020).

A pandemic causes economic downturn, causing income levels to decrease and job loss, which will lead to a decrease in housing demand, which is a sizeable part of construction demand (Allen-Coghlan and McQuinn 2020). A pandemic also causes a decrease in construction output due to the halting of construction activities on-site during full or partial lockdown, impacting construction progress (Allen-Coghlan and McQuinn 2020; Brown et al. 2020; Neupane and Mishra 2020). The supply chain for construction materials also could be impacted (Allen-Coghlan and McQuinn 2020). In some countries, the pandemic increased construction industry unemployment (Bauer and Weber 2020) and decreased the average salary level (Lea 2020).

To manage the pandemic, like many other countries, Singapore controlled its international borders tightly. The other strategies adopted in 2020 to manage the pandemic in Singapore can be divided broadly into containment, safe management measures, tracing, and isolation. In addition, the construction sector had to adopt more measures due to the high rate of infection among migrant construction workers (MOM 2020a).

Containment measures included a national-level lockdown and closure of work premises except for essential services from April 7 to June 1, 2020 (locally termed a circuit breaker) (Baker 2020). During the lockdown, 5% of the construction workforce, or about 20,000 workers, was allowed to go back to work from May 2020 (MOH 2020b). After the lockdown, Singapore opened up progressively, and construction work was allowed to resume in phases if all workers were healthy and safe distancing measures were adhered to (BCA 2020b). Enforcement actions were taken against those who flouted the rules (BCA 2021a).

Safe management measures include working from home as a default, allowing only those whose functions have to be carried out at the workplace to continue to work at their work premises (Lai 2020); and the mandatory wearing of masks outside one's home (Baker 2020). Contractors need to ensure that workers adhere to safe management measures such as maintaining a safe distance of at least 1 m, no cross-deployment to multiple worksites, and no intermingling of workers from different zones (MOH 2020c; BCA 2021a). Migrant construction workers had to undergo

rostered routine testing for COVID-19 (MOM 2020b), and those living in dormitories needed to comply with safe living measures (MOM 2020c, d, e). Human-based and digital contact tracing was carried out to identify and isolate those who were close contacts of infected persons (Lai et al. 2021; TraceTogether 2021).

The COVID-19 (Temporary Measures) Act (COTMA) 2020 (No. 14 of 2020) was enacted to provide temporary measures and deal with other matters relating to the COVID-19 pandemic. Part 2 of COTMA provides temporary relief from legal and enforcement action. Part 8 addresses contractors being granted universal extension of time and cost sharing of some permitted expenses.

Gap in Knowledge

The Covid-19 pandemic and the lockdown measures hit the construction industries hard in many countries. The suspension of work on-site and job losses have been reported in the US (Brown et al. 2020) and Nepal (Neupane and Mishra 2020). Singapore's construction industry was locked down for 122 days between April and August 2020, and after the lockdown was lifted construction work could restart only if the site met the COVID-safe restart criteria (BCA 2020b).

Although it is known that the construction sector in Singapore was the worst performing sector in 2020, hitherto there has been no systematic study of the extent to which project outcomes were affected and construction demand and construction output contracted due to the pandemic. Also unknown are the project owners' plans arising from the pandemic and the main reasons for the decrease in construction output. It is also not known how construction prices would behave in 2021 and beyond. This study fills these gaps.

The research questions were as follows:

Q1. How were project outcomes (schedule, budget, and quality) affected by the pandemic?

Q2. What are the project owners' short-term plans regarding their construction demand?

Q3. What can be done to prevent construction output from shrinking further?

Q4. How will tender prices for building projects change in the coming years?

Research Methodology

A large-scale study of the impact of COVID-19 on the construction industry was conducted. It adopted the mixed-methods research methodology, comprising a survey, analysis of published data, and in-depth interviews. An industry-wide survey of contractors and consultants was conducted using a specially designed questionnaire. Published documents were screened to collect numerical data for quantitative analysis. Structured interviews were conducted with subject matter experts. The mixed-methods research methodology was chosen because it combined the analysis of survey data, numerical data, and deep insights from subject matter experts to triangulate the findings.

For the industry-wide survey, the parts relating to project outcomes and the impact of COVID-19 on projects generally and on project opportunities in 2021 are reported in this paper. The population comprised all architectural, engineering, and construction (AEC) firms. The sampling frame randomly selected firms that were registered with the Building and Construction Authority (BCA). The Singapore Contractors Association (SCAL) also was approached to disseminate the questionnaire to its members. To ensure adequate samples, purposive sampling method was also adopted.

The quantitative research method used a cross-time comparison. Various construction-related statistics were extracted from websites maintained by the Singapore government (BCA 2021b; MOH 2020a; MOM 2021). The period of study was January–December 2020. 2020 was chosen because it was the year in which the COVID-19 pandemic occurred, and data were available for analysis. The data were compared with those of the preceding 3 years to detect any changes due to the pandemic. The main numerical data collected included the value of contracts awarded by project owners as a measure of construction demand, progress payments certified to measure contractors' construction output, tender price indexes, and the number of daily positive COVID-19 cases of migrant workers living in dormitories. The numerical data were compared with each other to detect the impact of COVID-19 on the construction industry.

Autoregressive time-series analysis was performed to predict tender price indexes. The open-source econometrics software gretl version 1.9.4 was used to perform the modeling. The autoregressive integrated moving average (ARIMA) modeling was selected because it is a common modeling technique for econometrics and is one of the most accurate forecasting models (Choi et al. 2021), with errors less than 2% (Ilbeigi et al. 2017a). All the available quarterly indexes from Q1 1987 to Q1 2021 were used to generate the ARIMA models (BCA 2021b). The aim of the analysis was to produce predicted indexes beyond Q1 2021, using actual indexes (predictors) between Q1 1987 and Q1 2021. Although the BCA publishes quarterly and annual indexes, the quarterly indexes were used to construct the models instead of the annual indexes to ensure that there were sufficient data points. Other studies (e.g., Fischer et al. 2020; Wang et al. 2018) also have conducted forecasting using quarterly data.

The robustness of the predicted ARIMA models was checked in several ways. The first was to investigate the three factors in the ARIMA model, represented as (p, d, q) (Tabachnick and Fidell 2018). The first factor (p) is the order of the autoregressive (AR) term which represents the memory of the process for preceding observations. When $p = 0$, there is no relationship between adjacent observations, and when $p = 1$, there is a relationship between observations at Lag 1 (Tabachnick and Fidell 2018). In the case of predicting tender price indexes in Q2 2021, for example, when $p = 0$, there is no relationship between the predicted index in Q2 2021 and the actual index in Q1 2021. When $p = 1$, there is a relationship between the index in Q2 2021 and the index in Q1 2021. When $p = 2$, there is a relationship between the index in Q2 2021 and the index in Q1 2021 and Q4 2020. This same pattern of explanation is applicable for higher values of p.

The second ARIMA factor (d) is the minimum number of differencings needed to make the series stationary. When $d = 0$, the predictors are more independent from each other, and when $d > 1$, the predictors are not independent, and differencing of different levels may be required (Tabachnick and Fidell 2018). In the case of predicting tender price indexes, $d = 0$ means that the tender price indexes have a constant mean and variance over the time period of the study. When $d = 1$, linear trend needs to be removed so that the series can be stationary. When $d = 2$, both linear and quadratic trends need to removed so that the series can be stationary. For nonstationary series, d values of 1 or 2 normally are sufficient to make the series stationary (Tabachnick and Fidell 2018).

The third ARIMA factor (q) is the order of the moving average (MA) term, which is the number of lagged forecast errors that should go into the ARIMA model. A lower number indicates that the lags are more recent (Tabachnick and Fidell 2018). In the case of predicting tender price indexes in Q2 2021, for example, when $q = 0$, there are no moving average components. When $q = 1$,

there is a relationship between the index in Q2 2021 and the random error at Q1 2021. When $q = 2$, there is a relationship between the index in Q2 2021 and the random error at Q4 2020 (Tabachnick and Fidell 2018).

The next test of robustness was the model's adjusted coefficient of determination (adjusted R^2). A higher adjusted R^2 means that the predicted model has a good fit with the actual numbers (predictors). In the case of predicting tender price indexes, this means that, for example, for Q4 2019 the predicted index is very close to the actual Q4 2019 index. In addition, mean average percentage error also was calculated.

To find the most suitable model, autoregressive time-series modeling was conducted using different values of p, d, and q in this order: $(0,0,0), (1,0,0), (2,0,0), \ldots, (1,0,1), \ldots, (3,0,3), \ldots, (1,1,0), \ldots, (2,2,0), (1,1,1), (2,2,2)$. A suitable model is one for which the parameters are significant at <0.05. Thereafter, the adjusted R^2 values of the suitable models were compared. The suitable model with the highest adjusted R^2 is the most fitted model, i.e., the one that can represent the data series most closely and is considered to be representative and good for forecasting (Levendis 2018).

The qualitative research was based on in-depth interviews with subject matter experts who were handling construction projects in 2020. The purpose was to discover how different parties managed their projects during the pandemic. The interview questions are provided in the Appendix. Three groups of stakeholders were contacted: contractors, consultants, and owners. Purposive and snowball sampling methods were used to select the interviewees. In snowball sampling, those who completed the interview were requested to introduce other suitable candidates to be interviewed. Targeted subject matter experts were emailed the interview questions and requested to participate in the research. If they agreed, an interview time, date, and venue were set up. Due to the ongoing pandemic, the majority of the interviews were conducted via video conferencing or telephone, and only a few were conducted in-person. Some interviewees preferred to provide their answers via email. Transcripts were prepared after each interview was conducted.

The interview transcripts were analyzed manually using content analysis method. This was done by systematically identifying the subject matter experts' replies and messages, and thereafter making inferences of the message to arrive at a narrative. Attention was paid to the presence of certain words or concepts in the transcripts. Based on this, inferences were made about the messages within the interview. Common trends across the interviews were identified for each question. Differences in responses were highlighted.

Characteristics of Sample

About 500 questionnaires were sent to targeted samples; 95 sets of completed questionnaires were received from 60 contractors and 35 consultants. An independent samples t-test showed that there was no significant difference ($p < 0.05$) in the way that contractors and consultants rated all the questions; hence, both groups were analyzed together.

About half of the respondents were middle management, and more than one-third were senior management, and they were involved in a wide variety of tasks in their projects (Table 1). The majority had more than 10 years of working experience.

The respondents also provided details of a project that they managed in 2020 (Q1 2020 was prepandemic, and the other three quarters were during the pandemic). There was a good mix of project types, with an almost equal distribution between public and private sector projects, and the majority of them were greater than 10,000 m^2 in gross floor area (GFA) (Table 2).

Table 1. General characteristics of respondents ($n = 95$)

Description	Frequency	Percentage (%)
Nature of firm		
Contractors	60	63.2
Consultants	35	36.6
Designation		
Professional	8	8.4
Middle management	52	54.7
Senior management	35	36.8
Working experience		
Less than 5 years	15	15.8
6–10 years	17	17.9
11–20 years	27	28.4
21–30 years	22	23.2
More than 30 years	14	14.7
Job responsibilities (more than one is possible)		
Construction management	52	54.7
Consultancy service	30	31.6
Architecture	14	14.7
Civil engineering	23	24.2
Mechanical and electrical engineering	22	23.2
Structural engineering	14	14.7
Quantity surveyor	30	31.6
Building information modeling	10	10.5

Note: Rounding-off error may have occurred in calculation of percentage.

Seventeen in-depth interviews were conducted. The subject matter experts' experience ranged from 7 to 40 years, with a mean of 23 years, and the majority of the experts held senior positions in their organizations (Table 3).

Results and Discussion

The section begins by presenting the survey results comprising project-level outcomes. The second part analyzes the industry-level demand and supply situation during the pandemic. The final part describes the ARIMA models which were used to predict future tender price indexes beyond 2020.

Schedule Performance

The survey respondents reported that their projects would be delayed by between 4 and 24 months, with a mean of 12 months. Schedule performance (Y1) was calculated as the percentage difference between the estimated or actual duration and the contract duration. This ranged from 7.3% to 266.7%, with a mean of 46.3%, which is significantly high (Table 4). Almost half of the projects were expected to take 40% more time to complete than originally was planned (Table 2).

According to the interviewees, the root cause of the project delays was the shortage of workers. In 2020, Singapore's employment for construction declined by 11.3% (MOM 2021). There was a shortage of workers because a large percentage of migrant construction workers living in dormitories contracted COVID-19. When one positive case was detected, many close contacts needed to be quarantined at dedicated facilities, therefore decreasing the number of people who were available to work (WHO 2020a).

Another reason for the shortage of workers was that migrant workers were not allowed to leave their dormitories even 2 months

Table 2. General characteristics of projects

Description	Frequency	Percentage (%)
Type of facility/project ($n = 79$)		
Infrastructure (including earth works and civil engineering works)	18	22.8
Institutional (include educational, healthcare, and other public buildings)	13	16.5
Residential	16	20.3
Commercial (include retail shops, restaurants, hotels, medical buildings and hospitals, shops, and office buildings)	30	38.0
Industrial	2	2.5
Gross floor area (m^2) ($n = 70$)		
Up to 10,000 m^2	25	35.7
10,001–20,000 m^2	13	18.6
20,001–30,000 m^2	5	7.1
30,001–40,000 m^2	1	1.4
>40,000 m^2	26	37.1
Ownership of facility or project ($n = 79$)		
Public sector	38	48.1
Private sector	39	49.4
Public–private joint venture	2	2.5
Schedule performance ($n = 74$)		
Less than 20%	17	23.0
20%–40%	24	32.4
41%–60%	19	25.7
61%–80%	5	6.8
More than 80%	9	12.2
Cost performance ($n = 79$)		
1 = Cost overrun >5%	56	70.9
2 = Cost overrun up to 5%	15	19.0
3 = Complete on budget	7	8.9
4 = Cost savings up to 5%	0	0
5 = Cost savings >5%	1	1.3
Quality performance ($n = 79$)		
1 = Significantly lower than prepandemic	9	11.4
2 = Slightly lower than prepandemic	16	20.3
3 = Similar to prepandemic	47	59.5
4 = Slightly higher than prepandemic	5	6.3
5 = Significantly higher than prepandemic	2	2.5

after the lockdown was lifted. Most interviewees stated that this was because they needed to wait for all the residents in their dormitories to be tested and cleared from the virus.

The existing pool of migrant workers who returned to their home countries during the pandemic also contributed to worker shortage. One contractor-interviewee (KT3) stated that "30% of migrant workers went back to their home countries and did not return to Singapore." This was echoed by another contractor-interviewee (KT1), who said that "many high-skilled Chinese workers decided to go back to China and did not return even when there were fewer COVID-19 positive cases in Singapore."

Another reason for project delay was the curtailment of the supply line. India and Bangladesh are the two major sources of migrant construction workers in Singapore. Due to the serious COVID-19 outbreak in these two countries, the Singapore government reduced the number of migrant workers from South Asia who were allowed to enter Singapore. Therefore, there were not enough migrant workers to be deployed to work on construction sites to undertake construction work.

Subject matter experts were asked how they managed the worker shortage. One contractor-interviewee (KT3) managed by forming smaller crews, and making every crew member work harder. All contractor-interviewees revealed that construction workers had to work longer hours, and sometimes 7 days/week. Contractors also negotiated with project owners for extension of time on the grounds of a shortage of workers.

To reduce this risk, contractor-interviewees suggested that migrant workers could be required to complete their vaccination at least 2 weeks before their entry into Singapore. This would be in addition to the current requirement of having a valid negative COVID-19 PCR test taken within 72 h before departure. However, some countries do not have enough vaccines to inoculate their population.

Cost Performance

Almost 90% of the projects were expected to have budget overrun of 5% or more (Table 2), and this was confirmed by the one-sample *t*-test which indicated significant cost overrun (Table 4). Contractor-interviewees stated that they managed the shortage of workers by contracting with other labor subcontractors at a higher price. All the interviewees disclosed that the supply of migrant

Table 3. Profile of interviewees

Interviewee code	Designation	Years in construction	Predominant business
KT1	Senior project manager	16	Construction firm
KT2	Project director	28	Construction firm
KT3	Project manager and assistant vice president	28	Construction firm
ON1	Director	23	Owner of public facility
ON2	Group director	20	Owner of commercial facilities
ON3	Deputy chief development officer	34	Property developer
ON4	Deputy director	28	Owner of public facility
CQS1	Senior associate	40	Cost engineering consultant
CQS2	Associate	25	Cost engineering consultant
CQS3	Associate	20	Cost engineering consultant
CQS4	Associate	11	Cost engineering consultant
CQS5	Associate	10	Cost engineering consultant
CPM1	Deputy director	29	Client's project manager
CPM2	Project manager	24	Project management consultant
CPM3	Director	38	Project management consultant
CSE1	Senior engineer	7	Structural engineering consultant
CAR1	Senior architect	12	Architecture consultant

Table 4. Effect of COVID-19 on projects

Code	Description	Scale	Mean	*t*-value	Significance (1-tailed)
Y1	Schedule performance	(Actual duration—contract duration)/(contract duration)	46.3%	9.696	0.000
Y2	Cost performance	1 = cost overrun >5%; 2 = cost overrun up to 5%; 3 = complete on budget; 4 = cost savings up to 5%; 5 = cost savings >5%	1.42	−18.471	0.000
Y3	Quality performance	Compared with prepandemic, quality performance would be: 1 = significantly lower; 2 = slightly lower; 3 = similar; 4 = slightly higher; 5 = significantly higher	2.68	−3.288	0.001
Z1	General impact of COVID-19 on project	Five-point scale, where 1 = much more negative than prepandemic; 3 = no difference; 5 = much more positive than prepandemic	2.08	−7.035	0.001
Z2	Construction volume or project opportunities in 2021 for your firm	Compared with prepandemic, volume/opportunities would be: 1 = significantly lower; 3 = no difference; 5 = significantly higher	2.46	−4.12	0.001

construction workers was not sufficient to meet the demand on-site, and the cost of workers had increased. They stated that most main contractors sourced workers through labor subcontractors, and these subcontractors were unable to supply the number of workers that originally was agreed upon. Labor shortage is a serious issue because it increases labor wages, causing cost and schedule overruns in construction projects (Kim et al. 2020).

Quality Performance

Respondents rated quality performance on a five-point scale, and one-third indicated that quality would be lower or significantly lower compared with before the pandemic situation and 60% indicated that quality would be similar to that before the pandemic (Table 2). The one-sample *t*-test (Table 4) indicated that quality would be significantly lower than before the pandemic (mean = 2.68, $p = 0.001$).

Construction Demand: Value of Contracts Awarded

Singapore's construction demand was experiencing an upward trend 3 years prior to the pandemic in 2020, with the total value of contracts awarded being S$24.8 billion in 2017, S$30.5 billion in 2018, and S$33.5 billion in 2019 (BCA 2021b) (S$1 ≈ US $0.75). The value of contracts awarded in the pandemic year of 2020 was S$21 billion (BCA 2021b), representing a decrease of 15.3%, 31.1%, and 37.3% compared with the values in 2017, 2018, and 2019, respectively. On average, the COVID-19 pandemic caused construction demand to decrease by about 27.9% in 2020 compared with that in the three preceding years. The public and private sector construction demand in 2020 decreased by 31% and 44%, respectively, from 2019 due to postponement of projects and market uncertainties (BCA 2021d). The decrease in construction demand due to the pandemic also occurred in other countries (Allen-Coghlan and McQuinn 2020).

The data on the value of contracts awarded was analyzed further by quarter (Table 5). The value of contracts awarded was much lower in Q3 and Q4 of 2020 compared with previous years' similar quarters, contracting by 65% and 32% in Q3 and Q4, respectively. This indicates that although the COVID-19 pandemic was declared in Q1 of 2020, project owners and developers took concrete action in Q3 and Q4 to stop awarding contracts when the impact of the pandemic was felt more acutely. The most severe contraction occurred in Q3. There still was contraction in Q4, but it was less severe. This reflects the gradual reopening of the economy and the return of demand for construction products because the pandemic was better managed.

The pandemic had a significantly negative impact on the respondents' projects (mean = 2.08, $p = 0.001$), and their construction volume or project opportunities in 2021 were significantly lower than before the pandemic (mean = 2.46, $p = 0.001$) (Table 4). Given the substantial reduction in construction demand in 2020, we asked about project owners' plans regarding their unfulfilled construction demand in 2020 and the near future. Projects generally fall into three categories: the construction stage, in which contracts already have been awarded; the tendering stage, in which tenders have been called and may or may not have closed; and the planning stage. All interviewees stated that projects for which contracts had been awarded when the pandemic started were allowed to proceed, and no steps were taken by the owner to rescind them. For projects for which tenders had been invited or closed, but contracts had not been awarded, some owners had let the offers lapse. The main reason was that the bid prices received during the pandemic were beyond the owners' budgets. This is consistent with the law of demand, which states that the higher is the price of a product, all else being equal, the less of it will be demanded, as depicted by a downward-sloping demand curve (Fernando 2020). Two owner-interviewees (ON1 and ON3) stated that bid prices for new projects had increased, even for projects that were to be completed 2–3 years later. Owners' strategy therefore is to wait for the market to be more

Table 5. Construction demand, value of contracts awarded: year-on-year comparison by quarter against 2020

Quarter	2020 (S$ million)	2019 (S$ million)	2018 (S$ million)	2017 (S$ million)	YoY change (2020 versus 2019) (%)	YoY change (2020 versus 2018) (%)	YoY change (2020 versus 2017) (%)	Average YoY change (%)
Q1	6,454.92	8,625.93	8,387.42	4,771.22	−25.2	−23.0	35.3	−4.3
Q2	5,975.42	7,276.30	6,252.02	4,882.45	−17.9	−4.4	22.4	0.0
Q3	2,670.96	9,615.10	6,549.79	7,258.39	−72.2	−59.2	−63.2	−64.9
Q4	5,705.84	8,006.52	9,345.95	7,886.47	−28.7	−38.9	−27.7	−31.8

Source: Data for 2017–2020 from BCA (2021b).
Note: Q = quarter; YoY = year on year; and S$1 ≈ US $0.75.

stable and for bid prices decrease before fulfilling their demand by calling fresh tenders at a later date. One interviewee who was a consultant architect (CAR1) stated that "Due to the pandemic, the capital available became less for construction. Therefore there were almost no new projects. As a result, my firm had to cut wages to survive."

For projects that were at the planning stage, owner and consultant-interviewees stated that these projects were suspended or postponed. The reasons were to wait for tender prices to decrease and construction labor supply to increase. A client-interviewee (ON2) stated that "There are projects that are not so urgent, for example redevelopment of certain facilities. We would postpone the implementation until the labor situation has improved."

Client-interviewee ON3 stated that they postponed the date of inviting bids, and used the time to review the project time line. This is consistent with the findings of Assaad and El-adaway (2021), who asserted that construction projects are expected to take longer to complete due to major safety changes on construction sites and the need to work with a reduced on-site workforce.

Interviewees also stated that due to the pandemic, the feasibility, scope, and design of some projects were reexamined because there would be a new normal after the pandemic. For example, Interviewee CQS5 stated that an aviation project was suspended indefinitely because the new normal postpandemic may not involve extensive flying. A careful review of projects that are needed in the long run is useful, and is consistent with the findings of Assaad and El-adaway (2021), who identified increased demand for healthcare facilities because the current capacities were not sufficient to accommodate the number of infected and sick people. Owner-interviewee ON1 asked users if they wanted to change designs (e.g., incorporate more touchless features). Project teams also used the time to conduct value engineering to see if costs could be reduced further without reducing quality.

During the most serious quarters of the pandemic in Q2 and Q3, contracts still were being awarded (Table 5). Owner-interviewee ON1 stated that his firm did not totally stop awarding contracts because end-users need the spaces and facilities to carry out their programs. ON3 saw a significant increase in demand for industrial facilities because companies require space to manufacture goods. ON3 stated that for very important projects, financial data were re-evaluated to see if the projects still could proceed but with the developer earning a lower profit margin. ON2 summed this up by saying that they would not change their long-term development plans, because the pandemic is considered to be short-term in nature.

In conclusion, the data show that construction demand in 2020 decreased by nearly 28% due to the pandemic. The interview findings corroborated the numerical data that showed that the COVID-19 pandemic caused a sharp decrease in the value of contracts awarded. Project owners plan to delay implementing their projects because they are waiting for tender prices to decrease and the labor supply to increase. The results regarding construction demand agree with Assaad and El-adaway's (2021) finding that the pandemic has both short- and long-term impacts, including negative and positive consequences. The critical challenges faced by owners are consistent with Morris (2020) view that there would be delays and suspensions of existing projects and cancellations of planned and new projects, although in Singapore, owners are not cancelling their projects but merely are postponing those that are not urgent or reprioritizing which projects to develop first.

The implication for contractors is that whereas they could bid high during the pandemic, or price a high markup, owners who operate within the law of demand would curtail their demand and not award the contracts. Owners are postponing their projects and using this time to re-examine the design, scope, financial feasibility, and timeline of their projects. The implication for consultants is that they might be very busy proposing alternative designs and associated costing, but might not be paid additional fees.

Construction Output: Value of Progress Payments Certified

In the years before the pandemic, construction output was stable, with payments certified at S$27.9 billion, S$26.6 billion and S$28.3 billion in 2017, 2018, and 2019, respectively (BCA 2021b). The total value of progress payments certified in 2020 was S$19.7 billion, a decrease of 29.4%, 25.9%, and 30.4% compared with those in 2017, 2018, and 2019, respectively. Overall, there was an average decrease of 28.6% in 2020 compared with the preceding 3 years.

The data on the value of progress payments were analyzed further by quarter (Table 6). The average change in construction output was +4.1%, −52%, −50%, and −18.4% in Q1–Q4, respectively, compared with similar quarters in the preceding 3 years. Generally, the construction output was much lower in the Q2 and Q3 of 2020 compared with previous years' similar quarters because most of the work on-site came to a standstill. The COVID-19 cases for each quarter were 926 (Q1), 42,981 (Q2), 13,858 (Q3), and 834 (Q4) (MOH 2021). The sharp decline in construction output in Q2 and Q3 coincided with the quarters that had the most COVID-19 cases in Singapore.

During the lockdown in Q2, some progress payments were certified (Table 6). This was because 5% and 10% of construction workforce (around 20,000 workers and 40,000 workers) were allowed to work in May and mid-June, respectively (MOH 2020b). In Q3 when the lockdown was lifted, construction output still was low. Most interviewees stated that this was due to the slow restart after the lockdown was lifted. A contractor-interviewee (KT1) revealed that "The amount of work done was 0% during the lockdown. Even 2 months after lockdown was eased, almost no work was done because labor unavailability. This increased gradually to 10% to 20% in July."

Table 6. Construction output, progress payments certified: year-on-year comparison by quarter against 2020

Quarter	2020 (S$ million)	2019 (S$ million)	2018 (S$ million)	2017 (S$ million)	YoY change (2020 versus 2019) (%)	YoY change (2020 versus 2018) (%)	YoY change (2020 versus 2017) (%)	Average YoY change (%)
Q1	7,403.46	7,085.75	6,741.56	7,545.46	4.5	9.8	−1.9	4.1
Q2	3,199.28	6,758.00	6,471.96	6,776.64	−52.7	−50.6	−52.8	−52.0
Q3	3,360.43	6,950.00	6,568.39	6,642.2	−51.6	−48.8	−49.4	−50.0
Q4	5,776.87	7,506.00	6,817.37	6,946.87	−23.0	−15.3	−16.8	−18.4

Source: Data for 2017 to 2020 from BCA (2021b).
Note: Q = quarter; YoY = year on year; and S$1 ≈ US $0.75.

However, several consult interviewees (CQS1, CQS2, CQS3, CQS5, CPM2, CPM3, and CAR1) stated that because their work could be done from home, their consulting work was not affected.

Although progress payments certified for Q3 increased (Table 6), interviewees stated that this was due to public sector clients making advance payment for public projects from July onward even though no actual work was done (BCA 2020a). The private sector followed suit. As more construction activities restarted when there were fewer COVID-19 cases in the later part of the year, construction output also increased in Q4.

Most interviewees stated that the main reasons for the low construction output even after the lockdown was lifted were the shortage of workers and compliance with safe management measures. The volume of construction works still was low, as also was the case in China, where the lockdown measures halted construction work and delayed construction progress (Zhuo 2020).

Adoption of Productive Technologies

Because the main reason for the reduction in construction output was the worker shortage, a natural question to ask is "Because manual labor is unavailable or scarce during a health pandemic, can construction projects adopt more productive technologies to reduce reliance on manual labor?" This question was posed to interviewees.

All the owner interviewees stated that they do encourage contractors to use productive technologies but do not force them to do so. One owner-interviewee (ON3) stated that "a balance needs to be struck because adopting these technologies translates to higher cost." To promote the use of more productive technologies, owner-interviewees stated that bidders who propose productive technologies receive higher scores in the quality and/or productivity portion of tender assessments.

A contractor interviewee (KT3) stated that productive technologies such as precast concrete and prefabrication already are adopted widely. Two other contractor interviewees (KT1 and KT2) disclosed that it is difficult for them to adopt further productive technologies because these cost more than labor. Consultant interviewees also stated that productive technologies will be adopted only if they cost less than workers. But because labor cost still is lower, it is difficult to adopt more productive technologies.

In addition, contractor interviewees revealed that productive technologies are suitable only for large projects in which there is enough repetitive design and economies of scale. For small to medium-sized projects, these technologies may not be suitable, and can add more trouble to site operations.

To encourage more projects to adopt productive technologies, one architect interviewee (CAR1) stated that "the government and owners of large projects should take the lead to prove that these technologies can save both cost and time so that other projects can follow the lead." The interviewees stated that the industry will adopt productive technologies only if they make commercial sense and cost less than workers (all interviewees' view); they help contractors in their branding and are a unique selling point to win tenders (contractor interviewees' point); and there is a strong push from the government, for example, making it compulsory for certain types of projects. However, according to Assaad and El-adaway (2021), the pandemic is a good opportunity to leverage off-site construction technologies and methods because such work is executed in a controlled environment in which the coronavirus precautions can be better controlled, managed, and applied. Therefore it is suggested that policies or regulations should be enacted to enable more use of productive technologies such as off-site construction. Increased leverage of existing technologies such as automation, robotics, and three-dimensional (3D) printing also are recommended (Assaad and El-adaway 2021).

Safe Management Measures at Worksite

Another reason for the reduction in construction output was the lower productivity and efficiency arising from the need to comply with safe management measures. Contractors had to comply with many COVID-safe restart measures before they physically could start work on-site (BCA 2021c).

The measures relate to reducing physical interaction, ensuring safe distancing, implementing contact tracing by performing digital check-in and check-outs and carrying Bluetooth tokens, maintaining workplace cleanliness, and putting in place a detailed monitoring plan to ensure compliance with safe management measures. Many of these also are practiced in other countries (Assaad and El-adaway 2021).

Many interviewees stated that the safe management measure impacted work progress. For example, each worker is confined to an assigned group and zone, and intermingling among groups and crossing of zones are not allowed. One contractor-interviewee (KT3) stated that "Before the pandemic, one worker can be deployed to multiple sites when there was work to do. However, with the safe management measures, one worker cannot be cross deployed, leading to lower work progress."

This finding is consistent with that of Amoah and Simpeh (2021), who found that these measures are not easy to fulfil and are challenging to comply with. Furthermore, in Singapore, the BCA conducts regular checks and takes enforcement actions (BCA 2021a).

Productivity also is reduced because workers have to stop work and go to testing centers to be tested every 14 days. However, one contractor interviewee (KT3) acknowledged that "the government has made the routine testing more convenient and workers need not take half a day to get their tests done." He also acknowledged that although there is some time loss, it is important to perform digital check-ins and check-outs to "help control and document who is on site and avoid cross infection."

In conclusion, the interview findings and the numerical data of progress payments certified show that the COVID-19 pandemic had a negative effect on construction output. The data show that construction output in 2020 decreased by nearly 29% due to the pandemic. The interview findings revealed that the reduction mainly was caused by the lockdown, during which nearly all construction work stopped for about 2 months, followed by a shortage of workers and having to comply with safe management measures, which slowed work on-site. The problems detected are consistent with those identified by Morris (2020), i.e., supply chain complications, production delays, and logistic bottlenecks; creation of additional and new risks related to the workplace, jobsites, and contract responsibilities; labor or workforce issues including shortage of labor, protection of workers, ensuring proper health and safety precautions; and decreased worker power. The results regarding construction output are in agreement with Assaad and El-adaway's (2021) finding that the pandemic gave rise to workforce-related issues and project and workplace considerations.

It was found that workers will be replaced by productive technologies to reduce the heavy reliance on labor only if the technologies cost less than labor, contractors receive preferential treatment in being awarded projects if they propose productive technologies, and adoption of these technologies is a made a mandatory requirement especially for large projects and public projects. These findings may inform policy regarding ways to increase construction productivity.

Table 7. Autoregressive time-series models for tender price indexes

	All buildings (M1)		Public housing (M2)		Private housing (M3)		Commercial (M4)	
Period	Actual	Fitted/predicted	Actual	Fitted/predicted	Actual	Fitted/predicted	Actual	Fitted/predicted
Q2 2020	101.0	101.9	93.0	94.3	103.8	104.9	97.7	98.7
Q3 2020	102.7	101.6	102.6	94.1	103.8	104.7	97.7	98.7
Q4 2020	106.5	103.9	103.0	104.6	111.5	104.7	103.3	98.6
Q1 2021	110.8	108.8	104.7	104.4	117.6	114.4	108.6	105.8
Q2 2021	116.1	113.5	110.1	105.9	120.8	120.6	111.8	111.4
Q3 2021	—	115.30	—	106.80	—	122.43	—	113.34
Q4 2021	—	116.36	—	107.40	—	123.47	—	114.58
Q1 2022	—	116.84	—	107.80	—	123.85	—	115.23
Q2 2022	—	116.89	—	108.00	—	123.76	—	115.42
Q3 2022	—	116.65	—	108.00	—	123.34	—	115.27
Q4 2022	—	116.22	—	107.80	—	122.72	—	114.87
Q1 2023	—	115.68	—	107.50	—	121.99	—	114.33
Q2 2023	—	115.11	—	107.20	—	121.22	—	113.71
Q3 2023	—	114.55	—	106.70	—	120.48	—	113.08
Q4 2023	—	114.03	—	106.20	—	119.81	—	112.48

Note: COVID-19 pandemic declared from Q1 2020 onward.

Forecasting and Predicting Tender Prices

With quarterly data from Q1 1987 to Q1 2021 and the autoregressive time-series analysis using ARIMA, four models to predict tender prices indexes for all building types (M1), public housing (M2), private housing (M3), and commercial projects (M4) until the end of 2023 was constructed (Table 7).

The changes to the predicted quarterly results of the four project types tended to be almost the same, without obvious difference. ARIMA thus was conducted based on yearly data, and a similar pattern was observed, suggesting that this was not due to the use of quarterly data rather than yearly data. Despite the similarity in the patterns of change, the predicted indexes for the four project types are reported here because different segments of the construction industry use different sets of tender price indexes. For example, owners of commercial projects refer to Model 4, whereas private property developers use Model 3.

The models were subjected to diagnostics validation tests, and the results indicated a high adjusted coefficient of determination (R^2), and acceptable mean absolute error (MAE), RMS error (RMSE), autoregressive term, minimum number of differencing, and moving average term (Table 8). In addition, Breusch–Godfrey test results indicated significantly high autocorrelations between actual indexes and fitted models, with $p < 0.05$. The diagnostics indicated that the most fitted models were robust because they were close to the actual indexes, indicating that the new indexes that they predict may be useful.

During the pandemic quarters (especially Q4 2020 to Q2 2021), the models' fitted indexes were lower than the actual indexes (Table 7). The MAE and RMSE were higher in the pandemic quarters (Q2 2020 to Q2 2021) than for the whole study period (Q1 1987 to Q2 2021), signifying that the fitted indexes were less accurate during the pandemic quarters. These observations suggest that the predicted indexes (Q3 2021 to Q4 2023) might be inaccurate because the predictions were made during the unprecedented pandemic conditions (such as supply chain disruption, governmental interventions, cash flow disruption, labor unavailability, and other pandemic-related disruptions), whereas ARIMA needs stable conditions to make accurate predictions. There is a likelihood that there the future indexes were underpredicted. One way to deal with this is to adjust the Q3 2021 to Q4 2023 predicted indexes upward by a quantum that lies between the MAE and RMSE (Table 8). For example, the predicted indexes could be increased by 3.04%–3.16%, 2.10%–2.45%, and 1.90%–1.97% for public housing, private housing, and commercial projects, respectively.

Predicted tender price indexes will continue to rise throughout 2021 and reach the peak in the first half of 2022 for all four project categories (Table 7). This is because of the increase in cost of production due to difficulty importing migrant workers into Singapore, supply chain disruption, unpredictable lockdowns, and additional measures to comply with if there are new waves of COVID-19 cases. After the first half of 2022, tender price indexes are predicted to decrease because by then the COVID-19 situation may be under

Table 8. Evaluation of ARIMA models

Description	All types (M1)	Public housing (M2)	Private housing (M3)	Commercial (M4)
Adjusted R^2	0.975	0.938	0.958	0.954
Significance of autocorrelation (p)	$1.91 \times 10^{-77**}$	$4.28 \times 10^{-67**}$	$7.13 \times 10^{-72**}$	$2.47 \times 10^{-67**}$
Autoregressive term	3	2	2	1
Minimum number of differencings	0	0	0	0
Moving average term	0	1	1	1
Mean absolute error (%)				
Q1 1987 to Q1 2021	1.39	2.88	1.50	1.29
Q2 2020 to Q2 2021 (pandemic)	1.69	3.04	2.10	1.90
RMS error (%)				
Q1 1987 to Q2 2021	1.29	2.54	1.43	1.22
Q2 2020 to Q2 2021 (pandemic)	1.84	3.16	2.45	1.97

Note: $^{**}p < 0.001$.

control, with more people vaccinated and the pandemic moving into an endemic stage and life returning to a new normal.

The implication of the finding is that most projects that are not urgent should be postponed because an upward trend in prices is predicted until mid-2022. Owners and contractors may use these models to help predict the future price of construction. Without the models, the approach to predict the future price of construction involves adding a fixed percentage of the estimated total cost of construction, i.e., adding a risk premium (Ilbeigi et al. 2017a). This percentage is difficult to determine objectively, may be inaccurate, and may increase the cost of the project unnecessarily because contractors are likely to be risk-averse in a pandemic.

Limitations of Research

One limitation of this study is that the data for supply and demand came from only one source—the BCA—because there are no other published sources in Singapore. BCA's data on progress payments certified may not fully reflect construction output, because it included advance payments made to contractors during the pandemic to alleviate their cash flow problems, and some projects may not have reported the payments certified. Regarding the value of contracts awarded, there also is the possibility that some contracts awarded were not reported. Moreover, the data were not able to capture tenders that were called but not awarded and projects that were postponed at the design stage. These limitations were mitigated by the questionnaire survey and qualitative research, in which interviews with subject matter experts were conducted to triangulate the numerical data and provide in-depth explanation of the quantitative results.

The next limitation is that the four sets of predicted tender price indexes might be inaccurate. Although the predicted tender price indexes comprised contractors' cost of inputs (labor, materials, and equipment) and markup, these do not capture all the factors that affect project costs because ARIMA may not be able to make reliable predictions under the unstable and unprecedented situation brought about by the pandemic. This limitation was lessened somewhat because the models incorporated actual indexes of 5 continuous pandemic quarters (Q2 2020 to Q2 2021), and by Q3 2021, Singapore's situation had stabilized, and the aggregate economic output returned to its prepandemic level (Monetary Authority of Singapore 2021). Some care should be taken in interpreting the results and using the predicted indexes—for example, adjusting it upward by a quantum that is within the MAE and RMSE range (Table 8). In the future, studies may explore modeling using nonlinear models such as artificial neural networks to see if they are more accurate in forecasting tender prices.

Although this study was conducted using data from Singapore, the proposed methodology can be utilized for similar data sets in other countries.

Conclusion

This study investigated the COVID-19 pandemic's impact on Singapore's construction industry. The first objective was to investigate project outcomes, and the results showed that construction projects were delayed significantly (by an average of 46%), faced significant cost overrun (more than 5%), and had significantly lower quality compared with those before the pandemic (Table 4). This finding suggests that contractors might negotiate intensely over the duration of extension of time, disagree on the quantum of liquidated damages, and claim for prolongation costs, and owners might counterclaim because product quality does not meet specifications. The findings provide a guide for the length of extension time and the quantum of claims to be considered.

The second objective was to analyze the pandemic's impact on the value of contracts awarded, and results revealed that construction demand decreased by 27.9% in 2020, with significant decreases in Q3 and Q4 of 2020 (Table 5). During the pandemic, some owners postponed their projects because tender prices exceeded budgets. They will invite tenders after bid prices decrease, the market has stabilized, and workers shortage problem is surmounted. Project owners used the suspension period to review timelines, budget, feasibility, scope, and design. This finding provides guidance to owners that they need to re-evaluate the timeline for developing each project, and invite bids during a pandemic only if the project is both urgent and important. Otherwise, a pause in their development plans may save them a considerable amount of money.

The third objective was to study the effect of COVID-19 pandemic on construction output, and it was found that output decreased by 28.6% in 2020 (Table 6). The reasons for the reduction were found to be work stoppage during the lockdown, worker shortage, and lower productivity due to compliance with safe management measures. The research found that it is difficult to reduce reliance on manual labor in a laissez-faire market because labor still is cheaper than technology. A law is needed to mandate the adoption of technology, and owners and end users need to pay for the adoption of the technology.

The final objective was to predict tender price indexes in the near future. All four models predicted that tender price indexes will continue to rise until mid-2022 before decreasing (Table 7). Owners need to provide a larger development budget, and end users need to be prepared to pay more for built products, because the predicted indexes show that tender prices are unlikely to decrease to prepandemic levels.

The contribution to knowledge is that the models show the likely future risk premium and timing to enter the market. The implication for contractors is that the models can inform them about the likely percentage to be added to their estimated total construction cost as a risk premium. The implication for owners is that they could time the calling of tenders to coincide with a lower tender price index.

Appendix. Interview Questions

Please answer the questions based on one project which was in the construction stage between June 2020 and January 2021 which you are/were involved in.

1. Compared to prepandemic period (e.g,. January 2020), the productivity in July–August 2020 (after lockdown) and January 2021 (1 year into the pandemic) at the construction site is higher, lower or the same? Why?
2. What is the likely/actual budget/cost performance? If there is cost overrun: (1) What are the reasons for this? (2) How is the cost overrun dealt with?
3. What is the likely/actual quality performance compared to a non-COVID19 situation?
4. What is the project's start date, contractual end date, estimated or actual end date? If there is a delay: (1) What are the reasons for delay? (2) How is the delay dealt with? (3) What are the implications of delay?
5. Has there been cancellation, postponement, or changes made to the project? How does your firm manage this?
6. Was there disruption in supply chain? How were the challenges overcome?

7. Did your project face cash flow and/or financing issues? How was this challenge overcome?
8. Between June 2020 and December 2020, did your project experience a shortage of foreign workers? What were the reasons?
9. Data show that the number of foreign workers who were infected with COVID-19 made up more than 94% of the confirmed cases in Singapore. Going forward, how can reliance on foreign workers be reduced so that projects are not too affected during a pandemic?
10. Going forward, will your organization adopt more labor-efficient technologies, automation and robots to reduce the reliance on labor? What will your organization do to increase the usage of these technologies? What are the barriers to the adoption of these technologies?
11. What extra digitalization efforts did your project adopt during the pandemic? Is this likely to continue post-COVID? What other efforts can projects implement to increase the adoption of digitalization?

Data Availability Statement

Some or all data generated and analyzed in the current study are also available from the corresponding author upon reasonable request.

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Exhibit 25

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Exhibit 25

Summary of COVID Productivity Loss Costs

Summary of COVID Productivity Loss Costs

MONTH	Field Overheads	Camp Costs	Field Overheads - Materials Management	ROW	Foundations	Structure	Stringing	Totals
31-Mar-20	$743,871	$96,808	$186,871	$185,882	$278,661	$1,205,033	$0	$2,697,125
30-Apr-20	$165,241	$9,063	$64,893	$13,301	-$16,481	-$3,323	$0	$232,694
31-May-20	$270,387	$36,666	$112,987	$56,940	$289	$144,458	$0	$621,727
30-Jun-20	$454,199	$32,451	$130,170	$74,988	$68,876	$768,422	$0	$1,529,105
31-Jul-20	$652,251	$41,260	$158,311	$135,220	$364,661	$1,317,104	$261,351	$2,930,158
31-Aug-20	$835,126	$64,066	$207,498	$192,578	$531,947	$2,131,396	$328,013	$4,290,625
30-Sep-20	$837,265	$98,582	$187,376	$179,141	$280,076	$1,254,015	$311,535	$3,147,991
31-Oct-20	$812,620	$99,634	$178,391	$208,812	$308,259	$1,280,912	$424,560	$3,313,187
30-Nov-20	$751,768	$100,357	$172,282	$203,759	$462,916	$1,531,452	$402,708	$3,625,242
31-Dec-20	$523,660	$101,682	$102,728	$175,691	$330,048	$858,201	$252,876	$2,344,887
31-Jan-21	$551,595	$96,177	$169,966	$190,653	$384,010	$975,216	$426,548	$2,794,165
28-Feb-21	$735,472	$37,212	$211,611	$232,387	$671,440	$1,730,442	$455,306	$4,073,871
31-Mar-21	$872,258	$46,070	$276,717	$113,103	$1,019,710	$2,561,765	$510,750	$5,400,372
30-Apr-21	$281,849	$21,733	$135,725	$75,311	$64,925	$97,076	$113,420	$790,039
31-May-21	$546,907	$28,221	$154,034	$248,421	$301,392	$1,061,363	$511,788	$2,852,125
30-Jun-21	$715,689	$34,028	$153,737	$316,734	$609,359	$1,615,722	$556,310	$4,001,579
31-Jul-21	$709,713	$39,493	$148,504	$325,666	$678,677	$1,650,450	$464,050	$4,016,553
31-Aug-21	$810,015	$34,219	$163,151	$232,093	$822,249	$1,781,787	$487,380	$4,330,894
30-Sep-21	$686,949	$38,695	$158,124	$150,748	$569,182	$1,904,639	$458,248	$3,966,584
31-Oct-21	$660,175	$32,288	$139,685	$96,137	$287,141	$2,130,018	$662,565	$4,008,009
30-Nov-21	$710,681	$30,565	$162,343	$64,868	$231,697	$1,621,366	$1,305,753	$4,127,272
31-Dec-21	$535,751	$25,476	$127,224	$40,332	$85,135	$900,795	$1,368,524	$3,083,238
31-Jan-22	$532,163	$52,577	$129,375	$14,544	$3,862	$322,829	$1,972,334	$3,027,686
28-Feb-22	$435,939	$78,325	$120,265	$9,451	$2,847	$17,602	$2,408,891	$3,073,320
31-Mar-22	$224,201	$65,755	$105,335	$7,866	-$537	$0	$468,029	$870,649
Subtotal	**$15,055,744**	**$1,341,403**	**$3,857,303**	**$3,544,626**	**$8,340,339**	**$28,858,740**	**$14,150,939**	**$75,149,095**
Add 15% Markup	$451,672	$40,242	$115,719	$106,339	$250,210	$865,762	$424,528	$2,254,473
Add 15% Markup	$2,326,112	$207,247	$595,953	$547,645	$1,288,582	$4,458,675	$2,186,320	$11,610,535
Totals	**$17,833,529**	**$1,588,892**	**$4,568,976**	**$4,198,609**	**$9,879,131**	**$34,183,178**	**$16,761,787**	**$89,014,103**

Exhibit 25

COVID Productivity Loss Labor Costs

COVID Productivity Loss Labor Costs

MONTH	Field Overheads	Camp Costs	Field Overheads - Materials Management	ROW	Foundations	Structure	Stringing	Totals
31-Mar-20	$466,396	$68,997	$105,861	$77,521	$144,169	$650,535	$0	$1,513,478
30-Apr-20	$103,604	$6,420	$36,761	$5,547	-$8,527	-$1,794	$0	$142,012
31-May-20	$169,529	$26,131	$64,006	$23,746	$149	$77,986	$0	$361,547
30-Jun-20	$284,776	$23,606	$73,740	$31,273	$35,634	$414,832	$0	$863,860
31-Jul-20	$408,952	$29,911	$89,682	$56,393	$188,662	$711,037	$128,761	$1,613,397
31-Aug-20	$523,612	$45,970	$117,546	$80,313	$275,209	$1,150,631	$161,604	$2,354,886
30-Sep-20	$524,953	$70,396	$106,147	$74,709	$144,901	$676,979	$153,486	$1,751,571
31-Oct-20	$509,501	$71,198	$101,057	$87,083	$159,481	$691,499	$209,170	$1,828,990
30-Nov-20	$471,348	$71,709	$97,596	$84,976	$239,495	$826,753	$198,405	$1,990,282
31-Dec-20	$328,327	$72,683	$58,194	$73,271	$170,754	$463,299	$124,586	$1,291,115
31-Jan-21	$345,842	$68,854	$96,284	$79,510	$198,672	$526,469	$210,150	$1,525,782
28-Feb-21	$461,130	$27,272	$119,876	$96,915	$347,378	$934,177	$224,319	$2,211,066
31-Mar-21	$546,893	$33,869	$156,757	$47,169	$527,560	$1,382,966	$251,634	$2,946,848
30-Apr-21	$176,715	$15,905	$76,887	$31,408	$33,590	$52,406	$55,879	$442,791
31-May-21	$342,903	$20,658	$87,259	$103,602	$155,929	$572,975	$252,146	$1,535,472
30-Jun-21	$448,726	$24,981	$87,091	$132,091	$315,260	$872,246	$274,081	$2,154,475
31-Jul-21	$444,980	$28,875	$84,126	$135,817	$351,122	$890,993	$228,626	$2,164,539
31-Aug-21	$507,867	$25,141	$92,423	$96,792	$425,401	$961,896	$240,121	$2,349,641
30-Sep-21	$430,707	$28,478	$89,576	$62,868	$294,473	$1,028,217	$225,768	$2,160,087
31-Oct-21	$413,920	$23,765	$79,130	$40,093	$148,556	$1,149,888	$326,430	$2,181,782
30-Nov-21	$445,587	$22,447	$91,966	$27,053	$119,871	$875,292	$643,313	$2,225,529
31-Dec-21	$335,908	$18,676	$72,071	$16,820	$44,046	$486,293	$674,239	$1,648,053
31-Jan-22	$333,659	$37,778	$73,290	$6,066	$1,998	$174,279	$971,722	$1,598,791
28-Feb-22	$273,327	$55,941	$68,129	$3,941	$1,473	$9,502	$1,186,803	$1,599,117
31-Mar-22	$140,571	$46,617	$59,671	$3,280	-$278	$0	$230,587	$480,448
Totals	**$9,439,733**	**$966,277**	**$2,185,126**	**$1,478,260**	**$4,314,978**	**$15,579,356**	**$6,971,831**	**$40,935,560**

Exhibit 25

COVID Productivity Loss Travel
LOA and Camp Costs

COVID Productivity Loss Travel, LOA and Camp Costs

MONTH	Field Overheads	Camp Costs	Field Overheads - Materials Management	ROW	Foundations	Structure	Stringing	Totals
31-Mar-20	$95,715	$17,096	$20,448	$15,461	$27,386	$130,120	$0	$306,225
30-Apr-20	$21,262	$1,625	$7,101	$1,106	-$1,620	-$359	$0	$29,115
31-May-20	$34,791	$6,476	$12,363	$4,736	$28	$15,599	$0	$73,993
30-Jun-20	$58,442	$5,437	$14,244	$6,237	$6,769	$82,975	$0	$174,104
31-Jul-20	$83,926	$6,977	$17,323	$11,247	$35,838	$142,222	$21,117	$318,649
31-Aug-20	$107,457	$11,124	$22,705	$16,018	$52,278	$230,149	$26,503	$466,234
30-Sep-20	$107,732	$17,326	$20,503	$14,900	$27,525	$135,409	$25,172	$348,568
31-Oct-20	$104,561	$17,480	$19,520	$17,368	$30,295	$138,314	$34,304	$361,841
30-Nov-20	$96,731	$17,610	$18,852	$16,948	$45,494	$165,367	$32,538	$393,540
31-Dec-20	$67,380	$17,826	$11,241	$14,613	$32,436	$92,669	$20,432	$256,598
31-Jan-21	$70,975	$16,796	$18,598	$15,858	$37,739	$105,304	$34,465	$299,734
28-Feb-21	$94,634	$6,111	$23,155	$19,329	$65,987	$186,854	$36,788	$432,858
31-Mar-21	$112,235	$7,500	$30,279	$9,407	$100,213	$276,621	$41,268	$577,524
30-Apr-21	$36,266	$3,582	$14,851	$6,264	$6,381	$10,482	$9,164	$86,991
31-May-21	$70,371	$4,649	$16,855	$20,663	$29,620	$114,607	$41,352	$298,116
30-Jun-21	$92,089	$5,562	$16,822	$26,345	$59,886	$174,467	$44,949	$420,119
31-Jul-21	$91,320	$6,527	$16,250	$27,087	$66,698	$178,217	$37,495	$423,593
31-Aug-21	$104,226	$5,581	$17,852	$19,304	$80,808	$192,398	$39,380	$459,549
30-Sep-21	$88,391	$6,280	$17,302	$12,539	$55,937	$205,664	$37,026	$423,139
31-Oct-21	$84,946	$5,240	$15,285	$7,996	$28,219	$230,001	$53,535	$425,221
30-Nov-21	$91,444	$4,990	$17,764	$5,395	$22,770	$175,076	$105,504	$422,944
31-Dec-21	$68,936	$4,181	$13,921	$3,355	$8,367	$97,268	$110,575	$306,603
31-Jan-22	$68,474	$9,098	$14,157	$1,210	$380	$34,859	$159,363	$287,540
28-Feb-22	$56,093	$13,760	$13,160	$786	$280	$1,901	$194,636	$280,615
31-Mar-22	$28,848	$11,765	$11,526	$654	-$53	$0	$37,816	$90,557
Totals	**$1,937,243**	**$230,598**	**$422,076**	**$294,826**	**$819,658**	**$3,116,184**	**$1,143,383**	**$7,963,967**

Exhibit 25

COVID Productivity Loss
Equipment Costs

COVID Productivity Loss Equipment Costs

MONTH	Field Overheads	Camp Costs	Field Overheads - Materials Management	ROW	Foundations	Structure	Stringing	Totals
31-Mar-20	$181,760	$10,715	$60,562	$92,900	$107,106	$424,377	$0	$877,421
30-Apr-20	$40,376	$1,018	$21,031	$6,648	-$6,335	-$1,170	$0	$61,568
31-May-20	$66,067	$4,059	$36,617	$28,458	$111	$50,874	$0	$186,186
30-Jun-20	$110,980	$3,408	$42,186	$37,478	$26,473	$270,616	$0	$491,141
31-Jul-20	$159,373	$4,373	$51,307	$67,581	$140,161	$463,845	$111,473	$998,112
31-Aug-20	$204,057	$6,972	$67,247	$96,247	$204,460	$750,615	$139,906	$1,469,505
30-Sep-20	$204,580	$10,859	$60,726	$89,531	$107,650	$441,627	$132,878	$1,047,852
31-Oct-20	$198,558	$10,956	$57,814	$104,360	$118,483	$451,100	$181,085	$1,122,356
30-Nov-20	$183,690	$11,037	$55,834	$101,835	$177,927	$539,333	$171,765	$1,241,420
31-Dec-20	$127,953	$11,173	$33,293	$87,807	$126,858	$302,233	$107,858	$797,174
31-Jan-21	$134,779	$10,527	$55,084	$95,285	$147,599	$343,442	$181,933	$968,648
28-Feb-21	$179,708	$3,830	$68,580	$116,143	$258,075	$609,411	$194,199	$1,429,946
31-Mar-21	$213,130	$4,701	$89,680	$56,527	$391,937	$902,178	$217,847	$1,876,001
30-Apr-21	$68,868	$2,245	$43,987	$37,639	$24,955	$34,187	$48,376	$260,257
31-May-21	$133,633	$2,914	$49,920	$124,156	$115,843	$373,781	$218,290	$1,018,538
30-Jun-21	$174,874	$3,486	$49,824	$158,298	$234,214	$569,010	$237,280	$1,426,985
31-Jul-21	$173,414	$4,091	$48,128	$162,762	$260,857	$581,240	$197,929	$1,428,421
31-Aug-21	$197,922	$3,498	$52,875	$115,996	$316,041	$627,493	$207,880	$1,521,704
30-Sep-21	$167,851	$3,936	$51,246	$75,341	$218,771	$670,758	$195,454	$1,383,358
31-Oct-21	$161,309	$3,284	$45,270	$48,047	$110,366	$750,130	$282,600	$1,401,007
30-Nov-21	$173,650	$3,127	$52,613	$32,420	$89,055	$570,997	$556,936	$1,478,799
31-Dec-21	$130,907	$2,620	$41,232	$20,157	$32,723	$317,234	$583,710	$1,128,582
31-Jan-22	$130,031	$5,702	$41,929	$7,269	$1,485	$113,691	$841,249	$1,141,355
28-Feb-22	$106,519	$8,624	$38,976	$4,723	$1,094	$6,199	$1,027,452	$1,193,587
31-Mar-22	$54,782	$7,374	$34,138	$3,931	-$206	$0	$199,626	$299,644
Totals	**$3,678,769**	**$144,528**	**$1,250,101**	**$1,771,540**	**$3,205,703**	**$10,163,201**	**$6,035,726**	**$26,249,568**

Exhibit 25

Summary of COVID Productivity Loss Hours and Actual Hourly Rates

Summary of COVID Productivity Loss Hours and Actual Hourly Rates

MONTH	Field Overheads	Camp Costs	Camp Costs - Setup	Field Overheads - Materials Management	ROW	Foundations	Structure	Stringing	Totals
31-Mar-20	6,664	232	958	1,424	1,076	1,907	9,060	-	21,321
30-Apr-20	1,480	7	106	494	77	(113)	(25)	-	2,027
31-May-20	2,422	87	363	861	330	2	1,086	-	5,152
30-Jun-20	4,069	253	126	992	434	471	5,777	-	12,122
31-Jul-20	5,843	283	202	1,206	783	2,495	9,902	1,470	22,186
31-Aug-20	7,482	267	508	1,581	1,115	3,640	16,024	1,845	32,462
30-Sep-20	7,501	286	920	1,428	1,037	1,916	9,428	1,753	24,269
31-Oct-20	7,280	308	909	1,359	1,209	2,109	9,630	2,388	25,193
30-Nov-20	6,735	308	918	1,313	1,180	3,167	11,514	2,265	27,400
31-Dec-20	4,691	322	920	783	1,017	2,258	6,452	1,423	17,866
31-Jan-21	4,942	343	826	1,295	1,104	2,628	7,332	2,400	20,869
28-Feb-21	6,589	364	62	1,612	1,346	4,594	13,010	2,561	30,138
31-Mar-21	7,814	489	33	2,108	655	6,977	19,260	2,873	40,210
30-Apr-21	2,525	204	45	1,034	436	444	730	638	6,057
31-May-21	4,900	267	57	1,174	1,439	2,062	7,979	2,879	20,756
30-Jun-21	6,412	348	39	1,171	1,834	4,170	12,147	3,130	29,251
31-Jul-21	6,358	361	93	1,131	1,886	4,644	12,408	2,611	29,493
31-Aug-21	7,257	357	31	1,243	1,344	5,626	13,396	2,742	31,996
30-Sep-21	6,154	422	15	1,205	873	3,895	14,319	2,578	29,461
31-Oct-21	5,914	353	12	1,064	557	1,965	16,014	3,727	29,606
30-Nov-21	6,367	316	31	1,237	376	1,585	12,190	7,346	29,447
31-Dec-21	4,800	251	40	969	234	583	6,772	7,699	21,347
31-Jan-22	4,768	238	396	986	84	26	2,427	11,096	20,020
28-Feb-22	3,905	231	727	916	55	19	132	13,552	19,538
31-Mar-22	2,009	67	752	803	46	(4)	-	2,633	6,305
Totals	**134,881**	**6,964**	**9,091**	**29,387**	**20,527**	**57,069**	**216,965**	**79,608**	**554,492**
Avg Labor Rate	**$69.99**	**$65.45**	**$56.15**	**$74.36**	**$72.01**	**$75.61**	**$71.81**	**$87.58**	**$73.83**
Avg Equip Rate	**$19.65**	**$6.59**	**$6.59**	**$30.86**	**$62.47**	**$40.33**	**$34.81**	**$55.11**	**$34.67**
Fueling & Mech Alloc.	**$5.32**	**$1.65**	**$1.65**	**$8.56**	**$16.58**	**$10.53**	**$8.47**	**$14.25**	**$8.86**
Unbooked Eq Cost Adj.	**$2.31**	**$0.76**	**$0.76**	**$3.12**	**$7.25**	**$5.31**	**$3.56**	**$6.46**	**$3.89**
Adjusted Hourly Eq Cost	**$27.27**	**$9.00**	**$9.00**	**$42.54**	**$86.30**	**$56.17**	**$46.84**	**$75.82**	**$47.42**
Travel, LOA and Camp Operations	**$14.36**	**$14.36**	**$14.36**	**$14.36**	**$14.36**	**$14.36**	**$14.36**	**$14.36**	**$14.36**

Exhibit 25

Monthly Labour Hours

Monthly Labour Hours

C2G Cost Type	MONTH	Field Overheads	Camp Costs	Camp Costs - Setup	Field Overheads - Materials Management	ROW	Foundations	Structure	Stringing	Totals
Labor	28-Feb-18	-		-						-
Labor	31-Mar-18	-		-						-
Labor	30-Apr-18	98								98
Labor	31-May-18	192								192
Labor	30-Jun-18	588		210						798
Labor	31-Jul-18	2,069		230						2,299
Labor	31-Aug-18	1,294		127						1,420
Labor	30-Sep-18	1,134		100						1,234
Labor	31-Oct-18	811								811
Labor	30-Nov-18	520								520
Labor	31-Dec-18	401		104						505
Labor	31-Jan-19	243								243
Labor	28-Feb-19	288								288
Labor	31-Mar-19	655		140						795
Labor	30-Apr-19	899		301						1,200
Labor	31-May-19	4,559		259						4,818
Labor	30-Jun-19	2,654	3	1,090						3,747
Labor	31-Jul-19	3,374	314	1,020						4,707
Labor	31-Aug-19	3,633	8	1,000						4,641
Labor	30-Sep-19	3,954	39	110	511					4,614
Labor	31-Oct-19	9,168	11	1,827	1,927	302	100			13,334
Labor	30-Nov-19	12,806	46	6,052	2,913	1,374	1,049	7,633		31,871
Labor	31-Dec-19	10,636	111	4,534	2,576	1,773	690	11,031		31,349
Labor	31-Jan-20	20,376	645	8,299	4,744	3,021	903	32,864		70,851
Labor	29-Feb-20	22,527	783	7,239	5,596	4,731	2,466	41,136		84,477
Labor	31-Mar-20	26,980	941	3,879	5,764	4,358	7,720	36,679		86,320
Labor	30-Apr-20	5,993	30	428	2,002	312	(457)	(101)		8,207
Labor	31-May-20	9,807	354	1,472	3,485	1,335	8	4,397		20,858
Labor	30-Jun-20	16,474	1,023	510	4,015	1,758	1,908	23,389		49,077
Labor	31-Jul-20	23,657	1,148	819	4,883	3,170	10,102	40,090	5,953	89,822
Labor	31-Aug-20	30,290	1,080	2,056	6,400	4,515	14,736	64,875	7,471	131,423
Labor	30-Sep-20	30,368	1,158	3,726	5,780	4,200	7,759	38,170	7,095	98,255
Labor	31-Oct-20	29,474	1,246	3,682	5,502	4,896	8,540	38,988	9,670	101,997
Labor	30-Nov-20	27,267	1,246	3,718	5,314	4,777	12,824	46,614	9,172	110,932
Labor	31-Dec-20	18,993	1,302	3,723	3,169	4,119	9,143	26,122	5,759	72,330
Labor	31-Jan-21	20,007	1,389	3,346	5,243	4,470	10,638	29,684	9,715	84,490
Labor	28-Feb-21	26,676	1,473	250	6,527	5,449	18,601	52,671	10,370	122,015
Labor	31-Mar-21	31,637	1,980	134	8,535	2,652	28,248	77,975	11,633	162,794
Labor	30-Apr-21	10,223	827	183	4,186	1,766	1,799	2,955	2,583	24,521
Labor	31-May-21	19,836	1,081	229	4,751	5,824	8,349	32,306	11,656	84,034
Labor	30-Jun-21	25,958	1,410	158	4,742	7,426	16,881	49,179	12,670	118,424
Labor	31-Jul-21	25,741	1,462	378	4,581	7,636	18,801	50,236	10,569	119,404
Labor	31-Aug-21	29,379	1,447	127	5,032	5,442	22,778	54,234	11,101	129,539

Monthly Labour Hours

C2G Cost Type	MONTH	Field Overheads	Camp Costs	Camp Costs - Setup	Field Overheads - Materials Management	ROW	Foundations	Structure	Stringing	Totals
Labor	30-Sep-21	24,916	1,709	61	4,877	3,534	15,768	57,973	10,437	119,276
Labor	31-Oct-21	23,945	1,428	49	4,309	2,254	7,955	64,833	15,091	119,862
Labor	30-Nov-21	25,777	1,280	127	5,007	1,521	6,419	49,351	29,740	119,221
Labor	31-Dec-21	19,432	1,015	163	3,924	946	2,358	27,418	31,169	86,426
Labor	31-Jan-22	19,302	963	1,602	3,991	341	107	9,826	44,922	81,053
Labor	28-Feb-22	15,812	934	2,944	3,710	222	79	536	54,865	79,101
Labor	31-Mar-22	8,132	271	3,045	3,249	184	(15)	-	10,660	25,526
		648,951	**30,153**	**69,448**	**137,242**	**94,307**	**236,255**	**971,061**	**322,300**	**2,509,717**

Exhibit 25

Monthly Labour Costs

Monthly Labor Costs

C2G Cost Type	MONTH	Field Overheads	Camp Costs	Camp Costs - Setup	Field Overheads - Materials Management	ROW	Foundations	Structure	Stringing	Totals
Labor	28-Feb-18	$136,818		$4,286						$141,104
Labor	31-Mar-18	$20,958		$1,721						$22,678
Labor	30-Apr-18	$16,112								$16,112
Labor	31-May-18	$19,676								$19,676
Labor	30-Jun-18	$50,810		$10,544						$61,354
Labor	31-Jul-18	$162,044		$11,564						$173,607
Labor	31-Aug-18	$81,012		$6,298						$87,310
Labor	30-Sep-18	$80,021		$4,739						$84,760
Labor	31-Oct-18	$64,810								$64,810
Labor	30-Nov-18	$44,330								$44,330
Labor	31-Dec-18	$40,643		$4,848						$45,492
Labor	31-Jan-19	$15,476								$15,476
Labor	28-Feb-19	$16,060								$16,060
Labor	31-Mar-19	$50,769		$7,277						$58,046
Labor	30-Apr-19	$58,953		$15,003						$73,957
Labor	31-May-19	$294,118		$13,704						$307,822
Labor	30-Jun-19	$415,873	$161	$97,645						$513,679
Labor	31-Jul-19	$69,486	$23,413	$76,788						$169,687
Labor	31-Aug-19	$269,075	-$471	$87,063						$355,667
Labor	30-Sep-19	$337,174	$3,845	$6,228	$32,224					$379,471
Labor	31-Oct-19	$674,072	$1,788	$108,878	$113,135	$18,572	$5,373			$921,818
Labor	30-Nov-19	$918,019	$3,300	$465,987	$185,929	$90,573	$75,086	$467,218		$2,206,112
Labor	31-Dec-19	$730,910	$7,550	$349,990	$172,148	$116,894	$52,248	$702,052		$2,131,792
Labor	31-Jan-20	$1,475,004	$42,266	$706,181	$341,227	$215,357	$66,510	$2,165,613		$5,012,158
Labor	29-Feb-20	$1,508,469	$46,249	$563,412	$389,401	$327,484	$187,009	$2,641,017		$5,663,039
Labor	31-Mar-20	$1,882,764	$57,602	$354,523	$442,129	$314,218	$662,118	$2,761,178		$6,474,532
Labor	30-Apr-20	$576,848	$5,077	$59,771	$206,847	$21,699	-$36,947	-$7,658		$825,638
Labor	31-May-20	$778,798	$18,637	$138,510	$274,696	$106,169	$532	$259,410		$1,576,752
Labor	30-Jun-20	$1,456,620	$65,419	$65,494	$374,476	$216,032	$182,608	$1,823,987		$4,184,637
Labor	31-Jul-20	$1,411,637	$64,792	$41,748	$252,127	$156,075	$744,986	$2,529,218	$512,754	$5,713,337
Labor	31-Aug-20	$2,106,713	$66,806	$156,005	$451,832	$337,792	$1,185,136	$4,379,693	$664,271	$9,348,248
Labor	30-Sep-20	$2,088,239	$70,661	$298,140	$405,627	$285,579	$607,720	$2,708,897	$661,488	$7,126,351
Labor	31-Oct-20	$2,069,287	$79,437	-$599,014	$403,026	$357,653	$663,764	$2,781,960	$853,402	$6,609,517
Labor	30-Nov-20	$1,912,891	$73,779	$306,289	$366,433	$329,064	$924,820	$3,114,217	$786,655	$7,814,148
Labor	31-Dec-20	$1,340,108	$77,752	$316,818	$231,076	$265,156	$693,125	$1,859,439	$496,072	$5,279,545
Labor	31-Jan-21	$1,461,643	$83,971	$299,481	$382,563	$290,413	$787,041	$2,093,699	$864,118	$6,262,930
Labor	28-Feb-21	$1,889,802	$88,675	$22,922	$475,928	$381,314	$1,415,596	$3,721,880	$969,049	$8,965,166
Labor	31-Mar-21	$2,217,464	$119,172	$11,754	$597,417	$176,163	$2,033,766	$5,611,094	$1,007,165	$11,773,996
Labor	30-Apr-21	$704,969	$51,967	$13,129	$290,448	$100,923	$152,908	$218,490	$275,904	$1,808,739
Labor	31-May-21	$580,250	$88,032	-$76,663	$358,664	$410,507	$574,314	$2,559,654	$674,445	$5,169,202
Labor	30-Jun-21	$2,163,981	$112,944	$19,003	$470,407	$641,732	$1,398,034	$4,009,588	$1,204,825	$10,020,513
Labor	31-Jul-21	$1,754,450	$93,064	$31,135	$342,125	$556,711	$1,406,175	$3,558,408	$859,992	$8,602,060
Labor	31-Aug-21	$1,960,438	$92,256	$10,731	$362,280	$391,857	$1,655,451	$3,792,010	$901,862	$9,166,884
Labor	30-Sep-21	$1,749,010	$114,519	$5,337	$372,455	$268,929	$1,209,178	$4,136,591	$899,211	$8,755,231

Monthly Labor Costs

C2G Cost Type	MONTH	Field Overheads	Camp Costs	Camp Costs - Setup	Field Overheads - Materials Management	ROW	Foundations	Structure	Stringing	Totals
Labor	31-Oct-21	$1,665,220	$96,417	$3,810	$313,669	$164,157	$583,975	$4,646,897	$1,283,523	$8,757,668
Labor	30-Nov-21	$1,762,091	$80,756	$11,135	$350,700	$101,152	$432,372	$3,529,995	$2,291,885	$8,560,085
Labor	31-Dec-21	$1,377,957	$73,806	$14,075	$287,867	$63,334	$180,339	$2,131,073	$2,564,690	$6,693,141
Labor	31-Jan-22	$1,425,762	$72,450	$109,809	$301,280	$20,788	$7,728	$782,835	$3,793,268	$6,513,920
Labor	28-Feb-22	$1,264,433	$70,969	$220,894	$291,517	$16,530	$5,531	$70,400	$4,776,967	$6,717,243
Labor	31-Mar-22	$616,166	$26,329	$231,926	$241,076	$10,909	-$723	$1,360	$1,884,489	$3,011,531
		$45,768,232	**$1,973,388**	**$4,608,921**	**$10,080,729**	**$6,753,737**	**$17,855,774**	**$69,050,215**	**$28,226,035**	**$184,317,032**

Exhibit 25

Travel LOA and Camp Cost Rate Calculation

Travel, LOA and Camp Cost Rate Calculation

Project Travel (Actual Costs (Aug 19 to Feb 22))		$20,329,847.13
Living Out Allowance (Actual Costs (Aug 19 to Feb 22))		$3,648,678.00
Camp Operations (Actual Costs (Aug 19 to Feb 22))		$18,804,016.20
	Total	**$42,782,541.33**
Credit Added Cost Attributed to COVID Flight Program		-$3,377,438.00
Credit Camp Costs Attributed to Kama Cliffs		-$95,799.99
Credit Camp Costs Attributed to Kama Cliffs		-$695,382.43
Credit Camp Costs Attributed to Forest Fire		-$852,417.39
	Adjusted Total	**$37,761,503.52**
Total Project Manhours (Aug 19 to Feb 22)		2,629,147.7
Average Cost per Manhour for Travel, LOA and Camp Operations		**$14.36**

Exhibit 25

Monthly Equipment Costs with all Allocations

East-West Tie Line Project

Monthly Equipment Costs with all Allocations

MONTH	Related Cost Type	Field Overheads	Camp Costs	Field Overheads - Travel-LOA	Field Overheads - Materials Management	Totals - Field OH Equip Related Allocations	ROW	Foundations	Stringing	Structure	Totals - Direct Equip Related Allocations	Totals - All Allocations for Mech & Fueling
28-Feb-18	Equipment Related	$1,219,620	$0	$0	$0	$1,219,620	$0	$0	$0	$0	$0	$1,219,620
31-Mar-18	Equipment Related	-$500,000	$0	$0	$0	-$500,000	$0	$0	$0	$0	$0	-$500,000
31-May-18	Equipment Related	$1,758	$0	$0	$0	$1,758	$0	$0	$0	$0	$0	$1,758
30-Jun-18	Equipment Related	$6,155	$0	$0	$0	$6,155	$0	$0	$0	$0	$0	$6,155
31-Jul-18	Equipment Related	$11,333	$0	$0	$0	$11,333	$0	$0	$0	$0	$0	$11,333
31-Aug-18	Equipment Related	$12,356	$0	$0	$0	$12,356	$0	$0	$0	$0	$0	$12,356
30-Sep-18	Equipment Related	$13,188	$0	$0	$0	$13,188	$0	$0	$0	$0	$0	$13,188
31-Oct-18	Equipment Related	$7,802	$0	$0	$0	$7,802	$0	$0	$0	$0	$0	$7,802
30-Nov-18	Equipment Related	$3,275	$0	$0	$0	$3,275	$0	$0	$0	$0	$0	$3,275
31-Dec-18	Equipment Related	$1,980	$0	$0	$0	$1,980	$0	$0	$0	$0	$0	$1,980
31-Jan-19	Equipment Related	-$950	$0	$0	$0	-$950	$0	$0	$0	$0	$0	-$950
28-Feb-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Mar-19	Equipment Related	$772	$0	$0	$0	$772	$0	$0	$0	$0	$0	$772
30-Apr-19	Equipment Related	$3,710	$0	$0	$0	$3,710	$0	$0	$0	$0	$0	$3,710
31-May-19	Equipment Related	$47,215	$0	$0	$0	$47,215	$0	$0	$0	$0	$0	$47,215
30-Jun-19	Equipment Related	$165,392	$0	$0	$0	$165,392	$0	$0	$0	$0	$0	$165,392
31-Jul-19	Equipment Related	$60,277	$4,000	$0	$0	$64,277	$0	$0	$0	$0	$0	$64,277
31-Aug-19	Equipment Related	$468,854	$286	$0	$0	$469,140	$0	$0	$0	$0	$0	$469,140
30-Sep-19	Equipment Related	-$336,900	$818	$0	$7,306	-$328,777	$0	$0	$0	$0	$0	-$328,777
31-Oct-19	Equipment Related	$133,198	$0	$0	$38,315	$171,513	$23,661	$1,387	$0	$0	$25,049	$196,561
30-Nov-19	Equipment Related	$236,315	$556	$0	$85,574	$322,445	$93,915	$31,109	$0	$140,465	$265,489	$587,934
31-Dec-19	Equipment Related	$180,069	$4,051	$0	$56,830	$240,951	$121,098	$18,028	$0	$160,799	$299,925	$540,876
31-Jan-20	Equipment Related	$380,847	-$2,391	$0	$145,228	$523,684	$194,701	$21,428	$0	$522,301	$738,430	$1,262,114
29-Feb-20	Equipment Related	$431,149	$4,803	$0	$186,353	$622,305	$250,893	$91,087	$0	$548,338	$890,318	$1,512,624
31-Mar-20	Equipment Related	$698,125	$862	$5,583	$223,079	$927,649	$337,545	$315,989	$0	$963,938	$1,617,471	$2,545,120
30-Apr-20	Equipment Related	$51,173	$1,558	-$10,140	$157,085	$199,676	$10,797	-$1,600	$26,520	-$11,789	$23,928	$223,604
31-May-20	Equipment Related	$112,304	$5,376	$26,956	$145,682	$290,318	$95,596	$0	-$11,816	$77,299	$161,078	$451,396
30-Jun-20	Equipment Related	$392,537	$15,003	$0	$123,274	$530,813	$134,649	$67,232	$368	$453,286	$655,535	$1,186,349
31-Jul-20	Equipment Related	$374,475	$11,484	$18,718	$89,048	$493,725	$176,180	$241,639	$330,389	$683,243	$1,431,452	$1,925,177
31-Aug-20	Equipment Related	$760,687	$48,554	$7,658	$492,932	$1,309,832	$522,163	$697,271	$567,052	$1,588,353	$3,374,838	$4,684,670
30-Sep-20	Equipment Related	$617,715	$38,294	$35,806	$206,007	$897,822	$253,170	$451,188	$642,484	$1,115,409	$2,462,251	$3,360,074
31-Oct-20	Equipment Related	$632,653	$28,902	$1,087	$197,222	$859,865	$560,149	$645,952	$817,180	$1,513,823	$3,537,104	$4,396,970
30-Nov-20	Equipment Related	$632,763	$29,364	$18,724	$184,305	$865,157	$559,817	$674,632	$802,728	$1,158,018	$3,195,195	$4,060,352
31-Dec-20	Equipment Related	$469,522	$23,724	$6,043	$116,758	$616,047	$288,421	$824,150	$492,690	$855,140	$2,460,402	$3,076,449
31-Jan-21	Equipment Related	$772,830	$34,654	$35,305	$193,120	$1,035,909	$245,425	$865,571	$876,151	$1,330,071	$3,317,218	$4,353,128
28-Feb-21	Equipment Related	$1,110,231	$49,049	$8,155	$293,171	$1,460,606	$414,335	$1,425,228	$1,105,106	$2,425,224	$5,369,893	$6,830,499
31-Mar-21	Equipment Related	$840,346	$41,413	$0	$261,112	$1,142,871	$198,625	$1,217,450	$950,678	$2,593,397	$4,960,150	$6,103,021
30-Apr-21	Equipment Related	$158,964	$12,142	$0	$128,908	$300,015	$105,296	$607,705	$138,729	$1,785,411	$2,637,141	$2,937,155
31-May-21	Equipment Related	$504,315	$9,536	$11,862	$170,465	$696,178	$375,534	$670,719	$727,049	$1,003,116	$2,776,417	$3,472,596
30-Jun-21	Equipment Related	$526,715	-$921	$0	$185,974	$711,767	$581,523	$708,272	$904,455	$765,830	$2,960,080	$3,671,847
31-Jul-21	Equipment Related	$819,407	$12,565	$0	$245,571	$1,077,543	$713,846	$869,856	$928,858	$1,429,089	$3,941,649	$5,019,192
31-Aug-21	Equipment Related	$838,748	$8,294	$101,571	$178,751	$1,127,364	$580,261	$1,083,777	$1,024,882	$2,667,179	$5,356,099	$6,483,464
30-Sep-21	Equipment Related	$717,025	$36,180	$210	$216,061	$969,475	$419,074	$606,665	$839,682	$1,728,854	$3,594,275	$4,563,750

Monthly Equipment Costs with all Allocations

MONTH	Related Cost Type	Field Overheads	Camp Costs	Field Overheads - Travel-LOA	Field Overheads - Materials Management	Totals - Field OH Equip Related Allocations	ROW	Foundations	Stringing	Structure	Totals - Direct Equip Related Allocations	Totals - All Allocations for Mech & Fueling
31-Oct-21	Equipment Related	$700,164	$171,101	$22	$192,848	$1,064,135	$223,304	$396,006	$1,384,517	$3,346,290	$5,350,116	$6,414,251
30-Nov-21	Equipment Related	$824,380	-$96,242	$16	$233,205	$961,358	$142,404	$332,873	$2,163,114	$2,324,329	$4,962,720	$5,924,077
31-Dec-21	Equipment Related	$933,785	$34,046	$0	$256,693	$1,224,524	$166,822	$160,459	$2,721,078	$2,238,894	$5,287,252	$6,511,777
31-Jan-22	Equipment Related	$548,403	$20,020	-$89,842	$211,434	$690,014	$21,181	$100,898	$2,610,334	$8,460,656	$11,193,069	$11,883,083
28-Feb-22	Equipment Related	$634,744	$20,324	$0	$220,224	$875,292	$30,192	$17,458	$3,585,708	$651,503	$4,284,861	$5,160,153
		$17,219,428	**$567,405**	**$177,734**	**$5,442,533**	**$23,407,099**	**$7,840,579**	**$13,142,429**	**$23,627,936**	**$42,518,465**	**$87,129,409**	**$110,536,509**

Exhibit 25

Unbooked Equipment Allocations

Unbooked Equipment Allocations

MONTH	Related Cost Type	Field Overheads	Camp Costs	Field Overheads - Travel-LOA	Field Overheads - Materials Management	Totals - Field OH Equip Related Allocations	ROW	Foundations	Stringing	Structure	Totals - Direct Equip Related Allocations	Totals - All Allocations for Mech & Fueling
28-Feb-18	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Mar-18	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-May-18	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30-Jun-18	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Jul-18	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Aug-18	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30-Sep-18	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Oct-18	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30-Nov-18	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Dec-18	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Jan-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
28-Feb-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Mar-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30-Apr-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-May-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30-Jun-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Jul-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Aug-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30-Sep-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Oct-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30-Nov-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Dec-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Jan-20	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
29-Feb-20	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Mar-20	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30-Apr-20	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-May-20	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30-Jun-20	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Jul-20	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Aug-20	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30-Sep-20	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Oct-20	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30-Nov-20	Equipment Related	$46,163	$2,142	$1,366	$13,446	$63,118	$40,842	$49,218	$58,563	$84,484	$233,106	$296,224
31-Dec-20	Equipment Related	$48,801	$2,466	$628	$12,136	$64,031	$29,978	$85,661	$51,209	$88,882	$255,730	$319,761
31-Jan-21	Equipment Related	$137,617	$6,171	$6,287	$34,389	$184,463	$43,703	$154,131	$156,015	$236,844	$590,693	$775,157
28-Feb-21	Equipment Related	$148,227	$6,549	$1,089	$39,141	$195,006	$55,318	$190,282	$147,543	$323,792	$716,935	$911,941
31-Mar-21	Equipment Related	$64,263	$3,167	$0	$19,968	$87,398	$15,189	$93,101	$72,700	$198,322	$379,313	$466,711
30-Apr-21	Equipment Related	$21,180	$1,618	$0	$17,175	$39,973	$14,029	$80,969	$18,484	$237,882	$351,364	$391,337
31-May-21	Equipment Related	$51,079	$966	$1,201	$17,265	$70,512	$38,036	$67,933	$73,639	$101,600	$281,208	$351,720
30-Jun-21	Equipment Related	$70,680	-$124	$0	$24,956	$95,512	$78,035	$95,043	$121,369	$102,767	$397,213	$492,725
31-Jul-21	Equipment Related	$118,601	$1,819	$0	$35,544	$155,963	$103,322	$125,902	$134,442	$206,845	$570,512	$726,475
31-Aug-21	Equipment Related	$66,327	$656	$8,032	$14,135	$89,151	$45,886	$85,704	$81,047	$210,918	$423,555	$512,705
30-Sep-21	Equipment Related	$107,541	$5,426	$31	$32,405	$145,405	$62,854	$90,989	$125,938	$259,298	$539,079	$684,484

Unbooked Equipment Allocations

MONTH	Related Cost Type	Field Overheads	Camp Costs	Field Overheads - Travel-LOA	Field Overheads - Materials Management	Totals - Field OH Equip Related Allocations	ROW	Foundations	Stringing	Structure	Totals - Direct Equip Related Allocations	Totals - All Allocations for Mech & Fueling
31-Oct-21	Equipment Related	$70,288	$17,176	$2	$19,360	$106,826	$22,417	$39,754	$138,989	$335,927	$537,086	$643,913
30-Nov-21	Equipment Related	$77,313	-$9,026	$1	$21,871	$90,159	$13,355	$31,218	$202,863	$217,982	$465,417	$555,576
31-Dec-21	Equipment Related	$215,864	$7,871	$0	$59,340	$283,075	$38,564	$37,093	$629,035	$517,568	$1,222,261	$1,505,336
31-Jan-22	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
28-Feb-22	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
		$1,243,945	**$46,876**	**$18,638**	**$361,131**	**$1,670,590**	**$601,528**	**$1,226,999**	**$2,011,835**	**$3,123,111**	**$6,963,473**	**$8,634,063**

Exhibit 25

Unbooked Equipment Adjustments

East-West Tie Line Project

Unbooked Equipment Adjustments

MONTH	Related Cost Type	Field Overheads	Camp Costs	Field Overheads - Travel-LOA	Field Overheads - Materials Management	Totals	ROW	Foundations	Stringing	Structure	Totals	Totals - All Booked Equipment Costs
28-Feb-18	Equipment Related	$1,219,620				$1,219,620					$0	$1,219,620
31-Mar-18	Equipment Related	-$500,000				-$500,000					$0	-$500,000
31-May-18	Equipment Related	$1,758				$1,758					$0	$1,758
30-Jun-18	Equipment Related	$6,155				$6,155					$0	$6,155
31-Jul-18	Equipment Related	$9,266				$9,266					$0	$9,266
31-Aug-18	Equipment Related	$11,112				$11,112					$0	$11,112
30-Sep-18	Equipment Related	$9,544				$9,544					$0	$9,544
31-Oct-18	Equipment Related	$6,958				$6,958					$0	$6,958
30-Nov-18	Equipment Related	$3,275				$3,275					$0	$3,275
31-Dec-18	Equipment Related	$1,980				$1,980					$0	$1,980
31-Jan-19	Equipment Related	-$950				-$950					$0	-$950
28-Feb-19	Equipment Related	$0				$0					$0	$0
31-Mar-19	Equipment Related	$772				$772					$0	$772
30-Apr-19	Equipment Related	$3,710				$3,710					$0	$3,710
31-May-19	Equipment Related	$47,215				$47,215					$0	$47,215
30-Jun-19	Equipment Related	$30,846				$30,846					$0	$30,846
31-Jul-19	Equipment Related	$28,163	$1,869			$30,032					$0	$30,032
31-Aug-19	Equipment Related	$432,731	$264			$432,995					$0	$432,995
30-Sep-19	Equipment Related	-$374,784	$910		$8,127	-$365,747					$0	-$365,747
31-Oct-19	Equipment Related	$77,265			$22,226	$99,490	$13,725	$805			$14,530	$114,021
30-Nov-19	Equipment Related	$145,406	$342		$52,654	$198,401	$57,787	$19,142		$86,428	$163,356	$361,758
31-Dec-19	Equipment Related	$114,013	$2,565		$35,983	$152,561	$76,675	$11,415		$101,812	$189,901	$342,463
31-Jan-20	Equipment Related	$203,618	-$1,278		$77,645	$279,985	$104,096	$11,457		$279,246	$394,798	$674,783
29-Feb-20	Equipment Related	$263,555	$2,936		$113,915	$380,406	$153,367	$55,680		$335,191	$544,239	$924,645
31-Mar-20	Equipment Related	$488,303	$603	$3,905	$156,032	$648,843	$236,095	$221,018	$0	$674,226	$1,131,339	$1,780,183
30-Apr-20	Equipment Related	$19,707	$600	-$3,905	$60,494	$76,896	$4,158	-$616	$10,213	-$4,540	$9,215	$86,111
31-May-20	Equipment Related	$97,066	$4,647	$23,299	$125,914	$250,925	$82,624		-$10,213	$66,810	$139,222	$390,147
30-Jun-20	Equipment Related	$255,805	$9,777		$80,334	$345,916	$87,747	$43,813	$240	$295,394	$427,194	$773,110
31-Jul-20	Equipment Related	$355,317	$10,897	$17,760	$84,493	$468,467	$167,167	$229,277	$313,487	$648,289	$1,358,221	$1,826,687
31-Aug-20	Equipment Related	$681,276	$43,485	$6,858	$441,473	$1,173,092	$467,652	$624,479	$507,855	$1,422,537	$3,022,523	$4,195,615
30-Sep-20	Equipment Related	$508,885	$31,547	$29,498	$169,712	$739,643	$208,566	$371,697	$529,291	$918,895	$2,028,448	$2,768,091
31-Oct-20	Equipment Related	$473,494	$21,631	$814	$147,606	$643,545	$419,230	$483,447	$611,599	$1,132,983	$2,647,259	$3,290,804
30-Nov-20	Equipment Related	$480,094	$22,279	$14,207	$139,837	$656,417	$424,748	$511,861	$609,051	$878,618	$2,424,278	$3,080,695
31-Dec-20	Equipment Related	$410,261	$20,730	$5,280	$102,022	$538,293	$252,018	$720,131	$430,505	$747,209	$2,149,863	$2,688,156
31-Jan-21	Equipment Related	$515,160	$23,100	$23,534	$128,732	$690,526	$163,598	$576,980	$584,033	$886,611	$2,211,222	$2,901,748
28-Feb-21	Equipment Related	$601,731	$26,584	$4,420	$158,895	$791,631	$224,565	$772,456	$598,954	$1,314,441	$2,910,416	$3,702,046
31-Mar-21	Equipment Related	$599,698	$29,553		$186,338	$815,589	$141,745	$868,811	$678,434	$1,850,731	$3,539,722	$4,355,311
30-Apr-21	Equipment Related	$120,635	$9,214		$97,826	$227,675	$79,907	$461,175	$105,278	$1,354,913	$2,001,274	$2,228,949
31-May-21	Equipment Related	$350,753	$6,632	$8,250	$118,559	$484,195	$261,185	$466,488	$505,666	$697,671	$1,931,011	$2,415,206
30-Jun-21	Equipment Related	$311,380	-$545		$109,943	$420,778	$343,782	$418,712	$534,690	$452,739	$1,749,922	$2,170,701
31-Jul-21	Equipment Related	$536,895	$8,233		$160,904	$706,032	$467,729	$569,951	$608,610	$936,374	$2,582,663	$3,288,696
31-Aug-21	Equipment Related	$627,283	$6,203	$75,963	$133,685	$843,134	$433,966	$810,535	$766,489	$1,994,731	$4,005,722	$4,848,856
30-Sep-21	Equipment Related	$537,650	$27,129	$157	$162,010	$726,945	$314,236	$454,898	$629,621	$1,296,353	$2,695,107	$3,422,052
31-Oct-21	Equipment Related	$498,696	$121,868	$16	$137,357	$757,936	$159,049	$282,057	$986,130	$2,383,414	$3,810,650	$4,568,587
30-Nov-21	Equipment Related	$598,070	-$69,822	$11	$169,185	$697,445	$103,311	$241,492	$1,569,293	$1,686,252	$3,600,349	$4,297,794
31-Dec-21	Equipment Related	$531,752	$19,388		$146,176	$697,316	$94,998	$91,375	$1,549,542	$1,274,958	$3,010,873	$3,708,189
31-Jan-22	Equipment Related	$463,684	$16,927	-$75,963	$178,771	$583,419	$17,909	$85,311	$2,207,085	$7,153,638	$9,463,942	$10,047,361
28-Feb-22	Equipment Related	$504,416	$16,151		$175,007	$695,574	$23,993	$13,873	$2,849,478	$517,734	$3,405,078	$4,100,652
Totals	**$0**	**$12,309,241**	**$414,420**	**$134,103**	**$3,881,854**	**$16,739,617**	**$0**	**$5,585,629**				**$80,301,957**

MONTH	Q1 Fleet Credit	Eliminate Flat Billings	Reduce Rates to 85%	Reduce Rates to 80%	Totals
28-Feb-18					$0.00
31-Mar-18					$0.00
31-May-18					$0.00
30-Jun-18					$0.00
31-Jul-18					$0.00
31-Aug-18					$0.00
30-Sep-18					$0.00
31-Oct-18					$0.00
30-Nov-18					$0.00
31-Dec-18					$0.00
31-Jan-19					$0.00
28-Feb-19					$0.00
31-Mar-19					$0.00
30-Apr-19					$0.00
31-May-19					$0.00
30-Jun-19					$0.00
31-Jul-19					$0.00
31-Aug-19					$0.00
30-Sep-19					$0.00
31-Oct-19					$0.00
30-Nov-19					$0.00
31-Dec-19					$0.00
31-Jan-20					$0.00
29-Feb-20					$0.00
31-Mar-20					$0.00
30-Apr-20					$0.00
31-May-20					$0.00
30-Jun-20					$0.00
31-Jul-20					$0.00
31-Aug-20					$0.00
30-Sep-20					$0.00
31-Oct-20					$0.00
30-Nov-20			$296,224.11		$296,224.11
31-Dec-20			$319,761.10		$319,761.10
31-Jan-21	$367,205.73		$407,950.82		$775,156.55
28-Feb-21	$432,002.96		$479,937.94		$911,940.90
31-Mar-21	$221,089.31		$245,621.34		$466,710.65
30-Apr-21		$125,190.67	$266,146.07		$391,336.74
31-May-21		$112,516.92	$239,202.62		$351,719.54
30-Jun-21		$170,467.47		$322,257.97	$492,725.44
31-Jul-21		$251,337.39		$475,137.44	$726,474.84
31-Aug-21		$177,379.93		$335,325.53	$512,705.46
30-Sep-21		$236,809.82		$447,673.99	$684,483.81
31-Oct-21		$222,773.45		$421,139.11	$643,912.56
30-Nov-21		$192,211.66		$363,363.98	$555,575.64
31-Dec-21		$520,798.69		$984,536.97	$1,505,335.66
31-Jan-22					$0.00
28-Feb-22					$0.00
	$1,020,298	**$2,009,486**	**$2,254,844**	**$3,349,435**	**$8,634,063**

Adjustments:

Q1 Credit Adjustment recorded in April to East West Tie (EWT Fleet over recovery for Q1)	$1,020,298.00
Elimination of flat billing - 216 hrs per vehicle Apr 21 to Dec 21)	$2,009,486.00
Credit to reduce equip. rates from 100% to 85% (Nov 20 to May 21)	$2,254,844.00
Credit to reduce equip. rates from 100% to 80% (June 21 forward)	$3,349,435.00
	$8,634,063.00

Exhibit 25

Equipment Mechanic and Fuel Allocations

Equipment Mechanic & Fuel Allocations

MONTH	Related Cost Type	Field Overheads	Camp Costs	Field Overheads - Travel-LOA	Field Overheads - Materials Management	Totals - Field OH Equip Related Allocations	ROW	Foundations	Stringing	Structure	Totals - Direct Equip Related Allocations	Totals - All Allocations for Mech & Fueling
28-Feb-18	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Mar-18	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-May-18	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30-Jun-18	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Jul-18	Equipment Related	$2,067	$0	$0	$0	$2,067	$0	$0	$0	$0	$0	$2,067
31-Aug-18	Equipment Related	$1,244	$0	$0	$0	$1,244	$0	$0	$0	$0	$0	$1,244
30-Sep-18	Equipment Related	$3,644	$0	$0	$0	$3,644	$0	$0	$0	$0	$0	$3,644
31-Oct-18	Equipment Related	$844	$0	$0	$0	$844	$0	$0	$0	$0	$0	$844
30-Nov-18	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Dec-18	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Jan-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
28-Feb-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-Mar-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30-Apr-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
31-May-19	Equipment Related	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30-Jun-19	Equipment Related	$134,546	$0	$0	$0	$134,546	$0	$0	$0	$0	$0	$134,546
31-Jul-19	Equipment Related	$32,115	$2,131	$0	$0	$34,246	$0	$0	$0	$0	$0	$34,246
31-Aug-19	Equipment Related	$36,124	$22	$0	$0	$36,146	$0	$0	$0	$0	$0	$36,146
30-Sep-19	Equipment Related	$37,884	-$92	$0	-$821	$36,970	$0	$0	$0	$0	$0	$36,970
31-Oct-19	Equipment Related	$55,933	$0	$0	$16,089	$72,022	$9,936	$582	$0	$0	$10,518	$82,541
30-Nov-19	Equipment Related	$90,910	$214	$0	$32,920	$124,043	$36,129	$11,968	$0	$54,036	$102,133	$226,176
31-Dec-19	Equipment Related	$66,056	$1,486	$0	$20,847	$88,390	$44,423	$6,613	$0	$58,987	$110,024	$198,413
31-Jan-20	Equipment Related	$177,229	-$1,113	$0	$67,583	$243,699	$90,605	$9,972	$0	$243,055	$343,632	$587,331
29-Feb-20	Equipment Related	$167,594	$1,867	$0	$72,438	$241,899	$97,526	$35,407	$0	$213,147	$346,080	$587,979
31-Mar-20	Equipment Related	$209,822	$259	$1,678	$67,046	$278,805	$101,449	$94,971	$0	$289,712	$486,132	$764,937
30-Apr-20	Equipment Related	$31,466	$958	-$6,235	$96,590	$122,779	$6,639	-$984	$16,307	-$7,249	$14,713	$137,493
31-May-20	Equipment Related	$15,238	$729	$3,658	$19,767	$39,393	$12,971	$0	-$1,603	$10,489	$21,857	$61,250
30-Jun-20	Equipment Related	$136,731	$5,226	$0	$42,940	$184,897	$46,902	$23,419	$128	$157,892	$228,341	$413,238
31-Jul-20	Equipment Related	$19,158	$588	$958	$4,556	$25,258	$9,013	$12,362	$16,902	$34,954	$73,231	$98,490
31-Aug-20	Equipment Related	$79,412	$5,069	$799	$51,459	$136,739	$54,511	$72,791	$59,197	$165,815	$352,315	$489,054
30-Sep-20	Equipment Related	$108,830	$6,747	$6,308	$36,295	$158,180	$44,604	$79,491	$113,194	$196,514	$433,803	$591,983
31-Oct-20	Equipment Related	$159,160	$7,271	$274	$49,616	$216,320	$140,919	$162,505	$205,582	$380,839	$889,846	$1,106,166
30-Nov-20	Equipment Related	$106,506	$4,943	$3,152	$31,022	$145,622	$94,228	$113,553	$135,114	$194,916	$537,811	$683,433
31-Dec-20	Equipment Related	$10,459	$528	$135	$2,601	$13,723	$6,425	$18,359	$10,975	$19,049	$54,808	$68,532
31-Jan-21	Equipment Related	$120,053	$5,383	$5,484	$30,000	$160,920	$38,125	$134,459	$136,103	$206,616	$515,303	$676,223
28-Feb-21	Equipment Related	$360,272	$15,916	$2,646	$95,135	$473,970	$134,453	$462,490	$358,609	$786,990	$1,742,542	$2,216,512
31-Mar-21	Equipment Related	$176,385	$8,692	$0	$54,806	$239,884	$41,691	$255,538	$199,544	$544,344	$1,041,116	$1,281,000
30-Apr-21	Equipment Related	$17,150	$1,310	$0	$13,907	$32,367	$11,360	$65,561	$14,966	$192,616	$284,503	$316,869
31-May-21	Equipment Related	$102,482	$1,938	$2,410	$34,640	$141,471	$76,313	$136,298	$147,744	$203,844	$564,199	$705,670
30-Jun-21	Equipment Related	$144,655	-$253	$0	$51,075	$195,477	$159,707	$194,517	$248,396	$210,324	$812,944	$1,008,421
31-Jul-21	Equipment Related	$163,911	$2,513	$0	$49,123	$215,548	$142,795	$174,003	$185,806	$285,870	$788,474	$1,004,022
31-Aug-21	Equipment Related	$145,137	$1,435	$17,576	$30,931	$195,080	$100,409	$187,537	$177,346	$461,530	$926,823	$1,121,902
30-Sep-21	Equipment Related	$71,834	$3,625	$21	$21,646	$97,126	$41,984	$60,778	$84,123	$173,203	$360,088	$457,214

Equipment Mechanic & Fuel Allocations

MONTH	Related Cost Type	Field Overheads	Camp Costs	Field Overheads - Travel-LOA	Field Overheads - Materials Management	Totals - Field OH Equip Related Allocations	ROW	Foundations	Stringing	Structure	Totals - Direct Equip Related Allocations	Totals - All Allocations for Mech & Fueling
31-Oct-21	Equipment Related	$131,180	$32,057	$4	$36,131	$199,373	$41,837	$74,194	$259,398	$626,949	$1,002,379	$1,201,752
30-Nov-21	Equipment Related	$148,997	-$17,395	$3	$42,149	$173,754	$25,738	$60,163	$390,958	$420,095	$896,954	$1,070,708
31-Dec-21	Equipment Related	$186,169	$6,788	$0	$51,177	$244,133	$33,259	$31,991	$542,501	$446,368	$1,054,119	$1,298,252
31-Jan-22	Equipment Related	$84,718	$3,093	-$13,879	$32,663	$106,595	$3,272	$15,587	$403,250	$1,307,019	$1,729,127	$1,835,722
28-Feb-22	Equipment Related	$130,328	$4,173	$0	$45,217	$179,718	$6,199	$3,584	$736,230	$133,769	$879,783	$1,059,501
		$3,666,242	**$106,109**	**$24,992**	**$1,199,549**	**$4,996,892**	**$1,653,422**	**$2,497,710**	**$4,440,770**	**$8,011,696**	**$16,603,597**	**$21,600,489**

Exhibit 25

Monthly Equipment Costs

Monthly Equipment Costs

MONTH	Related Cost Type	Field Overheads	Camp Costs	Field Overheads - Travel-LOA	Field Overheads - Materials Management	Totals	ROW	Foundations	Stringing	Structure	Totals	Totals - All Booked Equipment Costs	Field Overheads - Mechanic - Repairs	Fueling	Totals - All Equipment Related Costs	Totals - All Booked Equip & Related Costs
28-Feb-18	Equipment Related	$1,219,620				$1,219,620					$0	$1,219,620			$0	$1,219,620
31-Mar-18	Equipment Related	-$500,000				-$500,000					$0	-$500,000			$0	-$500,000
31-May-18	Equipment Related	$1,758				$1,758					$0	$1,758			$0	$1,758
30-Jun-18	Equipment Related	$6,155				$6,155					$0	$6,155			$0	$6,155
31-Jul-18	Equipment Related	$9,266				$9,266					$0	$9,266	$2,067		$2,067	$11,333
31-Aug-18	Equipment Related	$11,112				$11,112					$0	$11,112	$1,244		$1,244	$12,356
30-Sep-18	Equipment Related	$9,544				$9,544					$0	$9,544	$3,644		$3,644	$13,188
31-Oct-18	Equipment Related	$6,958				$6,958					$0	$6,958	$844		$844	$7,802
30-Nov-18	Equipment Related	$3,275				$3,275					$0	$3,275	$0		$0	$3,275
31-Dec-18	Equipment Related	$1,980				$1,980					$0	$1,980			$0	$1,980
31-Jan-19	Equipment Related	-$950				-$950					$0	-$950			$0	-$950
28-Feb-19	Equipment Related	$0				$0					$0	$0			$0	$0
31-Mar-19	Equipment Related	$772				$772					$0	$772			$0	$772
30-Apr-19	Equipment Related	$3,710				$3,710					$0	$3,710			$0	$3,710
31-May-19	Equipment Related	$47,215				$47,215					$0	$47,215			$0	$47,215
30-Jun-19	Equipment Related	$30,846				$30,846					$0	$30,846	$40	$134,506	$134,546	$165,392
31-Jul-19	Equipment Related	$28,163	$1,869			$30,032					$0	$30,032		$34,246	$34,246	$64,277
31-Aug-19	Equipment Related	$432,731	$264			$432,995					$0	$432,995	$597	$35,549	$36,146	$469,140
30-Sep-19	Equipment Related	-$374,784	$910		$8,127	-$365,747					$0	-$365,747	$406	$36,564	$36,970	-$328,777
31-Oct-19	Equipment Related	$77,265			$22,226	$99,490	$13,725	$805			$14,530	$114,021		$82,541	$82,541	$196,561
30-Nov-19	Equipment Related	$145,406	$342		$52,654	$198,401	$57,787	$19,142		$86,428	$163,356	$361,758	$23,882	$202,294	$226,176	$587,934
31-Dec-19	Equipment Related	$114,013	$2,565		$35,983	$152,561	$76,675	$11,415		$101,812	$189,901	$342,463	$6,966	$191,448	$198,413	$540,876
31-Jan-20	Equipment Related	$203,618	-$1,278		$77,645	$279,985	$104,096	$11,457		$279,246	$394,798	$674,783	$116,636	$470,695	$587,331	$1,262,114
29-Feb-20	Equipment Related	$263,555	$2,936		$113,915	$380,406	$153,367	$55,680		$335,191	$544,239	$924,645	$89,800	$498,179	$587,979	$1,512,624
31-Mar-20	Equipment Related	$488,303	$603	$3,905	$156,032	$648,843	$236,095	$221,018	$0	$674,226	$1,131,339	$1,780,183	$145,562	$619,375	$764,937	$2,545,120
30-Apr-20	Equipment Related	$19,707	$600	-$3,905	$60,494	$76,896	$4,158	-$616	$10,213	-$4,540	$9,215	$86,111	$46,204	$91,288	$137,493	$223,604
31-May-20	Equipment Related	$97,066	$4,647	$23,299	$125,914	$250,925	$82,624		-$10,213	$66,810	$139,222	$390,147	$12,265	$48,985	$61,250	$451,396
30-Jun-20	Equipment Related	$255,805	$9,777		$80,334	$345,916	$87,747	$43,813	$240	$295,394	$427,194	$773,110	$7,068	$406,170	$413,238	$1,186,349
31-Jul-20	Equipment Related	$355,317	$10,897	$17,760	$84,493	$468,467	$167,167	$229,277	$313,487	$648,289	$1,358,221	$1,826,687	$26,880	$71,610	$98,490	$1,925,177
31-Aug-20	Equipment Related	$681,276	$43,485	$6,858	$441,473	$1,173,092	$467,652	$624,479	$507,855	$1,422,537	$3,022,523	$4,195,615	$174,819	$314,235	$489,054	$4,684,670
30-Sep-20	Equipment Related	$508,885	$31,547	$29,498	$169,712	$739,643	$208,566	$371,697	$529,291	$918,895	$2,028,448	$2,768,091	$81,692	$510,291	$591,983	$3,360,074
31-Oct-20	Equipment Related	$473,494	$21,631	$814	$147,606	$643,545	$419,230	$483,447	$611,599	$1,132,983	$2,647,259	$3,290,804	$146,204	$959,962	$1,106,166	$4,396,970
30-Nov-20	Equipment Related	$480,094	$22,279	$14,207	$139,837	$656,417	$424,748	$511,861	$609,051	$878,618	$2,424,278	$3,080,695	$196,417	$487,016	$683,433	$3,764,128
31-Dec-20	Equipment Related	$410,261	$20,730	$5,280	$102,022	$538,293	$252,018	$720,131	$430,505	$747,209	$2,149,863	$2,688,156	$57,969	$10,562	$68,532	$2,756,687
31-Jan-21	Equipment Related	$515,160	$23,100	$23,534	$128,732	$690,526	$163,598	$576,980	$584,033	$886,611	$2,211,222	$2,901,748	$135,559	$540,665	$676,223	$3,577,971
28-Feb-21	Equipment Related	$601,731	$26,584	$4,420	$158,895	$791,631	$224,565	$772,456	$598,954	$1,314,441	$2,910,416	$3,702,046	$174,657	$2,041,855	$2,216,512	$5,918,558
31-Mar-21	Equipment Related	$599,698	$29,553		$186,338	$815,589	$141,745	$868,811	$678,434	$1,850,731	$3,539,722	$4,355,311	$177,449	$1,103,550	$1,281,000	$5,636,310
30-Apr-21	Equipment Related	$120,635	$9,214		$97,826	$227,675	$79,907	$461,175	$105,278	$1,354,913	$2,001,274	$2,228,949	$66,464	$250,405	$316,869	$2,545,819
31-May-21	Equipment Related	$350,753	$6,632	$8,250	$118,559	$484,195	$261,185	$466,488	$505,666	$697,671	$1,931,011	$2,415,206	$50,665	$655,006	$705,670	$3,120,876
30-Jun-21	Equipment Related	$311,380	-$545		$109,943	$420,778	$343,782	$418,712	$534,690	$452,739	$1,749,922	$2,170,701	$106,604	$901,817	$1,008,421	$3,179,122
31-Jul-21	Equipment Related	$536,895	$8,233		$160,904	$706,032	$467,729	$569,951	$608,610	$936,374	$2,582,663	$3,288,696	$74,338	$929,684	$1,004,022	$4,292,718
31-Aug-21	Equipment Related	$627,283	$6,203	$75,963	$133,685	$843,134	$433,966	$810,535	$766,489	$1,994,731	$4,005,722	$4,848,856	$137,974	$983,929	$1,121,902	$5,970,758
30-Sep-21	Equipment Related	$537,650	$27,129	$157	$162,010	$726,945	$314,236	$454,898	$629,621	$1,296,353	$2,695,107	$3,422,052	$133,668	$323,546	$457,214	$3,879,266
31-Oct-21	Equipment Related	$498,696	$121,868	$16	$137,357	$757,936	$159,049	$282,057	$986,130	$2,383,414	$3,810,650	$4,568,587	$299,291	$902,461	$1,201,752	$5,770,339
30-Nov-21	Equipment Related	$598,070	-$69,822	$11	$169,185	$697,445	$103,311	$241,492	$1,569,293	$1,686,252	$3,600,349	$4,297,794	$296,536	$774,172	$1,070,708	$5,368,502
31-Dec-21	Equipment Related	$531,752	$19,388		$146,176	$697,316	$94,998	$91,375	$1,549,542	$1,274,958	$3,010,873	$3,708,189	$272,706	$1,025,546	$1,298,252	$5,006,441
31-Jan-22	Equipment Related	$463,684	$16,927	-$75,963	$178,771	$583,419	$17,909	$85,311	$2,207,085	$7,153,638	$9,463,942	$10,047,361	$555,879	$1,279,843	$1,835,722	$11,883,083
28-Feb-22	Equipment Related	$504,416	$16,151		$175,007	$695,574	$23,993	$13,873	$2,849,478	$517,734	$3,405,078	$4,100,652	$288,742	$770,759	$1,059,501	$5,160,153
		$12,309,241	**$414,420**	**$134,103**	**$3,881,854**	**$16,739,617**	**$5,585,629**	**$9,417,720**	**$17,175,331**	**$31,383,659**	**$63,562,339**	**$80,301,957**	**$3,911,736**	**$17,688,752**	**$21,600,489**	**$101,902,446**